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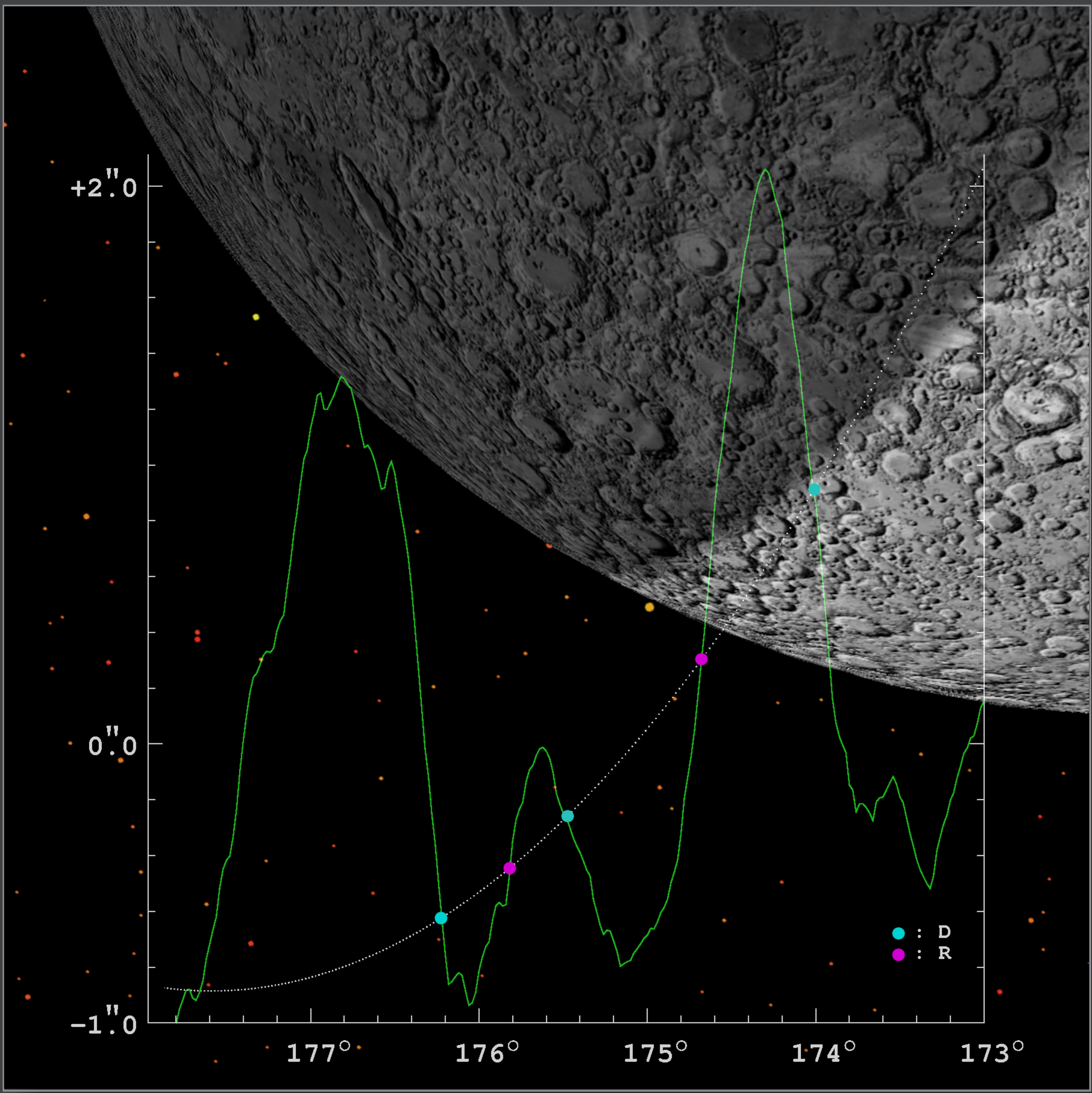

Observing Grazes at the Limit

Dear reader,

In this issue...

In recent years timings of total and grazing lunar occultations have taken a back seat to observations of asteroidal and outer solar system events. To inspire you to rediscover lunar occultations Wojciech Burzyński describes his fascination with observing lunar grazes of faint stars and the enjoyment and scientific value that he gains from his work.

Recording an occultation is only part of our challenge. We then need to extract a light curve from the video which can be difficult if the telescope was buffeted by strong winds or if the target star was faint. Read Bob Anderson's article about his new video analysis program, *PyMovie*, which is designed to handle these situations and is fully integrated with *PyOTE*.

Nikolai Wünsche then takes us Beyond Jupiter with the fascinating story of the discovery of (15760) Albion that lies in the Trans-Neptunian realm and why we still know so very little about it.

ESOP, the annual science meeting of IOTA/ES was held at the end of August at the historic Observatoire de Paris, France. This was one of the best attended ESOPs and it offered a comprehensive programme of informative talks and demonstrations of cameras and timing systems. Our meeting report provides links to the presentations and posters (in PDF form) and the Photo Galleries. Attended by delegates from 17 countries, this meeting expressed the very spirit of international *fraternité*.

Clear skies!

Alex Pratt
IOTA/ES, JOA Editorial Team

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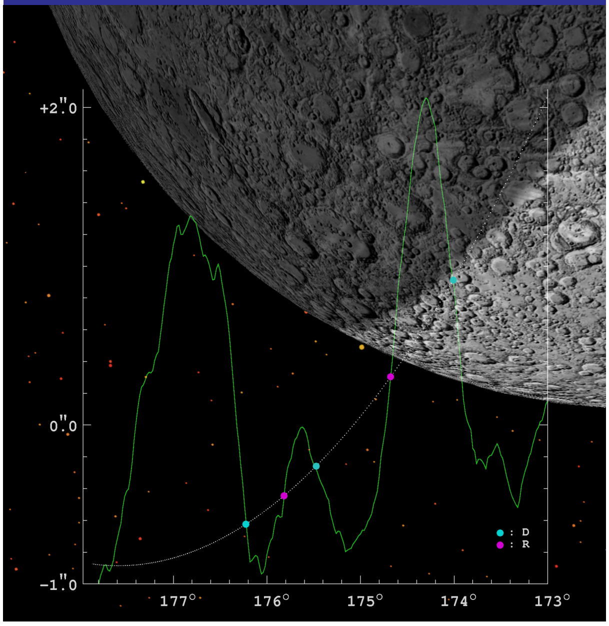
In this Issue:

COVER



A faint lunar graze of an 11.5 mag star was measured by Wojciech Burzyński and Maciej Jarmoc near Kowale, Poland in April 2019. This might be the world record in recording the faintest ever lunar graze. The graze curve presents the four observed contacts of this graze observation. The planetarium software simulation demonstrates the view of the grazing occultation from the actual observing site.

Image credit: W. Burzyński, M. Soma, Project Pluto GUIDE 9.1 Cover graphic: O. Klös

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Rules for Authors

In order to optimize 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/howtowrite.html .

The Chase for the Faintest Grazing Occultation - A Personal Report

Wojciech Burzyński • IOTA/ES • Białystok, Poland, wburzynski@poczta.onet.pl
Section for Observations of Positions and Occultation
of the Polish Amateur Astronomers Society

ABSTRACT: This article describes experiences of observing lunar grazing occultations, especially those of stars fainter than 9th magnitude. It aims to prove that such observations still have scientific sense. In addition to valuable final results, they offer a unique visual effect for free and a guarantee of being kept in suspense for the entire event duration. During grazing occultation observations we can experience extraordinary moments, soaked with a large dose of adrenaline and euphoria. Observing a dozen stellar disappearances and reappearances caused by the Moon's mountain peaks give the author more satisfaction and joy than a "single" moment of an asteroidal occultation.

Introduction

Fewer and fewer people in the world are making observations of lunar grazing occultations and focus only on asteroidal occultations. Why is this happening? Mainly because observers no longer see the point of improving the very accurate Moon's profile obtained by both the Kaguya and the LRO probes. Laser measurements of the relative heights at the lunar surface were made by these probes with an accuracy up to 1 metre. Meanwhile, our methods based on measurements using analog video cameras currently give the best chance of 20 m observation resolution at the Moon's surface level. This fact is probably depressing to many observers and therefore they gave up observing these spectacular phenomena focusing only on very bright grazing occultations. However, this does not discourage me and I treat each such observation as an exercise before the next lunar grazing and continuous testing of various configurations of my setup.

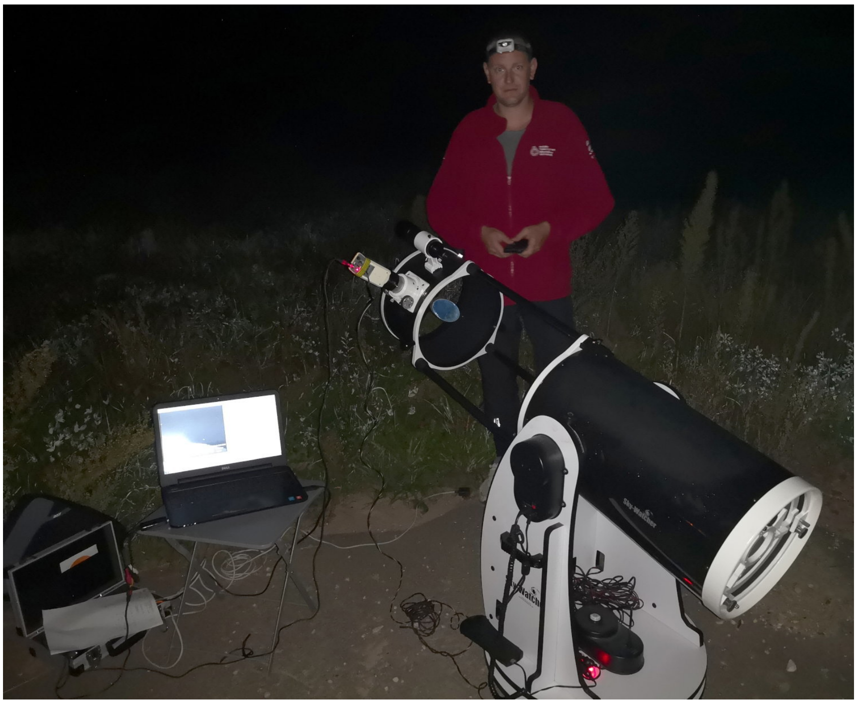

Figure 1. Wojciech Burzyński with 300/1500 mm Dobsonian scope connected to analogue NOVUS camera and the VTI.

The fact that fewer and fewer observers undertake grazing occultation observations is one thing. The second thing - almost no one observes both grazing and central events if a star is fainter than mag. 9. In the meantime, please imagine that the full XZ80 catalogue contains 230626 stars with brightnesses ranging from 9.0 to 12.5 mag! Only 13425 stars in the XZ80 catalogue are brighter than 9 mag. In Occult, we use the XZ80Q catalogue limited to a visual magnitude of 12.0, which contains 186798 stars, with numbers ranging between 1 and 187172. So, we still have a lot to observe and, I hope, to discover...new doubles!

My Personal Story

I began my adventure with lunar grazing observations on August 18, 1998 during the SAO 95715 (7.7 mag) occultation. For the visual observation method and the 11-cm telescope, this star seemed really faint at the time. I remember the perfectly visible Moon's earthshine at the Moon phase -17%. The Moon was visible in the second half of the night at an altitude of just 12 degrees above the horizon. Although I observed only one disappearance and one reappearance (my colleagues in the neighbouring station I prepared for them, had as many as 6) but the beauty and dynamics of the event were so strongly remembered by me that since then lunar grazing occultations have become my favourite type of occultation phenomena.

In those days of the second half of the 1990s when I started my adventures with occultations, the equipment I used was very basic - I recorded the entire phenomenon with my voice on a tape recorder, recording in parallel the DCF-77 acoustic reference signals. However, that observation was made correctly, as evidenced by small O-C values, less than 0.05” for each event.

Due to the success of this first grazing occultation, I began organizing expeditions for members of my Białystok Branch of the Polish Amateur Astronomers Society to observe grazing occultations at every opportunity. To this day, I have organized over 30 lunar grazing expeditions, most of them near to my home city but nationwide as well. More than half of the expeditions have brought positive results with many events recorded. The rest were less successful, but only because of cloud cover. In fact, since 2015 I am the only person in Poland who is organizing observations of lunar grazing occultations. I try to infect my colleagues with my enthusiasm, prepare ephemeris for them and remind the Polish astronomical community about the next phenomena. Sometimes it is possible to carry out a nationwide observing campaign mostly by members of the PAAS Occultation Section (*pol. SOPiZ*). Nevertheless, most of the grazing occultation observations are carried out by me near Białystok city, north-eastern Poland, where I live.

Since 2016, I have also been maintaining the SOPiZ website and try to systematically plan and coordinate for Polish observers both the knowledge needed to observe occultation phenomena and complete the archival of data of occultation events observed in our country. It was during the completion of these archival data that questions arose in my head - *Who and when observed the faintest lunar grazing occultation in Poland?* It seemed to me that the answer is simple and it was the grazing occultation of SAO 78974, 9.19 mag, observed by Mirosław Krasnowski and Artur Wrembel on May 12, 2005. The phenomenon was difficult, with the Moon’s phase +19% and its altitude 14 degrees above the horizon. At two stations they recorded 12 events using 15 cm and 25 cm telescopes and inexpensive analogue video cameras.

However, completing the archival data, I received the information that the grazing occultation of an even fainter star was observed by Leszek Benedyktowicz on January 12, 2000 - the occulted star XZ 32330 with visual brightness of 9.81 mag. The phenomenon occurred at lunar phase +30% and at a CA angle of 7.3 degrees, but Leszek has observed only 1 contact by the video method. The only disappearance was at the dark limb, but that was the lunar limb shape visible from his observation site, 7 km distant from the graze limit line of the phenomenon. It was in the Fort Skala Astronomical Observatory of the Jagiellonian University in Cracow and the equipment used was a 350/3300 mm professional Maksutov telescope.

Then I thought: “*Maybe I could try to personally observe the grazing occultation of a fainter star?*” The decision was made - I will try to break this *national record*!

How I Broke the National Record

The opportunity to break this national record happened to me on November 30, 2018. The star SAO 99271 was fainter by a small fraction of a magnitude in both the V band (9.83 mag) and the R band (9.53 mag) than the observation of the star XZ 32330 by Leszek Benedyktowicz in 2000. I used a Skywatcher 300/1500 mm Newtonian telescope, reading only 3 events from the recording. The observation was made northwest of Białystok during very strong gusts of cold wind, but the average residual O-C of these events was very good at -0.008”.

The Equipment and *Occult*’s Setting

Thinking about breaking “records”, I had to use the largest telescope available to me - it was the Skywatcher 300/1500 mm on an azimuth mount, but with the GOTO system. I used an inexpensive NOVUS analogue camera - NVC GDN5811C-2 model [1]. This camera has a slightly lower sensitivity compared to the very well-known Watec 910HX camera. The whole set is completed by a VTI GPS by Tomasz Wężyk.

I also had to set my own rules, when observations can be considered as record-breaking:

- *the shutter speed should be set to 1/50 sec (no integration mode)*

- *the only adjustment can be made by Automatic Gain Control: LOW (mainly) or HIGH.*

Why such assumptions? - so that you don’t lose time resolution by extending the shutter speed. The observation must be made as accurately as possible!

Another thing - how do I calculate the grazing occultations of such faint stars?

To generate grazing occultations up to 12.0 mag in *Occult*, I had to enter quite non-standard data, all in the “Edit site details” window:

- *maximum telescope aperture allowed by Occult - set as 500 cm*

- *correction to limiting magnitude - set as 2.0 mag*

- *travel distance for lunar grazes - set as 50 km or less (Occult will generate a lot of phenomena)*

For video observation, the “magnitude visibility table” generated by *Occult* together with graze ocuultation ephemeris is not applicable. The magnitude visibility table gives the faintest magnitude that will be visible at that cusp angle with different telescopes apertures, assuming good observing conditions. This table refers to observations made by visual methods [2] and the use of a sensitive camera allows you to observe occultations of fainter stars.

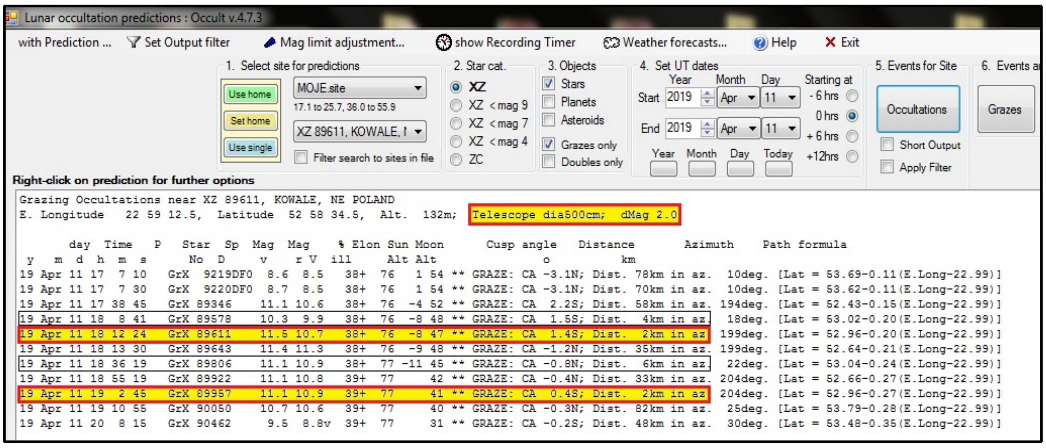

Figure 2. Ephemeris of fain stars grazing occultation on April 11, 2019 - we observed phenomena marked in yellow, please pay attention to two additional phenomena - stars XZ 89578 and XZ 89806 and the settings in the Occult's ephemeris header.

Appetite Comes with Eating!

All right, the national record is broken... The question became obvious: *Who observed the faintest lunar grazing occultation in the world?* Finding the answer to this question was not so simple. I asked Dave Herald to help me find the right data in the *Occult* database. From the historical grazes database it is not possible to directly sort data by star brightness - it can be done only by the catalogue number, the date of the phenomenon or the name of observer. Nevertheless, Dave advised me to search the historical grazes database by star catalogue number, but larger than XZ 32221 - the extended XZ catalogue contains fainter stars.
It turned out that the Japanese are the best in observing grazing occultations of faint stars:

• XZ 179173 (V = 10.50 mag, R = 10.15 mag) on November 17, 2007, Kunio Kenmotsu has observed this event 16 km SW from the centre of Okayama, in urban conditions! Using the SCT 200/1800 mm telescope and camera, he has obtained 6 contacts and a very good average residual value: - 0.022" ± 0.21". Moon phase + 44%, Moon altitude 35 °, CA 19.17°.

• XZ 67911 (V = 10.47 mag, R = 10.18 mag) on April 17, 2010, Hisashi Suzuki has observed this event 15 km NE from the centre of Hamamatsu, in urban conditions! Using the SCT 250/1270 mm telescope and camera, he has obtained 12 contacts and a very good average residual value: - 0.016" ± 0.08".

Of course, it seems that even fainter stars can be observed during a total eclipse of the Moon. So far, a record-breaking observation of this type was on November 29, 1993. Roger J. Venable has observed visually XZ 69715 (V = 10.59 mag, R = 9.64 mag) 18 km S from Augusta, USA. Using the SCT 400/1800 mm telescope he has obtained 9 contacts with average residual value: - 0.077". The observation was made 9 minutes after the end of the total eclipse.
I published this data as a curiosity on the SOPIZ website [3]. Some months later, Jan Mánek wrote to me and gave me data about the grazing occultation of XZ 75176 (V = 10.81 mag, R = 10.53 mag) which he has observed on August 16, 2009. It seemed that the "world record" belonged to him and not to the observer from Japan.

10.0 Mag Limit Broken

As usually happens in the spring, a series of cloudless evenings and nights began. The plan was crazy and basically spontaneous. On April 9 this year, after arriving home from work at approx. 17:30 UT, I looked at the grazing occultations list of faint stars up to 12.0 mag, which I generated by Occult a few months earlier.
At 18:10 UT I left Białystok, after a few minutes I am at Maciej Jarmoc's place in Ignatki, 8 km S of Białystok, loading our largest 30 cm telescope into the trunk. The sky is practically cloudless. The graze limit line for that event ran quite far from Białystok, according to Google maps about an hour by car. Although the prediction always gives the observer's shortest distance to the limit (47 km), in fact the road to the destination is always longer - in this case it was 65 km, near Boćki village.
At 19 hrs UT, an hour before the phenomenon I am at the proper site. Unfortunately, I see the sky temporarily cloudy to about 60-70%. Fortunately, there is a light wind - the clouds move quite quickly. The Moon is sometimes easily visible, sometimes it is completely covered by clouds. I am not giving up and I am starting to set up the equipment. I have travelled 65 km and I will

fight to the end, maybe I will succeed ... I am ready half an hour before the phenomenon, 22 minutes before the start of the event I start test recordings. Everything works great.

SAO 94076 (V = 10.30 mag, R = 9.59 mag) was occulted by a 19% Moon and only 1.8 degrees from the terminator [4], [5]. Therefore, the phenomenon was quite difficult, mainly due to the low brightness of the star and the proximity of the terminator. The altitude - just 13 degrees above the horizon - was also a very significant difficulty, indirectly reducing the brightness of the already faint star. I set the camera to the lowest gain settings. It turns out that the image is best at a shutter speed of 1/50s and AGC: LOW. In addition, at these settings I do not increase the camera's range artificially and I can still read the moments of the phenomenon with the greatest precision. The star is clearly visible. The wind moves the telescope slightly as seen in the recording, but at key moments all the star's events can be read with high accuracy, reaching 0.02 seconds. There are no two obvious moments when the star merged with the illuminated parts of the lunar disk. I'm lucky - about 10 minutes after the phenomenon, a band of dark clouds appears on the Moon...

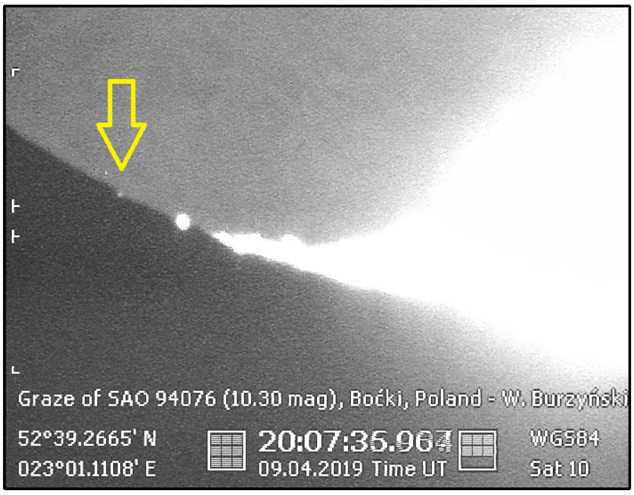

Figure 3. For a few seconds before the first disappearance during SAO 94076 (10.30 mag) near Boćki, NE Poland.

And that Day Has Come...

... just 2 days later, on April 11, 2019. The 10.30 mag star grazing occultation, recorded by me near Boćki village, kept the status of "new national record" only for 46 hours. Less than two days later, together with Maciek Jarmoc, we recorded two more lunar grazing occultations, with star brightness given by *Occult* at over 11 mag each! It was a lucky coincidence that from the same observation site near Kowale village, 40 km SW of Białystok, we can register two grazing occultations of very faint stars - XZ 89611 (V = 11.46 mag, R = 10.74 mag) and XZ 89957 (V = 11.13 mag, R = 10.92 mag), and that this optimally selected place guarantees multiple phenomena [6],[7]. In fact, a few kilometres away, the graze limits of two successive grazing occultations ran - 4 lunar grazes in the same place and at almost the same time, what a coincidence!

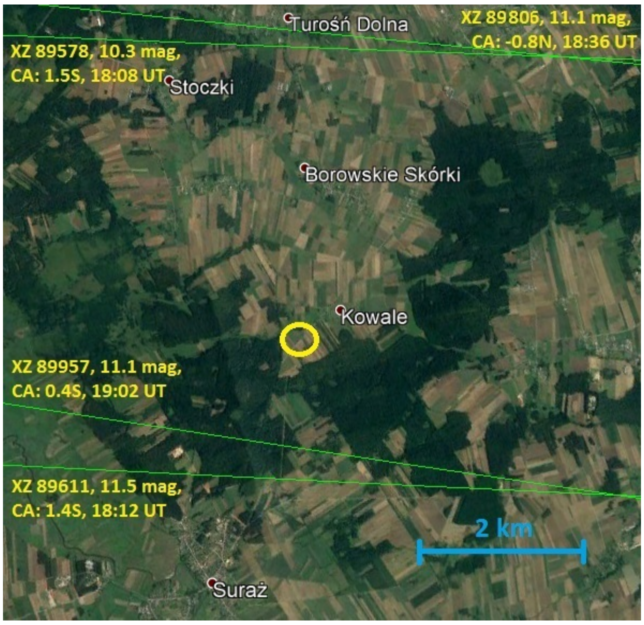

Figure 4. Kowale village, NE Poland - four grazes in one place and at almost the same time?... this is already excess!

From the precisely selected observation site, XZ 89578 (10.3 mag) missed the lunar limb, which we also observed on the laptop monitor during the XZ 89611 occultation. In turn, a grazing occultation of a fourth star, XZ 89806 (11.1 mag), observed from this place was not very attractive - one contact and a very close distance to the terminator. So, it turned out that the most cost-effective solution is to stay in the same place and observe only two extremely faint grazes - of the star XZ 89611 it was -2.075 km from the limit line, while for the star XZ 89957 the distance from the limit line was -1.617 km. Thus, we sacrificed the grazing occultation of the "bright" 10.3 mag star for two grazes of fainter stars but without certainty for a successful result.

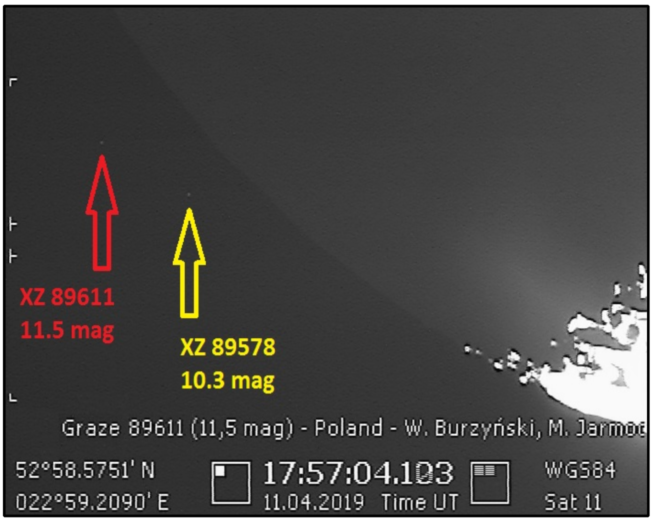

Figure 5. The printscreen of the recording 13 minutes before starting graze occultation of XZ 89611. From this observation site brighter star XZ 89578 has missed lunar limb.

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The weather forecast did not show a super clear sky, but due to the proximity of the place to Białystok city, we decided to go. The weather in April is very dynamic, it usually clears up in the evenings, hence our optimistic approach to this trip. A strip of dark clouds loomed over the northwestern horizon; faint clouds were circling the Moon. However, at a key moment both phenomena were recorded in a completely cloudless sky. This is a great, even unprecedented happiness, considering the fact that virtually all the rest of Poland was wrapped in thick clouds, and in the Białystok region we found ourselves in a narrow good weather window.

Trying a 12.0 Mag... Is It Possible?

Of course, I'd like to reach even further and observe grazing occultations of fainter stars. On May 11, 2019, I tried to record the phenomenon of the star XZ 114294 (V = 11.89 mag, R = 11.59 mag). The Moon was at phase + 47%, but with a small CA of only 2.4 degrees. Despite the cloudless sky, the star was unfortunately not visible on the recording.

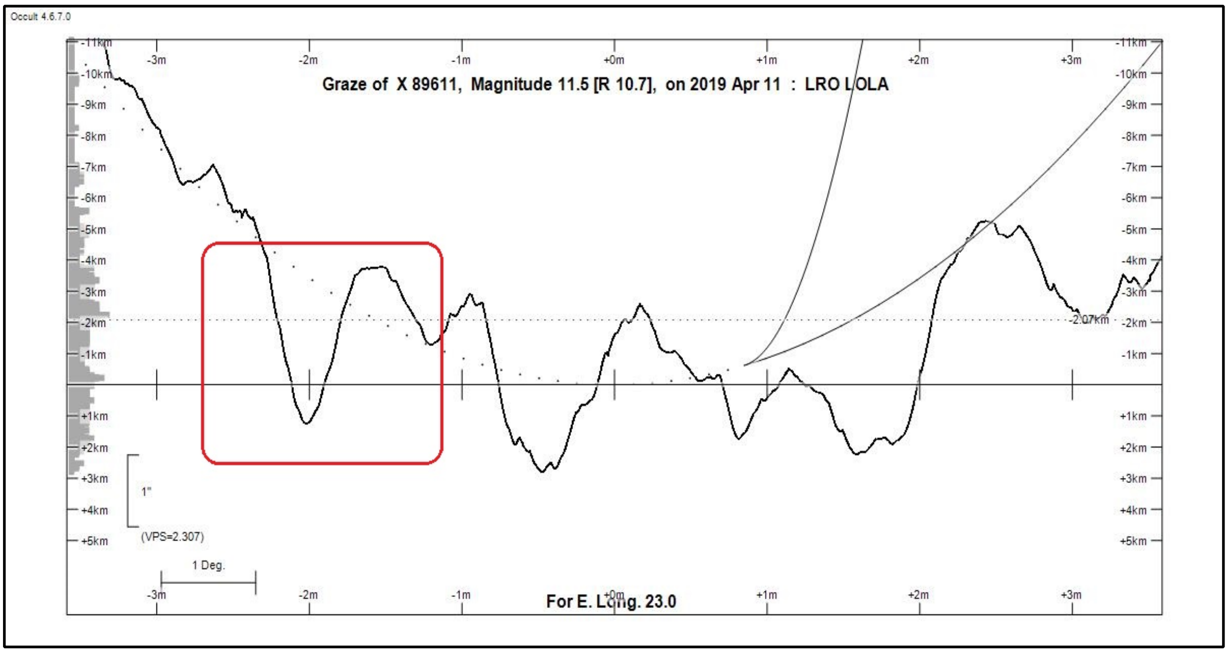

Figure 6. Profile by Occult for grazing occultation of XZ 89611. The red area marked the place of observed events.

Determining the real brightness of occulted stars is still an open question. Below, is a comparison of the brightness of both stars by various astrometric catalogues. Even if XZ 89611 isn't the expected 11.46 mag, the star XZ 89957 seems to be 11.13 mag. According to my knowledge, in case of any observed phenomena written above, this would mean a *WORLD RECORD* - the faintest star has been observed during lunar grazing occultation.

Cat ID	B	V	R
GaiaSrc3373081363674203904	11.5	9.9	8.8
GaiaSrc3373081398030251008	...	15.9	...
Source 3373081363674203904	...	...	...
GaiaSrc3373081359375614208	...	9.8	...
UCAC5 3373081359375614208	...	10.6	9.8
HSOY 3220289696799864485	...	9.8	9.6
UCAC4 556-030192	...	11.2	12.0
TYC 1341-522-1	...	11.6	...
URAT1 556-110212	13.0	11.2	10.5
3UC 223-065270	...	10.6	8.9
2UCAC 39291182	...	10.6	...
PPMXL 3220289696799864485	...	...	9.6
PPMX 063308.3+211049	...	11.4	10.6
CMC15 063308.3+211049	...	...	10.5
2MASS 06330830+2110496	...	...	11.5
USNO-B1.0 1111-0128689	...	...	10.7
NOMAD1 1111-0131404	...	11.5	10.6
CMC14 063308.3+211049	...	...	10.5

XZ 89611 (11.46 mag)

Cat ID	B	V	R
GaiaSrc3373095034551485824	11.3	11.1	10.8
Source 3373095034551485824	...	...	...
GaiaSrc3373095034551485824	...	11.1	...
TGAS Tyc2 1341-1610-1	...	11.1	...
UCAC5 3373095034551485824	...	11.1	11.1
HSOY 3220307086330909606	...	11.1	11.1
UCAC4 556-030581	...	11.1	11.4
TYC 1341-1610-1	...	11.2	...
URAT1 556-111711	11.5	11.1	11.1
3UC 223-066190	...	11.2	9.5
2UCAC 39291680	...	11.1	...
PPMXL 3220307086330909606	...	...	11.1
PPMX 063447.3+210938	...	11.1	10.9
CMC15 063447.3+210938	...	...	11.1
2MASS 06344737+2109386	...	...	11.1
USNO-B1.0 1111-0130035	...	...	10.9
NOMAD1 1111-0132790	...	11.1	10.9
CMC14 063447.3+210938	...	...	11.1

XZ 89957 (11.13 mag)

Figure 7. The brightness of the stars XZ 89611 (11.46 mag) and XZ 89957 (11.13 mag) according to various astrometric catalogs (Occult). Which value is closest to the truth?

The last opportunity to break the "world record" occurred on July 27, 2019. The star XZ 99069 (V = 11.98 mag, R = 11.70 mag) turned out to be too faint for my setup as well. The conditions were very favourable - Moon phase +16%, CA over 10 degrees, Moon altitude 17 degrees. Despite this, the star was noticed on the screen until 1 minute after the last scheduled graze event. Even with such a small phase of the Moon, the light from its illuminated part affected the recording.

As for earthshine - there is clearly a border that cannot be crossed anymore and it becomes impossible to observe ever fainter stars. For a given telescope with a specific mirror diameter and given camera exposure time settings, the brightness of earthshine will be the same or greater than the brightness of the occulted star at some point. No difference in brightness between star and earthshine makes it impossible to read the moments with the required time precision, even if the CA is very large. By increasing the shutter speed, it would probably be possible to register such a faint star as 12.0 mag, but the final result would be devoid of scientific value.

Summary

Analyzing the graphical results of lunar grazing occultations observations, it can be seen that we can still improve the Moon's limb profile data a little bit. Not much, but still! What's more, observing grazing occultations of faint stars, we usually observe those stars that have never been observed even during the total lunar occultations. In this case, we have an even greater chance to discover a new double star!

The results of lunar grazing occultations are still collected by Dr. Mitsuru Soma from Japan and are published on the website: https://www2.nao.ac.jp/~mitsurusoma/grazes.html. In recent years, the most active observers in the world were from Japan, USA, and just from Poland.

Personally, I will continue to observe lunar grazing occultations of such faint stars to get to know the capabilities of my observation setup depending on the magnitude of the star, the Moon's phase and the cusp angle, CA. Based on the data obtained, I will know in the future whether a given phenomenon can be recorded with my observation setup. For a 300/1500 mm telescope and a camera that I have, the real limit of observation seems to be the value between 11.5 and 12.0 mag. Thus, I will avoid disappointment when I go many kilometres for the next expedition. I hope that the data will also be useful for other grazing occultations observers around the world.

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[2] Schaefer, B. E., Bulder, H. J. J., and Bourgeois, J., Lunar occultation visibility, Icarus , *100*, 60-72 (1992)

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[4] Graze of SAO 94076 (10.30 mag) https://www.youtube.com/watch?v=aaw0BA_6N88&t=7s

[5] Burzyński W. Observation report of grazing occultation of SAO 94076 (10.30 mag) http://www.sopiz.ptma.pl/zakrycie-brzegowe-gwiazdy-sao-94076-9-kwietnia-2019/

[6] Graze of XZ 89611 (11.46 mag) movie https://www.youtube.com/watch?v=PgBrQEG6gtM

[7] Burzyński W. Observation report of grazing occultation of SAO 89611 (11.46 mag) http://www.sopiz.ptma.pl/rekordowe-zakrycia-brzegowe-11-kwietnia-2019

If anyone knows about the observation of fainter grazing occultations than I achieved, please contact me at my e-mail address: wburzynski@poczta.onet.pl

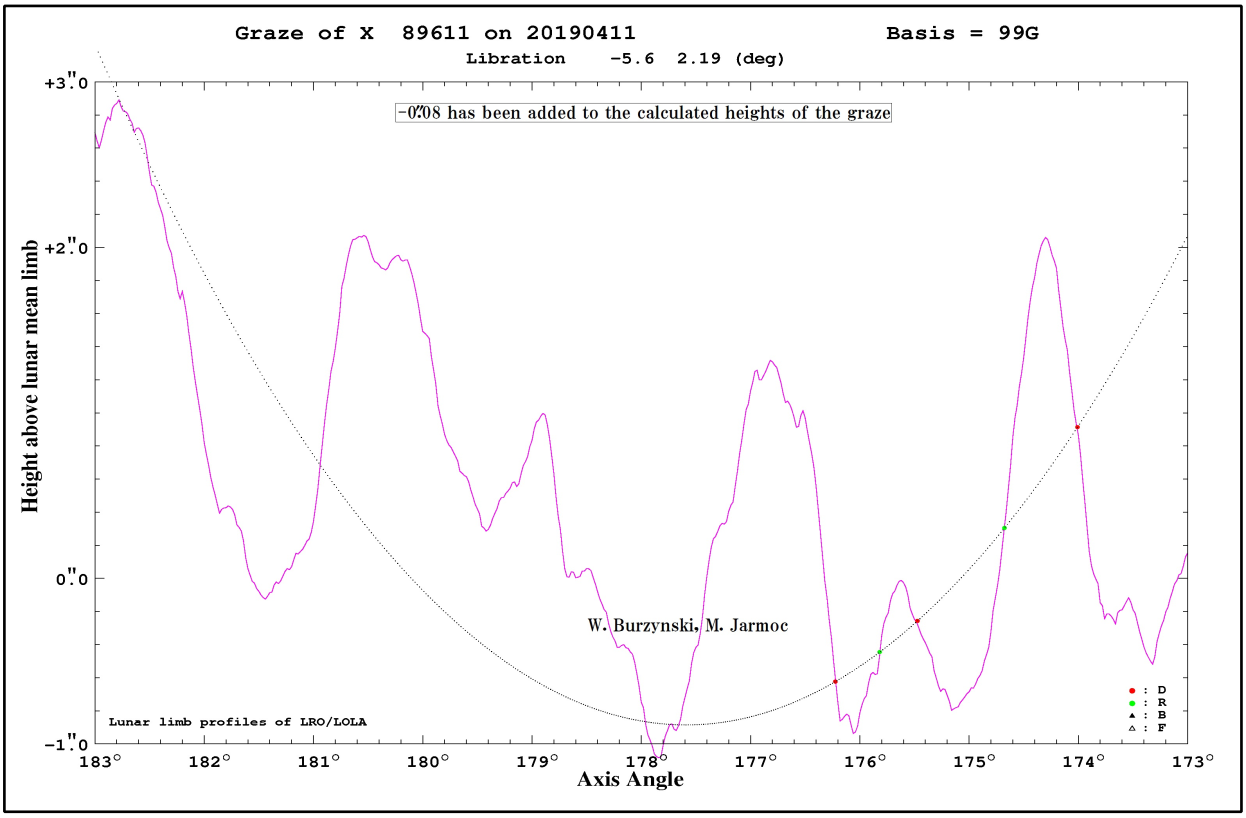

Figure 8. The results of grazing occultation XZ 89611 (11.46 mag) reduced by Dr. M. Soma - the faintest grazing lunar occultation ever observed?

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PyMovie A Stellar-Occultation Aperture-Photometry Program

Bob Anderson · IOTA · Lake Oswego, Oregon · USA · bob.anderson.ok@gmail.com

ABSTRACT: *PyMovie* is a multi-operating system (Windows/Mac/Linux) program for extracting light curves from stellar occultation videos. It is an alternative program to *Limovie* and *Tangra* that uses the idea of creating a shape fitting measurement mask from the star image itself in order to minimize the inclusion of background pixels. This has the effect of improving the signal to noise ratio of light curves, even when the images are distorted by shaking during the recording. The technique also makes it easier to keep measurement apertures properly positioned throughout the recording. The program also provides a set of tools to assist in the placement of measurement aperture on very hard-to-see target stars.

Introduction

For extracting light curves (plots of star intensity versus time) from videos of stellar occultation events, the astronomy community already has *Limovie*[1], the pioneer application in this field by Kazuhisa Myashita, and *Tangra*[2], the photometric oriented program by Hristo Pavlov. A natural question then is, "what are the reasons for yet another light curve analysis program?" The major responses to that question are listed below.

1. Wind Shake

The prime motivator that drove the development of this program was the belief that an aperture photometry program that could deal robustly and effectively with videos that have been affected by wind shake would be a useful tool. *PyMovie* uses the idea of forming a sampling mask from the image itself to get a sampling mask that adapts/conforms to the shape of a star image that has been distorted by wind shake. Such a mask minimizes the inclusion of background pixels. The expected benefit from this procedure is an increased SNR, particularly during the occultation as the intensity drops and the image gets smaller. This effect is useful even for videos that do not exhibit wind shake (Figure 1). The Limovie aperture remains fixed resulting in more background noise incorporated in the measurement. The *PyMovie* aperture mask changes size and shape with the size of the wind-shake star image resulting in optimum signal to noise measurement. An example is provided later in this paper.

2. Mutiple Platforms Supported

Operating System (OS) interoperability in *PyMovie* has been designed from the beginning to run on both MacOS and Windows platforms. It is implemented using *Python 3.7* and *PyQt5* (for the Graphical User Interface (GUI)) and thus inherits the platform independence of those packages. The program, as designed, should run on Linux and has been installed and run successfully on a Ubuntu 18.04 system using the same installation procedures written for the MacOS.

3. Usability

Ease of use, particularly for the occasional user, was constantly emphasized during the development. Of course, whether this goal has been achieved will be decided by those users.

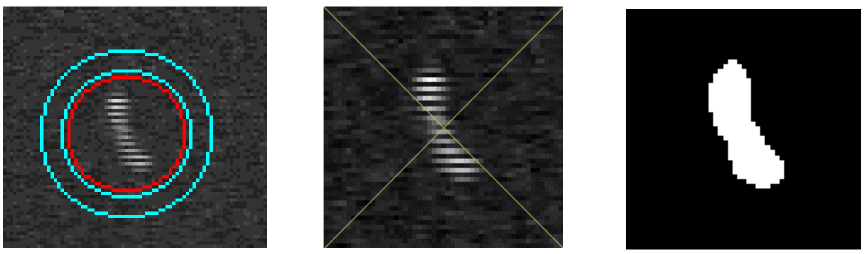


Figure 1.
A Limovie 18 pixel-radius aperture around a star with wind shake (left).
The same star frame as seen in PyMovie (centre).
The PyMovie aperture mask that defines the light curve measurement area (right).

[1] The acronym stands for "LIght Measurement tool for Occultation observation using VIdeo rEcorder"! *Limovie* fulfils a longstanding need of video observers to *automatically* derive light curves from captured video recordings of lunar and asteroidal occultations. Written and maintained by Kazuhisa Miyashita, Japan.
[2] *Tangra 3* - software package for astronomical video data reduction is maintained by Hristo Pavlov.

4. Aperture Placement Tools

A set of aids for assisting the user in placing a measurement aperture at the occulted star position have been built in:

a.

There is a simple-to-use tool that will register and sum a hundred or more frames (a simplified *RegiStax*[3]) and thus generate an image intensified "finder" frame that will make visible any object for which a light curve can be extracted. In a video with a faint target star, the starting frame looked like this (Figure 2):

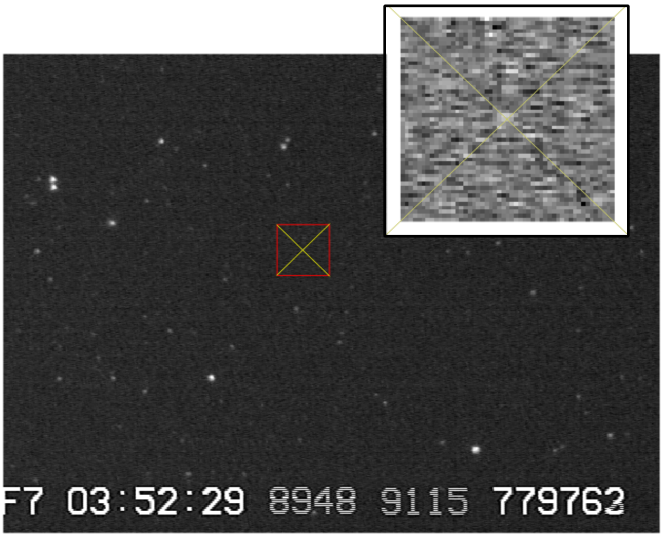


Figure 2. Starting frame of video. Corresponding thumbnail (top right).

It is difficult to see the target star in this image or thumbnail, even though there is already a correctly placed aperture that tells you exactly where to look. But the "finder" image that was generated from a 200-frame stack looks like this (Figure 3):

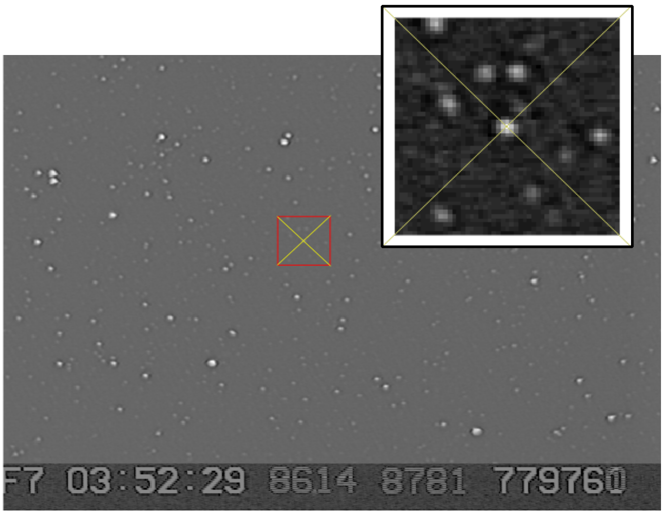


Figure 3. "Finder image" generated from a 200-frame stack with inserted thumbnail blow-up of the target aperture (top right).

[3] Copyright © 2010/2011 Cor Berrevoets (The Netherlands)

Now it is easy to see the target star and to properly position a measurement aperture relative to other nearby tracking stars.

b.

There is an available on-line connection to nova.astrometry.net. Through that connection, a frame can be submitted to nova.astrometry.net for WCS (World Coordinate System) calibration. With a WCS calibration available (which maps pixel x-y coordinates to Right Ascension (RA) Declination (Dec) coordinates), the user can position a measurement aperture at the occulted star position by specifying its RA Dec position. The star does not need to be visible on the video frame. To aid in getting RA Dec information, there is an on-line connection to VizierR which accepts a UCAC4 star ID and returns an International Celestial Reference System (ICRS) coordinate string ready to use --- in hours minutes seconds/degrees minutes seconds (hms/dms) format). In the video example shown in item a above, there is an image from a video with an unseen target star that was found by *PyMovie* using the nova.astrometry.net WCS tool. The thumbnail for the stacked image shows how well the star was located using the WCS tool. Unfortunately, the WCS tool cannot be used for videos with a field of view smaller than about 15 arc minutes. It also cannot be used where there are too many hot pixels in the field of view.

c.

When the WCS calibration tool cannot be used, it is also possible to perform a manual WCS calibration of the target star. The method is to select two field stars in a frame, provide their RA Dec coordinates, and then obtain a useable WCS calibration for an unseen target star in the frame through trigonometric solution.

5. Bi-directional Analysis

Reverse measurement makes it possible to analyze backwards from higher numbered frames to lower numbered frames. This provides an easy way to handle a video that has no usable reference stars and the moving target star disappears entirely during the occultation. With reverse measurement, aperture tracking occurs in reverse until the star completely disappears.

6. Enhanched Star Tracking

One or two nearby reference stars can be used to provide tracking information when the target star is faint. The use of two tracking stars compensates for field rotation during long videos or when the telescope is in alt/az mode and tracking near the zenith.

7. Time Insertion

PyMovie is able to extract timestamps from VTI (Video Time Inserter) overlays using optical character recognition (OCR) for the following VTI models:

- IOTA VTI 2
- IOTA VTI 3
- BoxSprite GPS 3 (not supported by *Limovie* or *Tangra*)
- KIWI 40 (not supported by *Tangra*)
- KIWI 41 (not supported by *Tangra*)

The position of the OCR boxes can be custom adjusted to provide for 100% OCR accuracy on most videos. Different OCR profiles can be created for different observer toolchains of camera-VTI-frame grabber-capture software. *PyMovie* also reads the QHY 174 GPS camera timestamp (as composed by the *SharpCap* capture software) from the FITS header for each frame in the FITS folder. *PyMovie* automatically adds timestamps to the csv output file.

8. Improved Background Measurement

The use of Robust Mean calculation simplifies and improves background measurement. The Robust Mean allows for accurate background measurement even in crowded star fields or drift-through videos with hot pixels in the path (Figure 4).

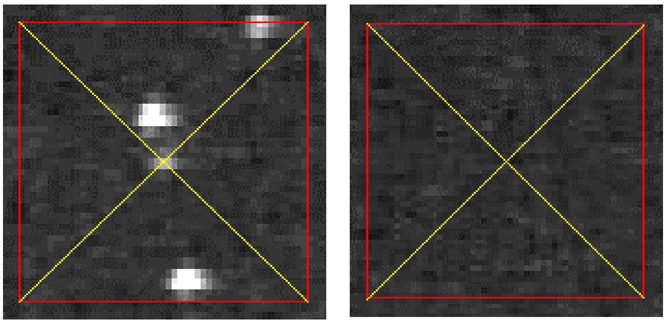


Figure 4.
Left: a faint target (crosshair) star in a crowded star field.
Star signal = 345. Robust Mean background = 31.45
Right: same frame, but a different aperture with no stars.
Robust Mean background = 30.5.
The variation in the Robust Mean background is 1/345 of the target signal with three brighter stars in the target aperture.

9. Image enhancement

Use the image contrast control to customize image scaling: ...will make it possible to turn the image display from this (Figure 5)...

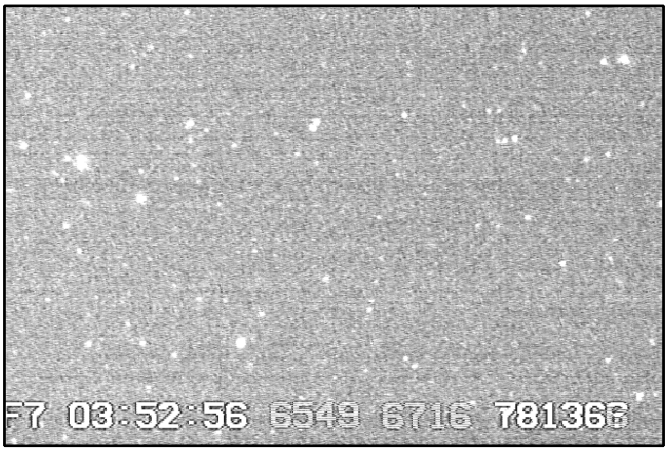


Figure 5.

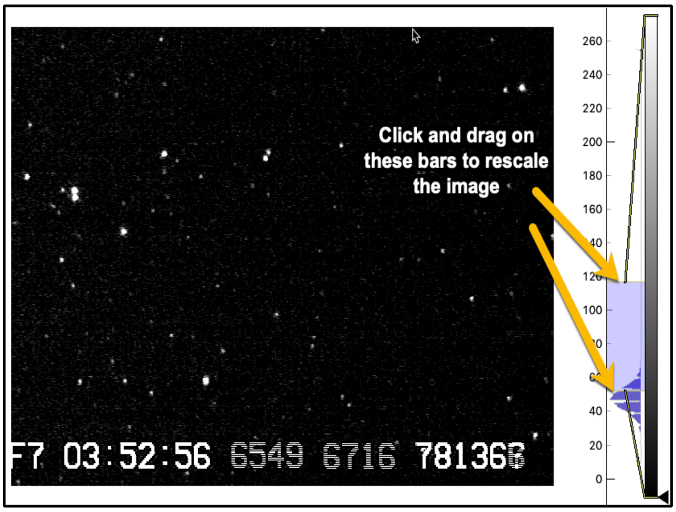


Figure 6.

... to this (Figure 6).

The frequency distribution histogram in the gadget output is also useful for identifying issues in the video, such as low brightness clipping.

10. Easy *PyOTE* Interface

PyMovie is fully integrated with *PyOTE* (Python Occultation Timing Extractor). Once a light curve is analyzed and a .csv light curve is saved, the light curve can be opened in *PyOTE* which will read the time stamps, measure the precise time of Disappearance and Reappearance and generate statistically correct error bars (including correlated noise) for three confidence levels: 0.68, 0.95, and 0.9973.

11. Easy Updates

PyMovie provides automatic update prompts on opening. The current version as of the date of this paper is *PyMovie 1.9.3*. Future revisions will be automatically available for update as improvements and bug fixes are made.

GUI Layout and Typical Wind Shake Results

The following GUI screen print is for a FITS sequence light curve from a Pluto occultation [unpublished NSF and SwRI research data used by permission] (Figure 7). The FITS images from the observation had moments of intense wind shake. The thumbnail images in the lower right-hand corner show the skewed light path on the video frame caused by severe wind shake for one of the field stars (left thumbnail) and the corresponding dynamic aperture mask used to measure the star brightness (right thumbnail). Video analysis tools such as *Limovie* and *Tangra* used fixed circular apertures to measure the light from a target star. Because *PyMovie*'s approach is different from *Limovie* and *Tangra*, a comparison analysis would be useful. Unfortunately, *Limovie* cannot analyse a FITS sequence, so we cannot do a comparison with *Limovie*. *Tangra* can analyse FITS sequences. We did a

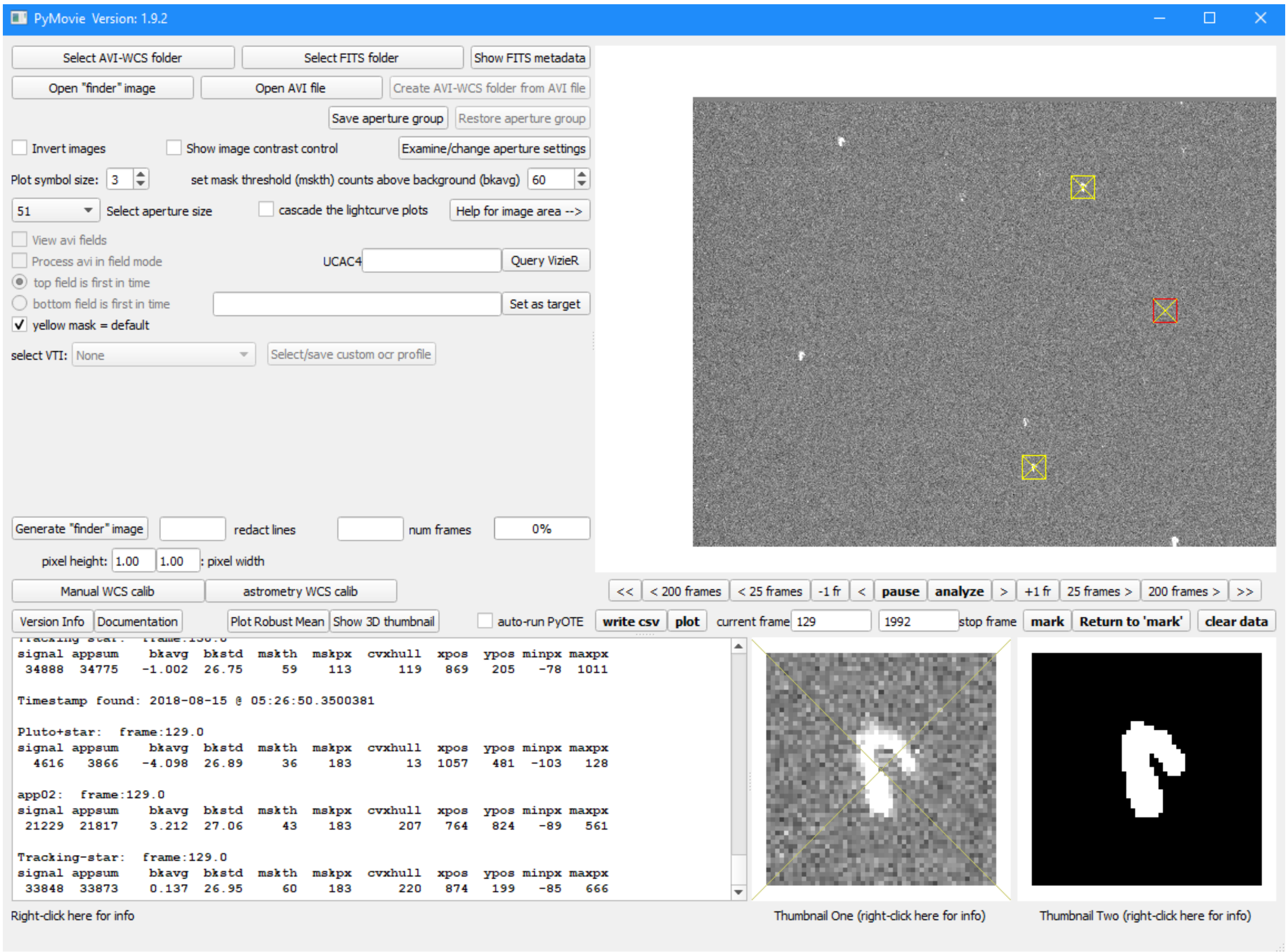


Figure 7.

comparison *Tangra* analysis of the FITS sequence, using two tracking stars and a target star aperture. All apertures were circular measurement aperture with average background subtraction. *Tangra* was set up in aperture photometry mode, the 'more accurate' setting, without full disappearance, was used since Pluto was always visible. We did not check the 'Stop on lost tracking' box because of the severe wind shake meant that nearly every frame in some sequences might lose tracking and require intervention, which would be too time consuming for this test. The light curve is as follows (Figure 8):

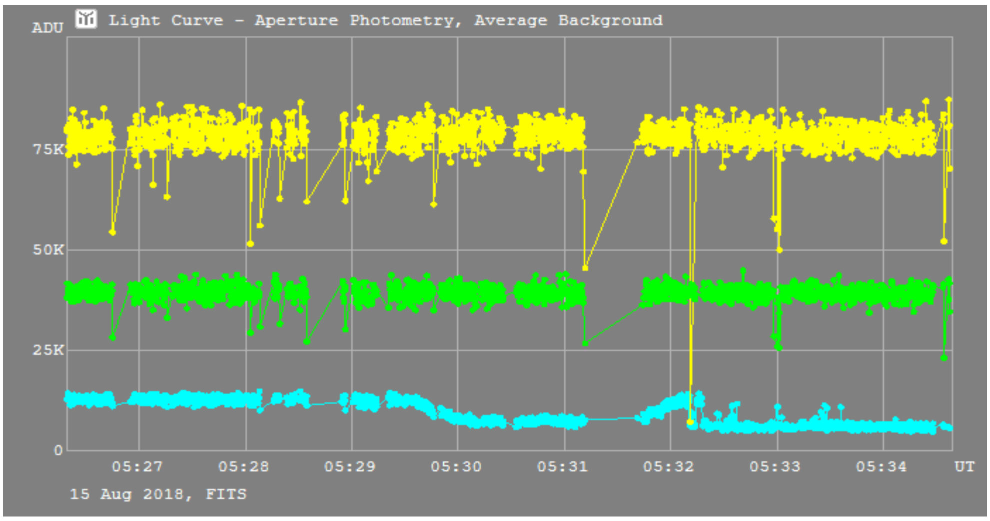
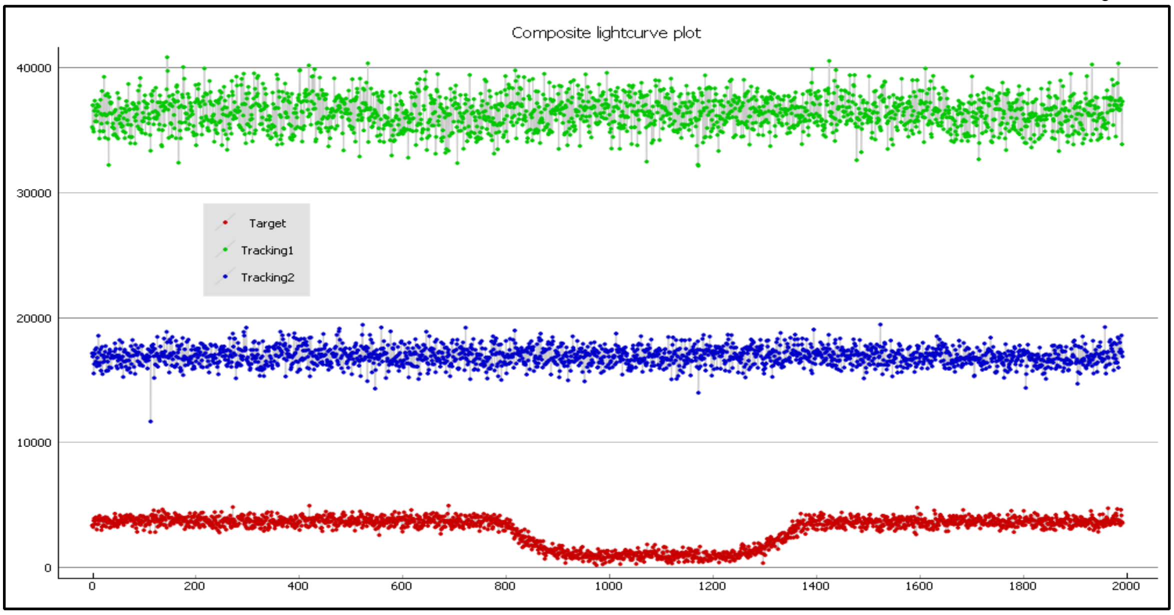


Figure 8.

The total elapsed time of the *Tangra* analysis was more than 60 minutes. Numerous dropouts can be seen due to wind shake and loss of tracking. Toward the end of the analysis, tracking of the target star was totally lost, even though the tracking stars were reacquired and measurable. This test was not intended as a definitive comparative test between *PyMovie* and *Tangra*. While many attempts were made to get a more complete light curve, the above light curve was the best that could be achieved. A more experienced user could likely retrieve a better light curve with *Tangra*. However, *PyMovie* is not targeted toward the experienced user, instead it is targeted toward the inexperienced user.
With a *PyMovie* analysis of the video, using two tracking stars and a dynamic aperture mask, the same light curve is as follows (Figure 9):

Figure 9.



The total elapsed time of the *Pymovie* analysis was 25 minutes. The dropouts caused by wind shake are dramatically reduced or eliminated by the two-star tracking and dynamic aperture mask method used in *PyMovie*. The author believes that most users, even the inexperienced users can achieve similar results with only modest review of the video tutorials provided in the release.

How to Acquire *PyMovie*

PyMovie is available through the following network link:

occultations.org/observing/software/pymovie

The above URL provides links to:
- Installation instructions for Windows, Mac, and soon to be added, Linux operating system
- An instruction manual
- Video tutorials that are intended for initial orientation to *PyMovie* and linked in order of increasing complexity.

Contact Information

The author, Bob Anderson, is available to provide program support and can be contacted at:

bob.anderson.ok@gmail.com

User support is provided by Tony George.
He may be contacted at:

triastro@oregontrail.net

Acknowledgements

Many people contributed to the creation of *PyMovie*. This project had its genesis in a discussion I had with Tony George. Tony also created and hosted a *PyMovie* Beta Test Group to help test the program and provide suggestions for improving the user experience (UX). The members of the beta test group were: Jerry Bardecker, Ted Blank, Tony George (leader), Ernie Iverson, Greg Lyzenga, Chuck McPartlin, John Moore, Ted Swift, and George Viscome. Ubuntu testing was provided by Dr. Altair R. Gomes-Júnior, UNESP – Guaratinguetá. Christopher Bennett fixed a Linux issue having to do with AVI-WCS folders.

We hope you find this program useful in your work.

Beyond Jupiter

The World of Distant Minor Planets

Since the downgrading of Pluto in 2006 by the IAU, the planet Neptune marks the end of the zone of planets. Beyond Neptune, the world of icy large and small bodies, with and without an atmosphere (called Trans Neptunian Objects or TNOs) starts. This zone between Jupiter and Neptune is also host to mysterious objects, namely the Centaurs and the Neptune Trojans. All of these groups are summarized as "distant minor planets". Occultation observers investigate these members of our solar system, without ever using a spacecraft. The sheer number of these minor planets is huge. As of 2019 September 26th, the *Minor Planet Center* listed 1084 Centaurs and 2408 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
5145	Pholus	Konrad Guhl	JOA 2 2016
8405	Asbolus	Oliver Klös	JOA 3 2016
10199	Chariklo	Mike Kretlow	JOA 1 2017
20000	Varuna	André Knöfel	JOA 2 2017
28728	Ixion	Nikolai Wünsche	JOA 2 2018
54598	Bienor	Konrad Guhl	JOA 3 2018
60558	Echeclus	Oliver Klös	JOA 4 2017
90482	Orcus	Konrad Guhl	JOA 3 2017
120347	Salacia	Andrea Guhl	JOA 4 2016
134340	Pluto	André Knöfel	JOA 2 2019
136108	Haumea	Mike Kretlow	JOA 3 2019
136199	Eris	André Knöfel	JOA 1 2018
136472	Makemake	Christoph Bittner	JOA 4 2018

In this Issue:

(15760) Albion

Nikolai Wünsche · IOTA/ES · Biesenthal · Germany · nwuensche@astw.de

ABSTRACT: The discovery of (15760) Albion is a story of a vision and great perseverance. David C. Jewitt and Jane X. Luu believed that there could be numerous small planets in the outer solar system and started a systematic search in 1986. Their search was only successful after new and better CCD cameras became available.
The celestial body discovered in 1992 turned out to be the first trans-Neptunian object next to Pluto and Chiron and became the prototype of a whole class, the Kuiper Belt Objects.
So far no stellar occultation by Albion has been observed. Since the last astrometric observation dates back to 2013, Albion's orbit is not sufficiently well known for accurate occultation predictions. So we still have to wait for a chance for a successfully observed stellar occultation by Albion.

Discovery

In the early 1980s David C. Jewitt[a] began to wonder why the outer regions of the solar system were apparently empty. He knew that the inner solar system, in addition to housing the terrestrial planets, was abuzz with vast numbers of asteroids and comets. But beyond Jupiter lay only the planets (including Pluto) and the strange interplanetary body (2060) Chiron[b].
He came to the conclusion that one possible explanation for the apparent emptiness could be the vast distances to the outer solar system. Objects could exist out there, but be so faint as to have escaped detection so far [1].
In 1982, Jewitt used one of the first CCD-cameras on the Palomar 5m-telescope to recover Comet Halley, four years before perihelion. He could capture the comet at magnitude 24 and beyond Saturn. With such cameras it might be possible to detect small bodies beyond Saturn – if there are any.
In 1986, Jane X. Luu[c] joined MIT. She was looking for a new project. It gave Jewitt an idea: Now it was time for a systematic search for the supposed bodies beyond Saturn.
Soon, Jewitt and Luu began to search for very faint, slow moving objects (<10"/hour, roughly the orbital speed of Saturn). They called it the SMO (slow-moving object) Survey. As it turned out, they would need a lot of patience: In the first years, they had taken many images and detected zero SMOs.
They continued the survey in Arizona until mid-1988, when they moved to the Institute for Astronomy in Hawaii.

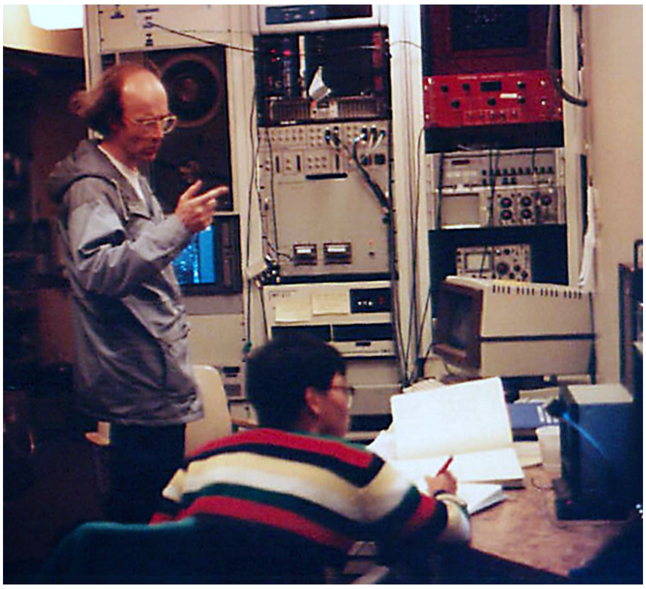


Figure 1. Jewitt and Luu in the control room of UH 88 during the Survey, in 1990. Credit: courtesy of David Jewitt

In the following years Jewitt and Luu obtained a huge number of observations for the Survey. They were taking advantage of newer, bigger and better CCDs as they became available.
Another advantage was the much better seeing at Mauna Kea compared to the telescope sites in Arizona.

Figure 2. The 2m- (88inch-) telescope of the University of Hawaii ("UH88") in 2011. Credit: Eli Duke / Wikimedia

In the night from 29 to 30 August, Jewitt and Luu had acquired observing time at the 2.2-m telescope of the University of Hawaii ("UH88") to continue the Survey.
When the scientists compared the first two images of the session, they saw a moving point, an unknown object of magnitude 22, with a slow motion and in the expected direction (west). Four images were taken during this night; all four showed the slowly moving object. While they were still observing, they calculated

[a] as Research Assistant at the California Institute of Technology, now director of the Institute for Planets & Exoplanets, University of California at Los Angeles (UCLA). See also http://www2.ess.ucla.edu/~jewitt/cv.pdf
[b] Chiron has a chaotic and unstable orbital motion. In 1991 a coma around Chiron was discovered. Since then it also counts as a comet and is hence named 95P/Chiron.
[c] as a graduate student at the Massachusetts Institute of Technology; see also http://www.imagiverse.org/interviews/janeluu/jane_luu_21_03_03.htm

the distance from the speed and estimated the size. By the end of the night, Jewitt and Luu knew that they had found a solar system object far beyond Neptune and further away than ever seen before, that it had a diameter of about 250 km, and that probably thousands of similar objects were waiting to be discovered [2].
After taking a closer look at the data, they specified the motion data as very slow (3"/hour), retrograde and close to opposition.
In the following nights they observed the very dim object again. David Jewitt and Jane Luu had discovered the first Trans-Neptunian object (TNO) after Pluto and Chiron!
Jewitt and Luu reported their discovery to the Minor Planet Center (MPC). The provisional designation '1992 QB_1' was soon assigned to the new object.

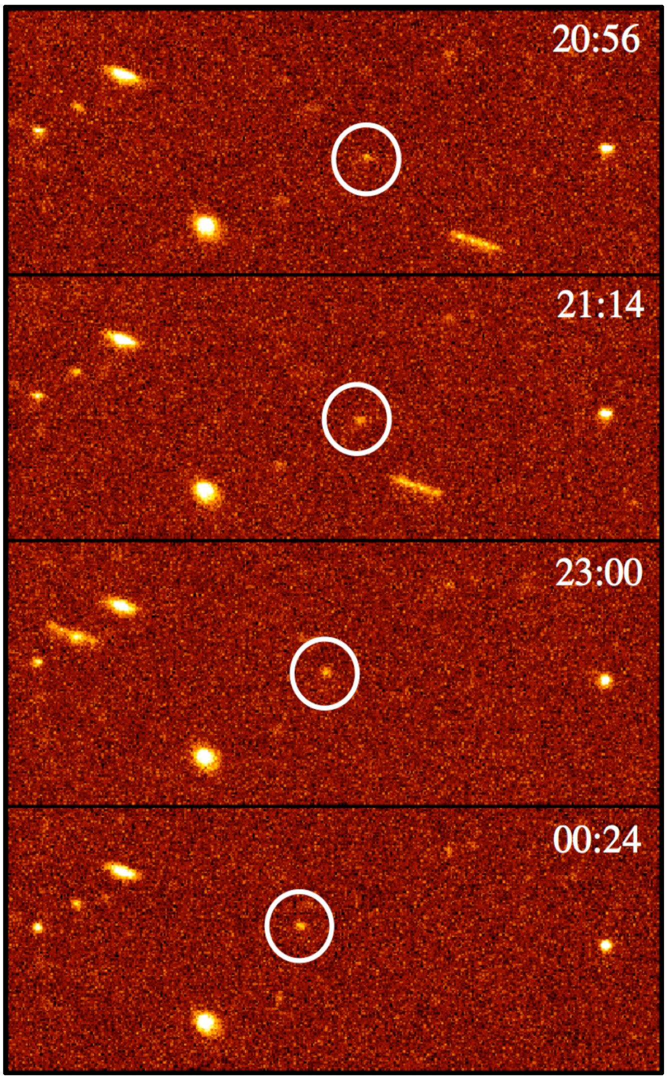


Figure 3. The discovery images. The circle marks the discovered object. The fast-moving object on the first three images is another, much nearer asteroid. Credit: courtesy of David Jewitt / Maunakea Observatories / University of Hawaii

Orbit

Often earlier observations of a newly discovered object can be found. But 1992 QB_1 could not be identified on earlier images. At magnitude 22 to 24, it was simply much too faint to appear on old photo plates. Therefore, the arc of observations started with the discovery of QB_1 in 1992. It took quite a while for the orbital elements to be considered secure. After 75 observations over more than 8 years, the Minor Planet Center assigned the number 15760 to 1992 QB_1 [3]. Between 1992 and 2013, 84 astrometric observations were made.

Parameter	Value
Perihelion date	1992-05-03.75541
Inclination (°)	2.18229
Eccentricity	0.0683013
Perihelion distance (AU)	40.8092225
Semi-major axis (AU)	43.8008814
Aphelion distance (AU)	46.793
Period (years)	290
Absolute magnitude	7.1

Cubewanos

QB_1 did not remain a unique discovery. Jewitt and Luu had broken a barrier. To date, more than 3000 trans-Neptunian objects have been discovered. The whole swarm of QB_1 cohorts was named the Kuiper Belt, after the Dutch-American astronomer Gerard Kuiper, who had discussed the outer solar system in 1951.
As the number of discovered Kuiper Belt Objects (KBOs) increased, different new classes of KBOs were identified. As it turned out, 1992 QB_1 is the prototype for Classical Kuiper Belt Objects (CKBOs) with the following characteristics:

- Low eccentricity of the orbits similar to the classical planets
- Low inclination of at most 30 degrees
- Not controlled by an orbital resonance with Neptune
- Orbits beyond Neptune's orbit (40 - 50 AU)
- Thier orbits do not cross the orbit of Neptune

Classical KBOs were also referred to as Cubewanos, after the provisional designation QB_1 (Cu-be-wan).
In contrast to the resonance-free orbits of the Cubewanos, numerous different resonances with Neptune's orbit have been observed. The 2:3 resonance at 39.4 AU is by far the dominant category among the resonance objects, containing about a quarter of all known KBOs. Pluto was the first celestial body to be discovered orbiting with this resonance. Therefore the whole group is called Plutinos. Further resonance ratios have been identified in the meantime, for example 3:5, 4:7 and 1:2.
KBOs orbiting with 1:2 resonance at 47.8 AU are called Twotinos. They likely form the outer edge of the classical Kuiper Belt. In the outer Kuiper Belt we find higher-order resonances, of which 2:5 is the most important.

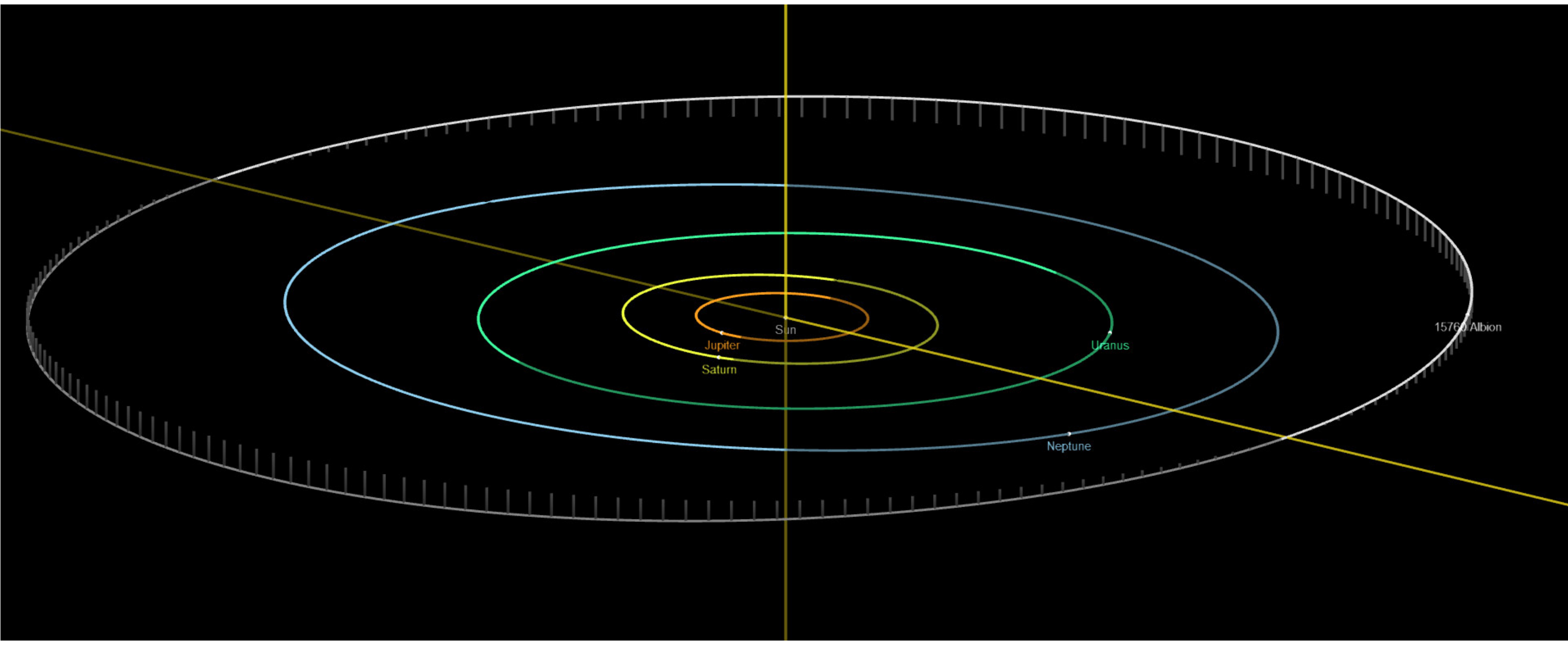


Figure 4. Albion's orbit. Both, low eccentricity and low inclination are typical for classical KBOs. Credit: JPL Small-Body Database, NASA/JPL/California Institute of Technology

Name

In articles on the internet one can read: "The discoverers suggested the name "Smiley" for (15760) 1992 QB_1 [4]. Dave Jewitt: *"No, I didn't suggest Smiley. That was just an informal way Jane and I described it to each other at the telescope instead of saying "it". She was reading a book by John Le Carré*[d] *at the time, that's where it came from"* [5]. An official naming as "Smiley" was out of the question: This name had already been allocated decades earlier to the asteroid (1613) Smiley in honour of Charles Hugh Smiley, an American astronomer. How did the name "Albion" come about?

In the creation mythology of William Blake[e] (1757-1827), "*Albion is the island-dwelling primordial man who divided himself into the four Zoas (Urthona, Urizen, Luvah and Tharmas), each representing important aspects of human character"* [6]. Albion is also an ancient, alternative name for the island of Great Britain respectively for England. This name is known since Antiquity.
David Jewitt: *"We received many, many suggestions over the years, but we didn't bother to formally name it. Recently, the IAU threatened me that if we did not name it, they would allocate a name suggested by somebody else. Unfortunately, there are strange rules about naming objects. Basically, it has to be a god or some sort of mythical figure. I am not interested in mythology, but I am interested in William Blake [7]. And, crazy guy that he was, he made his own mythology in which Albion was the key guy. So, it's Albion. The fact that Albion & England are intertwined, and that I'm English, is coincidence"* [8].
And so it came to pass that the Minor Planet Center announced on January 31, 2018: The minor planet 15760 officially received the name "Albion" [9].

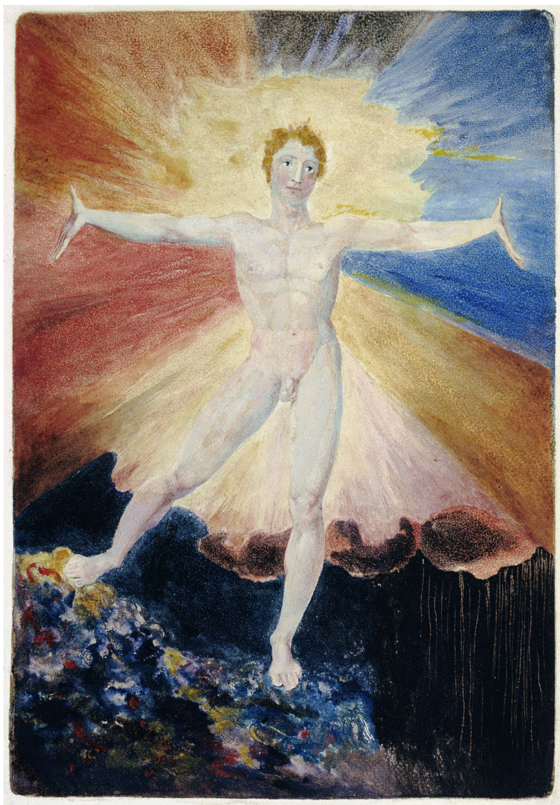


Figure 5. Albion rose. William Blake's painting of his mythological figure Albion from 'A Large Book of Designs' (1763). Credit: The William Blake Archive / Wikimedia

[d] George Smiley is a fictional character created by John Le Carré
[e] English poet, painter, and printmaker

Occultations by Albion

In 1992, Jewitt and Luu estimated the diameter of QB_1 at ~250km only from its brightness and distance. In the "List of known TNOs" the diameter is 168km, but with a question mark [10].
The best way to determine the diameter and shape of a TNO is to observe multi-chord stellar occultations. Unfortunately, TNOs move very slowly and hence rarely occult stars. So it is no surprise that no stellar occultation by Albion has ever been observed.
I asked Bruno Sicardy of the Paris Observatory whether at least predictions would be calculated. *"No, not at present"*, I got as an answer.
Josselin Desmars from the Paris Observatory explains why not: *"There are no astrometric positions since 2013. Actually, its apparent magnitude is 22-23 so it is hard to get new astrometry. I don't even try to fit an orbit but I am pretty sure that the orbit is not good enough. For example, for August 2019, AstDys [11] gives an uncertainty of around 900mas which corresponds to about 26,000km at 41.4au (current distance of Albion) whereas Albion's diameter is estimated to 167km… Excepted if there are new astrometric observations, I don't think we will add Albion in our list for occultations in the near future"* [12].
Albion is very small, the uncertainty of the prediction very large - it would be a grandiose coincidence, if a multi-chord observation would succeed. Also, an atmosphere around Albion can be discounted; its gravity is too weak.
It seems logical that it is currently not worthwhile to actively observe stellar occultations by Albion.

30 years ago, David Jewitt had found it difficult to secure enough telescope time for his Trans-Neptunian research [13]. Has the situation improved over time?

In contrast to 1992, TNOs are more in the focus of science today. But telescope time is still competitive and expensive today.
Perhaps in the future, on the basis of new astrometry, observations of stellar occultations by Albion will succeed. It would be appropriate to know what size the first Kuiper Belt Object really is.
Until then, you might have time to study William Blake, who was completely misunderstood during his lifetime and whose works have finally been recognized and appreciated.

Acknowledgement

The author thanks David Jewitt for reviewing this article and for his constructive comments.

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[1] David Jewitt in Astronomy Beat 48, 2010, p. 1
[2] David Jewitt in Astronomy Beat 48, 2010, p. 4
[3] Minor Planet Circular 40992, July 26th, 2000
[4] https://en.wikipedia.org/wiki/15760_Albion ; retrieved 2019-Aug. 19
[5] E-Mail of D. Jewitt to the author, Aug. 2019
[6] Minor Planet Circ. 108697
[7]http://www2.ess.ucla.edu/~jewitt/blake.html
[8] Same e-mail of D. Jewitt to the author, Aug. 2019
[9] Minor Planet Circ. 108697
[10] http://www.johnstonsarchive.net/astro/tnoslist.html
[11] Asteroids – Dynamic Site.
https://newton.spacedys.com/astdys2/index.php?pc=1.1.0&n=15760
[12] By e-mail to the author, Aug. 2019
[13] BBC TV's series Horizon; in 'Asteroids - The Good, the Bad and the Ugly' (Nov. 2000);
https://www.bbc.co.uk/programmes/b00vv0w8

Breaking News

Successful Observation of Occultation by (50000) Quaoar on 2019 Sep 26

Good news from the Southern Hemisphere. Positive observations of an occultation by (50000) Quaoar were recorded at 3 observing sites in Namibia. Mike Kretlow, IOTA/ES, was observing with the *M2*, the portable 50cm telescope of IOTA/ES, near Grootfontein. Michael Bakes et al. used a 35cm telescope in Windoek and Wolfgang Beisker, IOTA/ES, made his measurements with a 50cm telescope at *IAS (International Amateur Observatory)* in Hakos. Clyde Foster was successful with a telescope of 35cm aperture in South Africa.

Bruno Sicardy, Lucky Star project, reported via e-mail:
All stations in Namibia and RSA acquired data during Weywot's orbit crossing (Quaoar's satellite). Analysis must be done to see whether the satellite was detected or not (knowing that the probability is low due to the uncertainty on Weywot's position along its orbit). La Reunion was clouded out in one site (Bernard Mondon) and clear only for Weywot's orbit crossing at Les Makes (Jean-Paul Teng). Any other reports and/or detection would be welcome.

In any case, this is quite a successful campaign, which shows that even smallish telescopes can do a great job!

Journal for Occultation Astronomy

ESOP XXXVIII

Report of the 38th European Symposium on Occultation Projects

Paris, France, 2019 August 30 - September 1

Alex Pratt · IOTA/ES · BAA · Leeds· United Kingdom · alex.pratt@bcs.org.uk
Oliver Klös · IOTA/ES · Eppstein-Bremthal · Germany · oliverkloes@nexgo.de

Figure 1. The participants of ESOP XXXVIII in front of the observatory building. (Benoît Goffin)

ABSTRACT: A total of 80 amateur and professional occultation observers and researchers from 17 countries - Algeria, Argentina, Australia, Belgium, Brazil, China, the Czech Republic, France, Germany, Greece, Italy, Poland, Portugal, Spain, Switzerland, the United Kingdom and the United States - with accompanying persons, attended the 38th annual science meeting of IOTA/ES in Paris, France, during the weekend of 2019 August 30 to September 1, followed by social excursions on the next two days.

Friday 30th August
Welcome Reception

Informal proceedings began on the Friday evening with a warm welcome at *Café Oz* adjacent to Denfert-Rochereau station with delegate registration and socialising over a few drinks. This was an opportunity for old friends to catch up and also to meet other fellow observers with whom we'd only ever corresponded via Planoccult and e-mails. Following the recommendations of the Local Organising Committee we had booked into various hotels and guest houses in this area, the 14th arrondissement of Paris, (arrondissement de l'Observatoire).
The symposium presentations took place during the Saturday and Sunday at the nearby historic *l'Observatoire de Paris*. Because of safety and security restrictions on site, our numbers were limited to 80 delegates. The Symposium was so popular that it became oversubscribed, with up to another 20 persons retained on a waiting list. Seven accompanying persons turned up for a tour with Michelle Wong-Barroy around the Paris Latin Quarter, taking the small streets south towards the Cluny (Middle Ages arts & crafts) Museum and to the Pantheon, with a very Breton lunch at a Crêperie nearby. Then, some went on to an Opera theatre visit and some enjoyed the sun through the Park du Luxembourg before heading back to the Observatoire de Paris historic setting.

The Symposium Programme can be viewed here:
http://lesia.obspm.fr/lucky-star/esop38/programme.php
where many of the speakers' presentations are available in PDF form.

Saturday 31st August
Session A - Introduction Chaired by Josselin Desmars

On the Saturday morning ESOP XXXVIII was formally opened in the famous Meridian Room (Salle Cassini) by a 'Welcome back to Paris' address from Bruno Sicardy (*Lucky Star*) and Thierry Midavaine (*Club Eclipse*) of the LOC. (ESOP XXIII was held in the Paris Observatory in 2004). After a musical interlude played on flute and violin by Cordelia Eberle and Johannes Philipp from Stuttgart Observatory the *IOTA/ES* President, Konrad Guhl, welcomed everyone to the 38th ESOP. The Symposium was to take the form of plenary sessions, attended by all delegates, and parallel sessions where smaller groups would cover specific topics. Alex Pratt conveyed a 'best wishes to ESOP' message from Harrie Rutten, Netherlands, who is recovering from a serious accident and hopes to attend ESOP in 2020.

Parallel Session B1 - Future Occultation Observation Techniques Chaired by Wolfgang Beisker

This group discussed how we could better support projects that are investigating the numerous bodies in the outer solar system. To monitor objects such as Chariklo and its rings we need to use large apertures with fast cameras, e.g. a 40 cm reflector can reach mag. 16. We should use our personal contacts at amateur and professional observatories equipped with large telescopes to try to involve them in occultation work.

Figure 2. Wolfgang Beisker, Felipe Braga Ribas and Bruno Sicardy (left to right) at the workshop. (Oliver Klös)

Bruno Sicardy commented that big telescopes can reveal high resolution details in their light curves, but smaller 'scopes are still useful because they confirm the locations of the quality chords across the target body. Small 'scopes give us astrometry; large 'scopes give us science.
The group discussed the plethora of light curve analysis software available to the observer, viz. *AOTA*, *Limovie*, *PyMovie*, *PyOTE*, *Tangra*, etc. It would be useful to carry out a comparative study of their different approaches and their results.
Felipe Braga Ribas outlined the production of the *RIO* predictions which are used by Dave Gault to create his *RIO* feed to *OccultWatcher*. Bruno described the information available on the *Lucky Star* website, such as the Predictions tab and the Publications tab, where a number of papers can be viewed without subscription to a professional Journal. When submitting data to the *Lucky Star* group, observers are advised to send their provisional light curve and raw data in a zipped file, not as separate files. Selecting a smaller region of interest window for their camera can produce smaller files.
The *Lucky Star* ERC Advanced Grant is ending next year and will be succeeded by *Far Horizons*, which will build on the successes of our Pro-Am collaborative work.

Parallel Session B2 - *OccultWatcher* Tutorial
Presented by Hristo Pavlov

Hristo conducted a tutorial on his *OccultWatcher* software and announced that he is developing *OW Mobile* for iPhone and Android platforms.

Figure 3. Between sessions. Flavia Luane Rommel, Felipe Braga Ribas, Dave Gault, Dave Herald, Roland Boninsegna, Josselin Desmars and Hristo Pavlov (left to right) (Benoît Goffin)

Parallel Session B3 - French Language Sessions Chaired by Arnaud Leroy

After an introduction by Thierry Midavaine a report of 10 years of occultation observations at Visker observatoire was shown by Jean Jacques J. Castellani (*Dinastro*). Lionel Rousselot (*SAPC*) presented solutions for digital cameras and amateur observations in the field of occultations by J. P. Godard. Jean-Marie Vugnon (*Club Eclipse*) gave a lecture about NTP time stamp solutions.

All participants then met for lunch, with spare time to peruse the posters displayed by delegates and sponsors. QHYCCD brought a selection of their imaging systems.

Posters are available for download at:
http://lesia.obspm.fr/lucky-star/esop38/posters.php

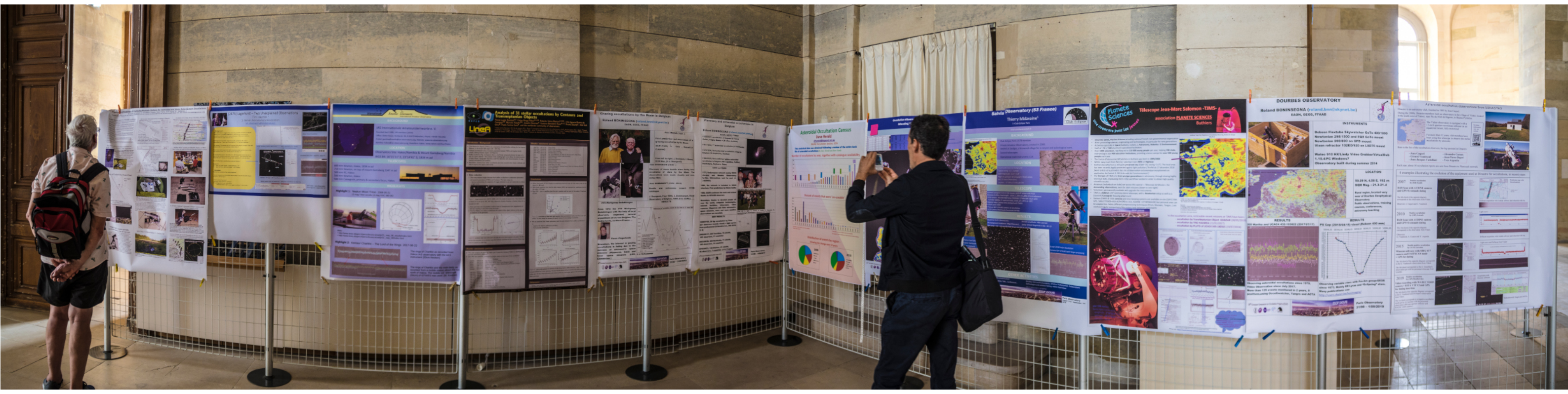

Figure 4. Poster presentation in the Cassini room. (Benoît Goffin)

Parallel Session C1 - Timestamping Issues and Alternate Solutions
Chaired by Thierry Midavaine

In the Cassini room sessions were continued with the lecture Operational activities of the REFMET Team: Timescales Generation and Dissemination by Michel Abgrall; Cesar Valencia (*Club Eclipse*) talked about timing issues in occultations. Andreas Schweizer and Stefan Meister from *Bülach Observatory* in Switzerland presented a first look at a new digital Camera with onboard GPS time inserter. Afterwards another timing tool called Chronoflash, a simple device for asteroid occultation timing, was shown by Jean-Yves Prado (*PLATINEO*). The Session was closed by Chad Ellington's presentation of Astro Flash Timer at 1000 Hz.

Parallel Session C2 - *Tangra* Tutorial
Presented by Hristo Pavlov

While session C1 continued in Salle Cassini Hristo Pavlov condutcted a tutorial on his *Tangra* software. Participants took their own computers with them and could try the different features at first hand.

After the sessions the particpants met in front of the observatory building for the group photo (Figure 1).

Parallel Session D1 - Test Bench and Camera Setup latency masurements
Chaired by Pierre Barroy

During this session participants could have a close look at the following technical features and setups:

- UTC OP TTL Output on Oscilloscope (M. Abgrall)
- Bernard Christophe's PPS driven artificial stars (T. Midavaine)
- SEXTA Target Test Bench (D. Gault)
- QHY CCD camera demonstration (H. Qiu)
- Raptor camera demonstration and Timebox demonstration (C. Valencia)
- AstroFlashTimer at 1000 Hz (C. Ellington)
- Latency test of camera setup for ESOP participants

Parallel Session D2 - *IOTA/ES* General Assembly
Chaired by Konrad Guhl

At this business meeting the board of *IOTA/ES* gave an overview about past and upcoming projects to its members. The board was re-elected for another two years, Nikolai Wünsche joined the board as Secretary for the first time.

Parallel Session D3 - Onsite Tours

A series of guided tours was conducted to visit the SYRTE UTC-OP atomic clock timekeeping facility and to see the historic Coupole Arago housing the large refractor with its 38cm objective on the roof of the Observatory building.

Figure 5. Tour of the Arago. Stefan Meister has a closer look at the impressive telescope. (Benoît Goffin)

This concluded the first day of talks.
That evening the social highlight of ESOP, the Symposium dinner, was held in the African-style restaurant *La Baraka*.

Sunday 1st September
Session E - Occultations and Campaign Results
Chaired by Wolfgang Beisker

The second and final day of ESOP was comprised of plenary sessions, attended by all delegates.
Bruno Sicardy gave an overview of the results of the *Lucky Star* project and took a view into the future, while in the following lecture Felipe Brage Ribas showed how international collaboration for observation of stellar occultations is accomplished by the *Meudon*, *Rio* and *Granada* Groups. Dave Herald presented how occultations help with 3D shape reconstruction. How tight and contact binaries could be detected from occultations was discussed by Rodrigo Leiva from the *Southwest Research Institute*.

Session F - Occultation Observations (1)
Chaired by Konrad Guhl

The second session of this morning started with a presentation of occultations observed by the *Sabadell* group during the last year by Carles Schnabel. Jiří Kubánek impressed the participants with 26 positive observations of 21 events in just 17 months. A successful observing campaign of an occultation by (156) Xanthippe gave many chords from England. The results were shown by Tim Haymes. Results from the *Section for Observations of Positions and Occultation* in Poland were presented by Wojciech Burzyński. The section celebrates its 40th anniversary. The session was closed with Bernd Gährken's lecture about measuring exo-planets with amateur equipment.

After lunch the particpants quickly returned to the Salle Cassini. A small hole in the south wall projected an image of the Sun onto the floor and we watched as it traversed the Paris Meridian line.

Figure 6. The image of the Sun close to the Paris Meridian line. Martina Haupt and Bruno Sicardy taking pictures of the event. (Alex Pratt)

Session G - Occultation Observations (2)
Chaired by Bruno Sicardy

After the observation of the traverse, the Sun was the topic of the first lecture of the afternoon held by Konrad Guhl. He reported about his Baily's Beads observation made during the total solar eclipse on July 2nd in 2019. Djounai Baba Aissa showed analyses of stellar occultations observed in Algeria. In the following lecture Joana Marques Oliveira presented models of the atmosphere of Triton obtained by the measurements made during the occultation in October 2017. A special 'observatory' was presented by Vagelis Tsamis, he observed occultations from inside a tipi. With a report of an observation of 2014 MU_{69} in Senegal by François Colas the session was closed.

Session H - Occultation Technologies
Chaired by Pierre Barroy

In this technical session Hongyun Qiu and Jan Soldan gave an overview of the QHY174GPS, a digital camera with integrated GPS, and Franck Marchis presented via internet first contributions to occultation science by the Unistellar network.

Session I - Future of Occultations
Chaired by Pierre Barroy

João Ferreira from the *Université Côte d'Azur* told the participants about a new approach to stellar occultations in the Gaia era. Paths maps of occultation highlights of asteroids in 2020 were given by Oliver Klös. Very wide paths, long durations and asteroids with satellites were in focus. Finally Josselin Desmars presented fothcoming *Lucky Star* predictions.

Konrad Guhl and Karl-Ludwig Bath invited the delegates to attend ESOP XXXVIX in Freiburg im Breisgau, Germany, on August 28 – 30, 2020.

Closing Remarks

Dave Gault presented a SEXTA timing device to *Club Eclipse*, to great applause from the meeting. This will be made available for testing timing systems.
Thierry Midavaine presented a Treasurer's report showing the skilful financial management of the Symposium and optional excursions programme – all costs were covered thanks to generous sponsorship from *Lucky Star*, QHYCCD, Raptor Photonics and Unistellar. He asked speakers to send PDFs of their talks to Josselin Desmars for the ESOP website and delegates to submit their pictures for an ESOP Photo Gallery:

http://lesia.obspm.fr/lucky-star/esop38/photos.php
and
https://benoitgoffin.zenfolio.com/p85417794

Thierry proposed a list of tasks and challenges for everyone to take back to their home countries to promote our work.
At the formal closing of the proceedings the delegates expressed their grateful thanks to the Local Organising Committee of Pierre Barroy, Michelle Wong-Barroy, Gustavo Benedetti-Rossi, Felipe Braga Ribas, Emmanuel Brochard, François Colas, Josselin Desmars, Joana Marques Oliveira, Thierry Midavaine and Bruno Sicardy for a very productive and most enjoyable ESOP.

Excursions - *Monday 2nd September*

On the Monday morning delegates and accompanying persons met outside the north gate of the Observatory and joined an excursion by coach to visit the *Château de Fontainebleau*, a World Heritage Site about 55 km southeast of Paris. The earliest parts of this Palace date from 1137 and over the next 700 years it was significantly expanded by France's monarchs. We had a couple of hours to walk through the park and gardens, followed by a picnic, then we had a guided tour of the Château to see the classical artwork and furnishings decorating its rooms and corridors.
We continued on to Buthiers Leisure Park, Seine-et-Marne, the home of the *Jean-Marc Salomon Astronomy Centre*, named in memory of their energetic young colleague who tragically lost his life in a car accident. Constructed in a forest clearing the Centre has two large domes housing telescopes 50cm and 60 cm in diameter, the latter is known as the Télescope Jean-Marc Salomon (TJMS). There is a large observing terrace where other instruments can be set up and visitors can enjoy the night sky. Our hosts were Planète Sciences whose aim is to introduce all young people to the wonders of astronomy, irrespective of any form of handicap.
After an evening meal some of our group returned to Paris on the coach but a number of us stayed overnight at Buthiers. It was a clear night and we were treated to views through the TJMS of popular objects such as the Ring Nebula (M57) and the Dumbbell (M27) etc. This 'scope and other instruments were then used for more serious work, such as to image the field of the upcoming Chiron occultation. In the early hours we drifted down the hill back to our dormitory accommodation.

Tuesday 3rd September

After a leisurely breakfast our coach took us to Juvisy-sur-Orge where we picked up those who had returned from Paris. We had a nice lunch in the Chez Jacqueline restaurant then we had a short walk to *Camille Flammarion's Observatory*. He was a great populariser of astronomy, writing many books on various topics. He founded the *Société astronomique de France (SAF)* and published their journal *l'Astronomie*. Flammarion's 240mm refractor is still in use and it was projecting the Sun during our visit. In the grounds we were guided to see the last resting place of Camille Flammarion, alongside his first wife Sylvie Petiaux-Hugo and his second wife Gabrielle Renaudot, who bequeathed the observatory, buildings and gardens to the *SAF*.
At the end of the visit Thierry Midavaine distributed free copies of *l'Astronomie* to our group and encouraged delegates to submit articles on our work. Whatever your mother tongue, your contribution can be translated.

An excellent ESOP!

The Symposium and excursions were a great success due to the hard work of the staff from the *Lucky Star* team, *l'Observatoire de Paris* and members of *Club Eclipse*, *Planète Sciences* and *SAF*. On our return to Paris we once again thanked the LOC, exchanged 'au revoir', and we all looked forward to meeting at our next ESOP in Freiburg, Germany in 2020.

Figure 7.
Waiting for sunset at Jean-Marc Salomon Astronomy Centre.
(Thierry Midavaine)

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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.

The Journal for Occultation Astronomy (JOA) is published on behalf of IOTA, IOTA/ES and RASNZ and for the worldwide occultation astronomy community.

IOTA President: Steve Preston . . . . stevepr@acm.org
IOTA Executive Vice-President: Roger Venable . . . . rjvmd@hughes.net
IOTA Executive Secretary: Richard Nugent . . . . RNugent@wt.net
IOTA Secretary & Treasurer: Joan Dunham . . . . iotatreas@yahoo.com
IOTA Vice President f. Grazing Occultation Services: Dr. Mitsuru Soma . . . . Mitsuru.Soma@gmail.com
IOTA Vice President f. Lunar Occultation Services: Walt Robinson . . . . webmaster@lunar-occultations.com
IOTA Vice President f. Planetary Occultation Services: John Moore . . . . reports@asteroidoccultation.com

IOTA/ES President: Konrad Guhl. . . . . president@iota-es.de
IOTA/ES Research & Development: Dr. Wolfgang Beisker . . . . wbeisker@iota-es.de
IOTA/ES Treasurer: Andreas Tegtmeier . . . . treasurer@iota-es.de
IOTA/ES Public Relations: Oliver Klös . . . . PR@iota-es.de
IOTA/ES Secretary: Nikolai Wünsche . . . . secretary@iota-es.de

RASNZ Occultation Section Director: Steve Kerr . . . . Director@occultations.org.nz
RASNZ President: John Drummond . . . . president@rasnz.org.nz
RASNZ Vice President: Nicholas Rattenbury . . . . nicholas.rattenbury@gmail.com
RASNZ Secretary: Nichola Van der Aa. . . . . secretary@rasnz.org.nz
RASNZ Treasurer: Simon Lowther. . . . . treasurer@rasnz.org.nz

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www.occultations.org
www.iota-es.de
www.occultations.org.nz

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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