Journal for
Occultation Astronomy

2015–02

Time is on our side

Occultation-work without time-keeping is not possible.

For Columbus it was told, that he used the local Spanish time-computation for a lunar eclipse to refine his position while crossing the Atlantic Ocean. For several hundreds of years time-balls were used at worldwide harbours to adjust the chronometers of all the ships crossing the oceans. One of the measurement possibilities was using stellar occultations of the moon to determine positions on earth as well as lunar orbit-positions.

Using stopwatches (starting in the sixties) combined to time signals of short-waves radios leaded to these positional data. DCF77- and nowadays GPS-Time combined with high-speed-CCD-Cameras are used to measure everything within nanosecond – but what for?
Regarded to living, no use for nanoseconds, just leave it (Dali) …

Journal for
Occultation Astronomy

Dear reader,

Writers Wanted!

I am very sorry, but it looks like a never ending story: Each time we are waiting for actual articles of the occultation-work you did, the new experience you won prepared for presentation to others or the latest records you received having discovered something new – but again nothing or only little things happened that could be printed in your Journal for Occultation Astronomy. Again we had to wait until we reached the full amount of pages we need for producing, or making boring news filling empty pages – which doesn't seem very worthwhile.

If you are still doing occultation-work – or aren't you? – then you have to inform your colleagues concerning your efforts and failures for providing and preventing them by others.

Klaus-J. Bode

JOA 2015-2 · $ 5.00 · $ 6.25 OTHER · (ISSN 0737-6766)

In this issue:

Writing articles for JOA:

The rules below should be regarded while writing an article; using them will greatly facilitate the production and layout of ON!

If your article does not conform to these rules, please correct it.

There are 3 different possibilities for submitting articles:

- pdf-articles (must be editable – these can be converted)
- unformatted Word *.doc-files containing pictures/graphs or their names (marked red: <figure_01>) at the desired position(s)
- *.txt-files must contain at the desired position the name of each graph/picture

The simplest way to write an article is just use Word as usual and after you have finished writing it, delete all your format-commands by selecting within the push-down-list "STYLE" (in general it's to the left of FONT & FONTSIZE) the command "CLEAR FORMATTING". After having done this you can insert your pictures/graphs or mark the positions of them (marked red: <figure_01>) within the text.

txt-files: Details, that should be regarded

- Format-commands are forbidden
- In case of pictures, mark them within the text like <picture001> where they should be positioned

Name of the author should be written in the 2nd line of the article, right after the title of the article; a contact e-mail address (even if just of the national coordinator) should be given after the author's name.

IMPORTANT:Use only the end-of-line command (press ENTER) if it's really necessary (new paragraph, etc.) and not when you see it's the end of the line!

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Journal for Occultation Astronomy

Lunar limb profile models in the past and today

Dietmar Büttner, IOTA/ES · dietmar.buettner@t-online.de

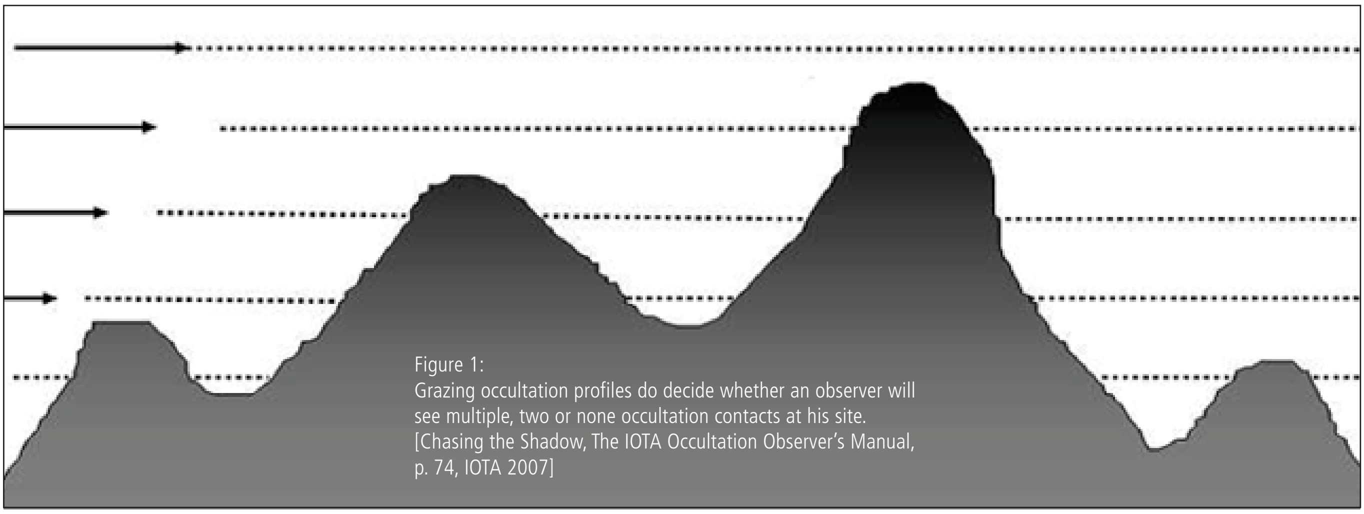


Figure 1:
Grazing occultation profiles do decide whether an observer will see multiple, two or none occultation contacts at his site.
[Chasing the Shadow, The IOTA Occultation Observer's Manual, p. 74, IOTA 2007]

Introduction

The lunar limb profile is the outline contour of the lunar disk.

It is formed by the projection of the lunar surface on the edge of the Moon's disk as seen from the Earth. The profile changes with the orientation of the Moon's globe to the observer, which is numerically expressed by the libration values in longitude and latitude.

Lunar limb data are needed for

- **grazing occultation predictions**
- **occultation observation reductions**
- **solar eclipse observation reductions**

There is a long time experience and a long tradition with lunar limb profiles within the IOTA.

Over the decades, several important lunar limb profiles models have been developed and used. This paper describes their history and their properties. It is the print version of a lecture held by the author at the ESOP 2014 in Prague.

Lunar limb profile data are used either numerically as a single value for the height of a particular limb point or graphically as a display of the limb contour for a selected section of the limb.

The Moon's limb may be displayed by several methods, namely by

- **A solid line**
- **Single surface points**
- **Single limb points (which not necessarily need to be identical with surface points)**

Watts Charts

The first comprehensive lunar limb model were the famous and historical Watts Charts. They are named after Chester B. Watts of USNO (U.S. Naval Observatory, Washington) who published them in 1963. Watts derived the data from Earth based photographic exposures. His set consists of 1800 charts with 0.2° steps in Axis Angle (position angle measured from the Moon's northern pole) around the whole lunar disk. This enormous work was done by him in the pre-computer age! Watts used a mechanical profile measuring machine in order to derive the limb contour from each single lunar photo. The Watts charts were digitised by the Her Majestic Nautical Almanac Office (HMNAO; then at Herstmonceux Castle) in 1970. This important step made it possible to use the data in an automated way by computers. The Watts data were firstly used for graze predictions at the HMNAO.

There have been some limitations with the Watts charts:

- **Offset between the centres of mass and figure**
- **Offset between the axis angle reference line and the rotation axis of the Moon**
- **Partial incompleteness behind the lunar pols due to the geometry of illumination within the so called 'Cassini regions'**

ACLPPP

The next important limb model was the ACLPPP, which is the abbreviation for 'Automatic Computer Lunar Profile Plotting Program'.

ACLPPP was first introduced in 1975 by Berton Stevens of IOTA. In the profile plots ACLPPP combined Watts and occultation data. For the very

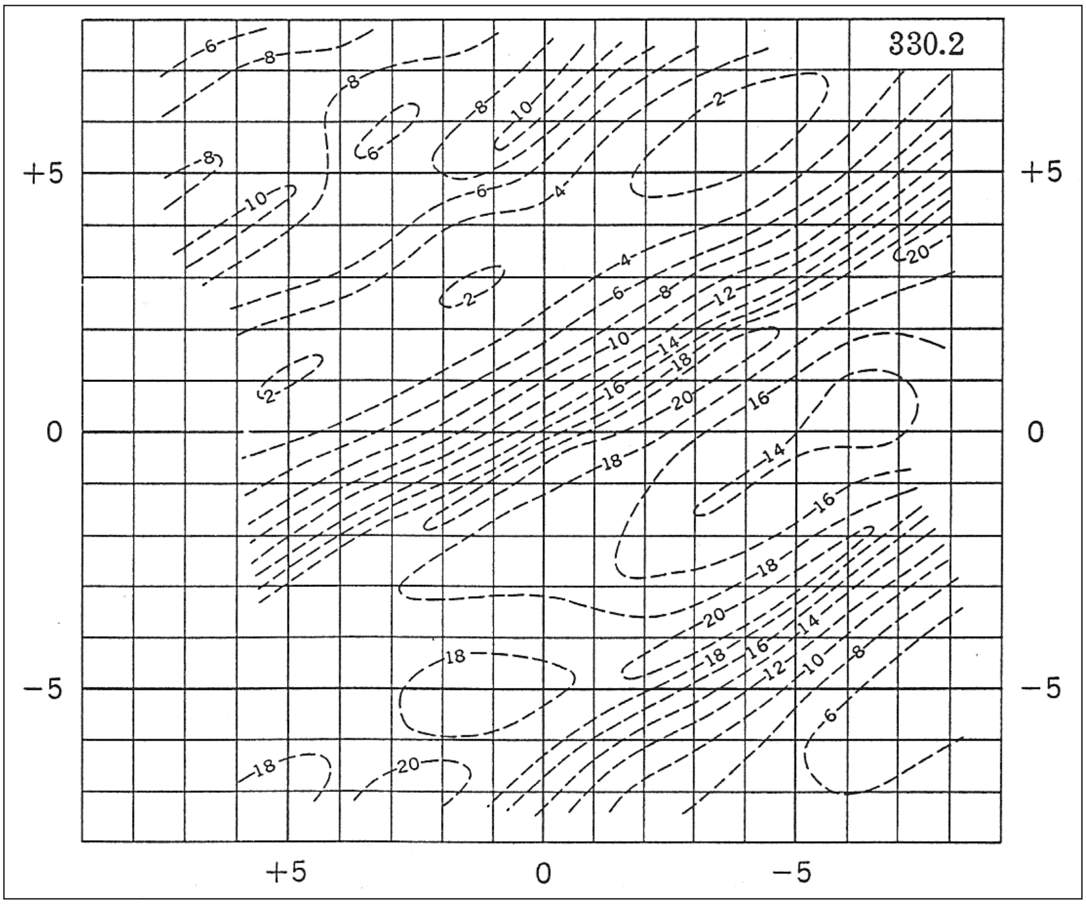


Figure 2:
Lunar limb chart by C.B. Watts

first time lunar limb data from real lunar grazing occultation observations were used for predicted profiles. ACLPPP was intended to fill the gaps in the Cassini regions and to improve the prediction accuracy. Actually, the ACLPPP data base contained observed graze data only, which were merged with Watts' data for the profile plots.

The ACLPPP was firstly mentioned in 'Occultation Newsletter' (ON) in April 1975 and firstly described in ON in August 1975.

It is interestingly to notice that the foundation of the IOTA was firstly mentioned in the same ON issue as ACLPPP was. So we can resume that ACLPPP is as old as the IOTA. In 2015 both they become 40 years old. Happy birthday!

With ACLPPP a new pseudo graphic format for the profile display was introduced.

ACLPPP formed the first basis for the worldwide successful grazing occultation prediction service offered by IOTA. In 1993 it was adopted to be used by Eberhard Riedel in his (in those days) new PC software GRAZEREG after the shutdown of the main frame computers at the U.S. Naval Observatory on which IOTA's graze predictions were based until then.

Originally, David W. Dunham was the person who added new grazing occultation observations to the ACLPPP data base over many years. Later this was continued by Mitsuru Soma until the Kaguya Moon's probe era.

As with each other model there were some limitations of ACLPPP too:

- Pseudo graphic with limited resolution of profile display
- Accuracy of profile points partly rather poor due to some uncertain observations and due to its stepwise historical development over about 30 years
- No complete coverage of the entire pole regions due to the limited number of Watts and occultation observations

Kubo – Watts

An intermediate limb profile model was the so called 'Kubo – Watts'.

Its profile contour data were completely based on the Watts charts. However, they were corrected for the offset between the mass and figure centres. These corrections were based on an analysis of lunar occultation observations by Yoshio Kubo of Japan and were incorporated by Reinhold Büchner (IOTA/ES). The only known usage of 'Kubo –Watts' was in GRAZEREG by Eberhard Riedel.

MOONLIMB

MOONLIMB was an IOTA/ES project run by the author. It is the first profile model solely based on observations of grazing and total oc-

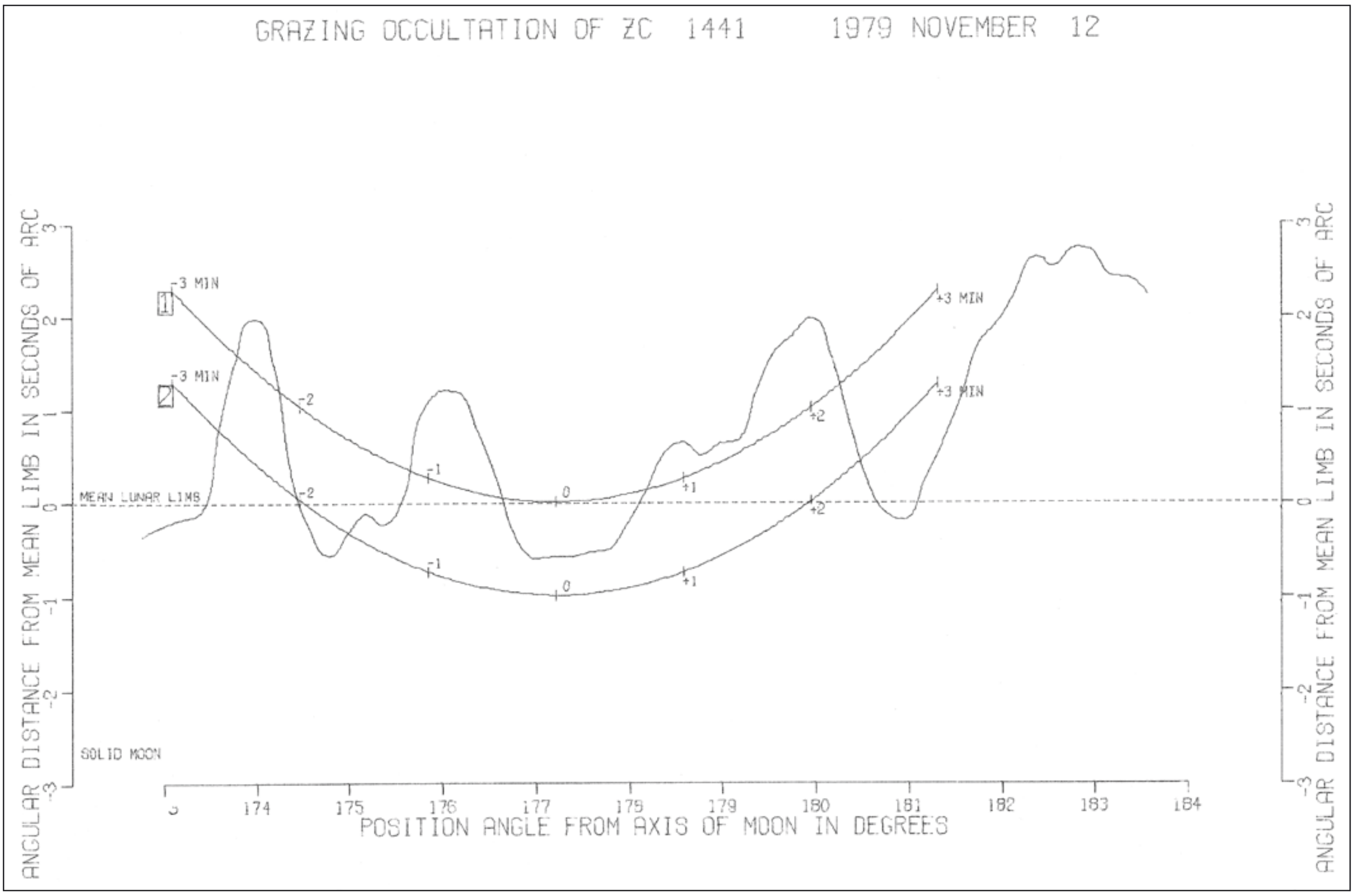


Figure 3:
Usage of Watts' data for graze predictions at the HMNAO

cultations. It used all available observations collected by the HMNAO, the IOTA and the ILOC (International Occultation Timing Association, Tokyo).

For each observation the theoretic distance between the mean lunar limb and the star was calculated using the (at this time) modern lunar ephemerides and star positions (LE 405, Hipparcos) resulting in one limb point per occultation observation. All limb points are related to the centre of mass like the ephemerides. MOONLIMB is a model quite independent from Watts charts.

Several versions were released from 1996 up to 2007. The MOONLIMB data were used by Eberhard Riedel in his GRAZEREG software for grazing occultation predictions.

The limitations of MOONLIMB were:

- Limited to the polar regions only
- Incomplete coverage of all possible combinations of librations and axis angles due to limited number of occultation observations
- Accuracy of limb points depends on the quality of the observations. In spite of comprehensive efforts in MOONLIMB, the quality assessment of the observations was partly difficult due to various reasons.

Modern limb models

Today's lunar limb models are based on laser altitude measurements by the lunar probes Kaguya and Lunar Reconnaissance Orbiter (LRO). Such limb models do use a very large number of single topographic points which describe the Moon's surface.

The profiles are the results of complex and comprehensive calculations with 3-D-geometry considering the appropriate view angle defined by the librations. The large number of single topographic points causes very large data files and needs a lot of computing time.

Limb models from Kaguya and LRO have been derived with several resolution levels by Mitsuru Soma firstly and by David Herald during the last years. They are used for graze reductions (M. Soma) and in the program OCCULT (D. Herald; only Kaguya) for predictions and reductions. GRAZPREP used the low resolution Kaguya based profiles created by David Herald until the end of 2014.

Late in 2014 the author released a new limb model named LUNLIMB. It was developed exclusively for the use with GRAZPREP and consists of a complete set of high resolution limb data derived from the Kaguya measurements. Investigations on the density of the Kaguya points have been made in order to find a suitable profile resolution. This resulted in the selection of the step sizes of 0.1° for the librations and 0.05° for the Axis Angle. The data set covers the polar regions within ±30° in Axis

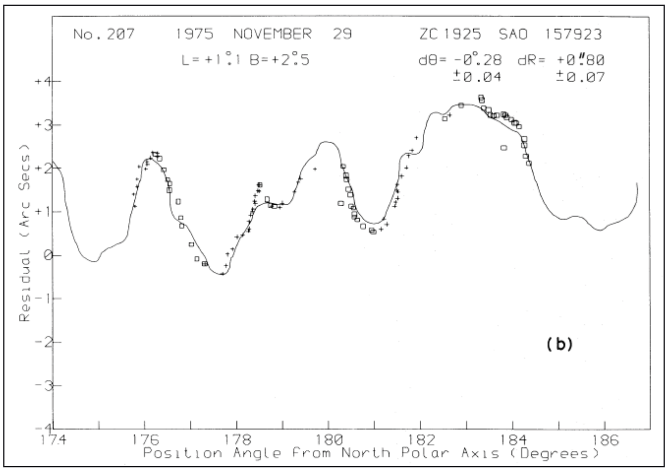


Figure 4: Graze reduction by the HMNAO using Watts' data [Monthly Notices of the Royal Astronomical Society (1983) 205, 60]

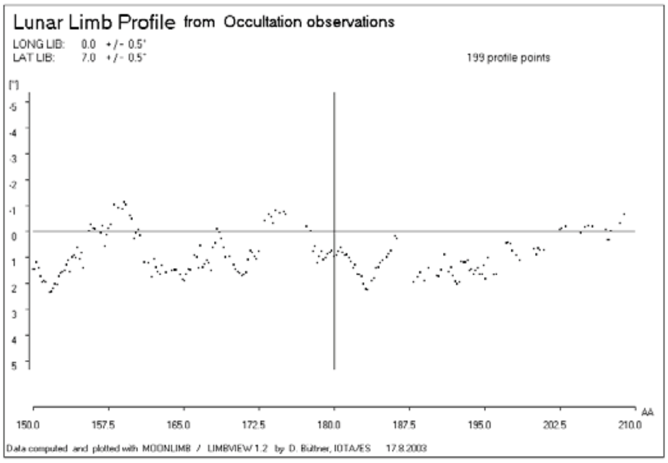


Figure 7: MOONLIMB profile by Dietmar Büttner

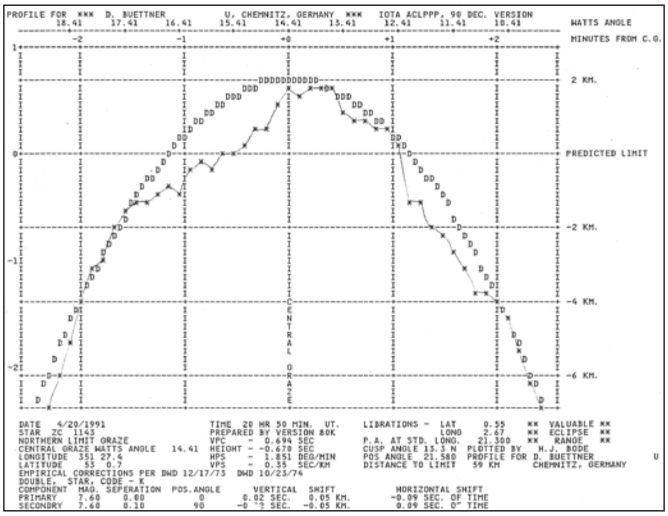


Figure 5: Original ACLPPP graze prediction

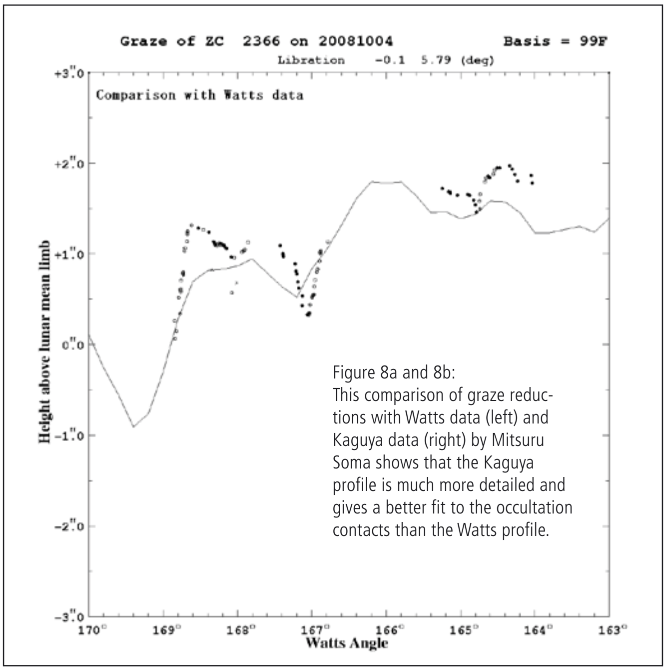
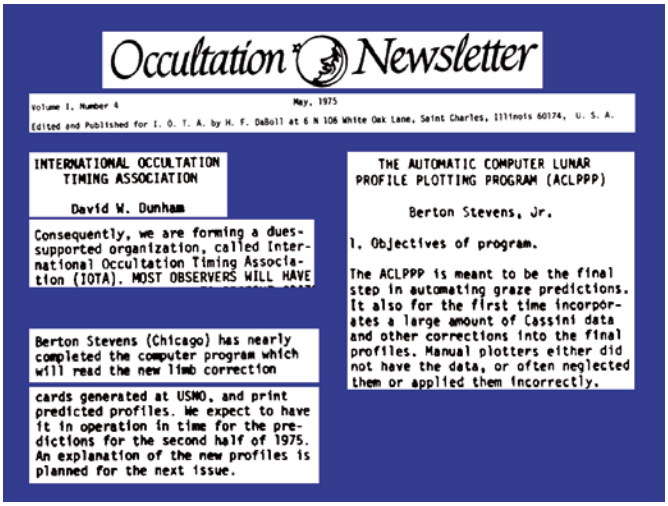


Figure 8a and 8b:
This comparison of graze reductions with Watts data (left) and Kaguya data (right) by Mitsuru Soma shows that the Kaguya profile is much more detailed and gives a better fit to the occultation contacts than the Watts profile.



Occultation Newsletter

Volume I, Number 4 May, 1975

Edited and Published for I. O. T. A. by H. F. DaBoll at 6 N 106 White Oak Lane, Saint Charles, Illinois 60174, U. S. A.

INTERNATIONAL OCCULTATION TIMING ASSOCIATION

David W. Dunham

Consequently, we are forming a dues-supported organization, called International Occultation Timing Association (IOTA). MOST OBSERVERS WILL HAVE

Berton Stevens (Chicago) has nearly completed the computer program which will read the new limb correction

cards generated at USNO, and print predicted profiles. We expect to have it in operation in time for the predictions for the second half of 1975. An explanation of the new profiles is planned for the next issue.

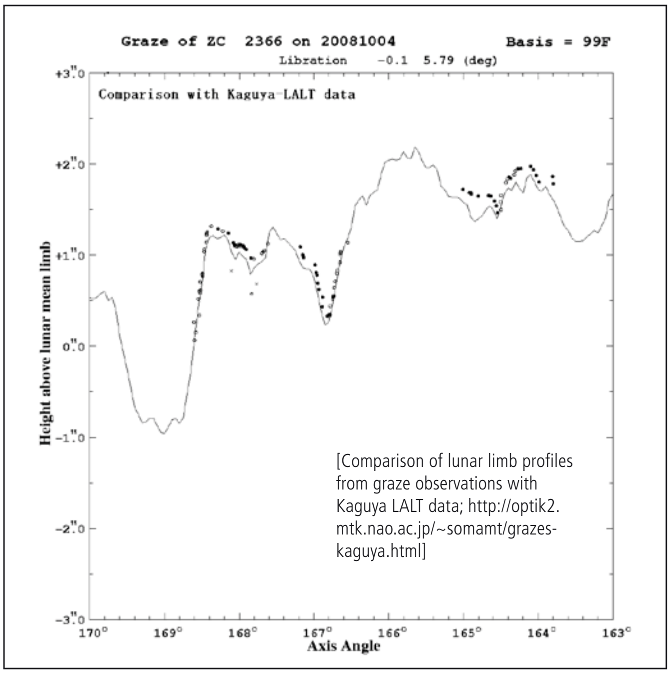
THE AUTOMATIC COMPUTER LUNAR PROFILE PLOTTING PROGRAM (ACLPPP)

Berton Stevens, Jr.

1. Objectives of program.

The ACLPPP is meant to be the final step in automating graze predictions. It also for the first time incorporates a large amount of Cassini data and other corrections into the final profiles. Manual plotters either did not have the data, or often neglected them or applied them incorrectly.

Figure 6: History of the IOTA and ACLPPP: The foundation of IOTA was firstly mentioned in Occultation Newsletter (ON), Vol. I, No. 4, p. 27, April 1975. ACLPPP was firstly mentioned in the same ON issue on p. 33 (left column) and firstly described in ON, Vol. I, No. 5, p. 46 August 1975 (right column).



[Comparison of lunar limb profiles from graze observations with Kaguya LALT data; http://optik2.mtk.nao.ac.jp/~somamt/grazes-kaguya.html]

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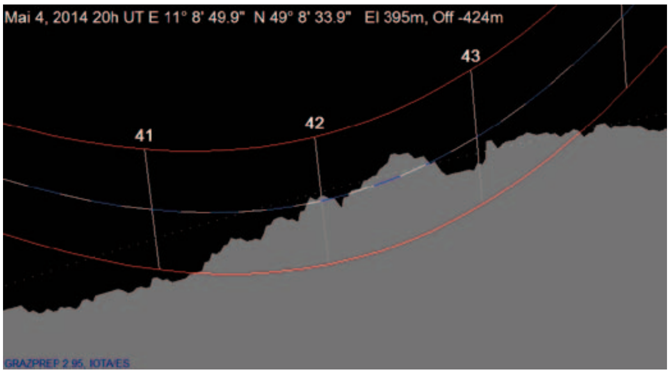

Figure 9:
GRAZPREP profile using the high resolution Kaguya / LUNLIMB data.
Event: Graze of ZC 1106 (Gem) on 2014 May 4

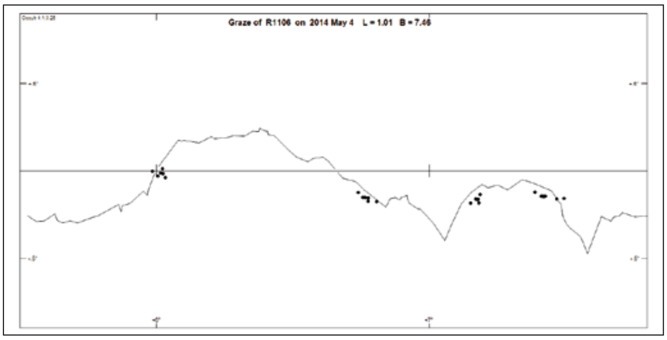

Figure 10:
Graze reduction using high resolution Kaguya data with OCCULT by David Herald

Angle AA centred at the north and south poles and the libration ranges from -9 to +9° in longitude and -8 to +8° in latitude. All together a total of 34.969.200 data points for each polar region within 29.141 libration combinations were derived.

The complete set of the pre-calculated profile data can be directly used in GRAZPREP and doesn't need any more calculations. This enables a quick profile display in GRAZPREP without any noticeable delay. It has been in use since January 2015 starting with the GRAZPREP version 2.95.

Conclusion

The parallel work by Mitsuru Soma, David Herald and the author does not mean any competition among the three, but it's a useful addition. It ensures an independency from only one source. Additionally, it may help to further develop our knowledge on and the usage of the limb profiles.

One limitation of the limb profiles based on lunar probe measurements is the difficulty to find the real outer limb points from the huge number of topographic points. Another limitation is the even too low density of the topography points in some regions.

There are many Kaguya and LRO measure points, but there are many gaps between them too.

Thus, occultation observations still continue to be needed for filling these gaps!

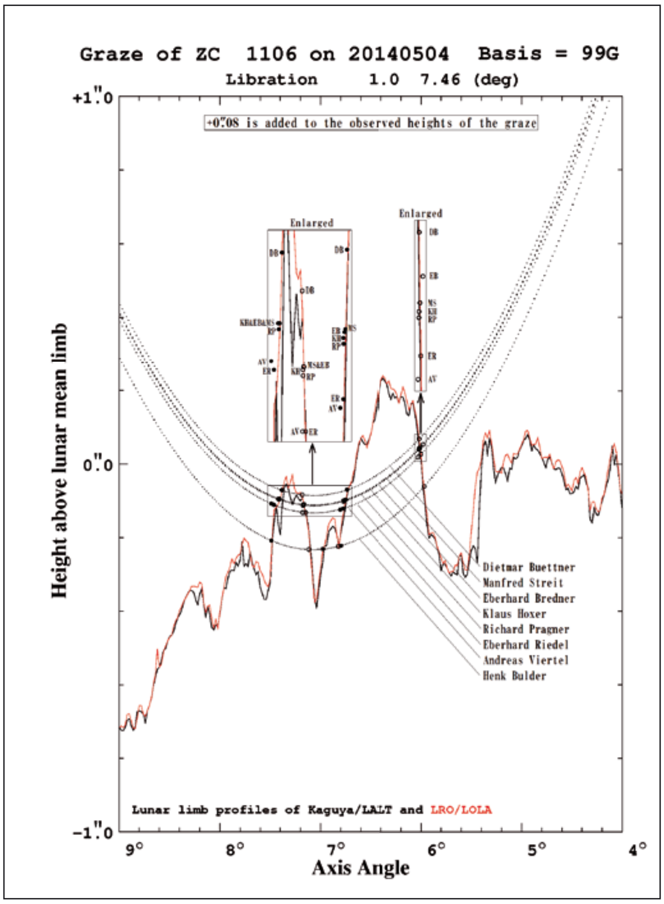

Figure 11:
Graze reduction with Kaguya and LRO profiles by Mitsuru Soma
[Reductions of graze observations; http://optik2.mtk.nao.ac.jp/~somamt/grazes.html]

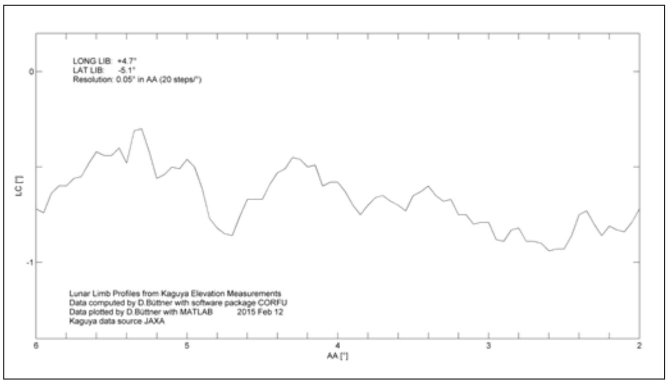

Figure 12:
LUNLIMB profile at the northern lunar limb derived by Dietmar Büttner from the Kaguya data

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Occultation Astronomy

Exoplanets and occultations

Dave Herald · Murrumbateman, Australia

IOTA has been approached to assist with the efforts to detect exoplanets by the Kepler satellite. This article sets out what is involved.

BACKGROUND

We all know that the Kepler satellite has been extraordinarily successful in detecting exoplanets. There is plenty of information on the web about how Kepler worked. A key element was that it pointed on the same part of the sky for the whole mission – with that part of the sky being located far from the ecliptic (in Cygnus).

This all came to an end in May 2013 when the number of fully functional reaction wheels was reduced to two, preventing it from maintaining stable pointing. Subsequently the technicians worked out a way that they could get stable pointing of Kepler. In essence, they are using the light pressure of the sunlight on the solar panels to stabilise the satellite. This mechanism is explained in the Wikipedia item on the Kepler satellite

http://en.wikipedia.org/wiki/Kepler_(spacecraft)

The end result is that the satellite can point at a region of the sky close with two important constraints. Firstly, the pointing location must be quite close to the ecliptic. Secondly, it is only possible to maintain this pointing for a period of about 83 days. This has led to the K2Mission, which is set out at:

http://keplerscience.arc.nasa.gov/K2/

The observing field locations and dates are set out at:

http://keplerscience.arc.nasa.gov/K2/Fields.shtml

Also available from this location is a list of targets for each field – as they become established. At the moment the target catalogues are only available for fields 0, 1, 2 and 3.

WHY OCCULTATIONS?

The reason for our involvement is explained by James Lloyd as:

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I am a professor of astronomy at Cornell University, where I work primarily on studies of extrasolar planets. Recently I have been working on following up exoplanets discovered by the Kepler spacecraft

http://www.nasa.gov/mission_pages/kepler/main/index.html

for which high spatial resolution observations are very important, since additional stars in the system hosting a transiting planet will dilute the transit signal and possibly create false positives from diluted eclipsing binaries. Kepler has been an extra-ordinarily successful mission, but unfortunately due to a reaction wheel failure ended its primary mission a little over a year ago. However, a workaround has been developed where the radiation pressure torques on the spacecraft are balanced, eliminating the need to control the spacecraft roll with a reaction wheel. This torque balancing only occurs when the telescope boresight is oriented along the ecliptic.

Fortuitously, this means that rather than observing the high ecliptic latitude field it had previously been observing, Kepler, in an extended mission dubbed K2

http://keplerscience.arc.nasa.gov/K2/

will now be observing a series of fields on the ecliptic, searching for transiting planets. Therefore, many of the stars for which we require high resolution observations will be occulted by the Moon.

I would like to approach you as president of the International Occultation Timing Association to enquire if your organization would be interested in partnering with me and my collaborators to co-ordinate lunar occultations of stars of interest for exoplanet studies. We are planning to conduct occultation observations with large telescopes, but there are of course many occultations we will not be able to observe, so observations from the amateur community will be extremely valuable.

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and

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The observations we are looking for are conventional lunar occultations to detect binary stars. Detecting the exoplanets themselves is indeed essentially impossible with lunar occultation. However, if there is an unknown or poorly known binary in a system that has an exoplanetary transit, the light from that binary dilutes the transit depth. Since the inferred size of the planet is measured from the transit depth, this results in errors in the planet size, in some cases leading to mistaking a diluted eclipsing binary for an exoplanet.

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and

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Yes, it's definitely advantageous to get the observations going as soon as possible. I just came back from a meeting Baltimore reviewing the proposals for campaigns 4 and 5, and there was a lot of interest in this when I talked to the NASA program officers.

That is, a lunar (or asteroidal) occultation will not result in the detection of an exoplanet. However an occultation can detect close binary systems – and this will have a direct effect on the interpretation of the data from Kepler2.

What is being asked of us is to make video recordings of lunar occultations of K2 target stars, and obtain a light curve.

Personally, I think this is an exciting opportunity to become involved in exoplanet detection!

CHALLENGES

This project has some practical challenges, as follows:

The K2 mission has 10 fields. However the target lists have only been established for the first four fields. Further target lists will become available in the months ahead. This will result in regular updates to the list of stars of interest, as well as a continuing need to review past observations for newly-added stars.

the great majority of stars in the target lists are far too faint for occultation observations – especially lunar occultations. Nevertheless, the first three Kepler2 fields contain 6365 target stars that are present in the XZ80Q catalogue we use for lunar occultation predictions. And of those stars, 347 are brighter than mag 9.0.

the best time to observe a lunar occultation and get a decent light curve – especially of a faint star – is in the period 3 days before 1st quarter to one day after – and a similar period at last quarter. This places significant restraints on our ability to obtain light curves of any particular star.

the motion of the moon (and in particular, the motion of the orbital nodes) means that for most stars there will only one or two 'good' occultations in a 9-year period – and those opportunities will likely be available in only one of the three regional observing regions (Europe/North America/Japan-Australasia)

A consequence of (d) is that we need to start observing relevant stars as soon as possible. In particular, we should not wait until we have established the reporting mechanism.

ACTION SO FAR

There are three distinct aspects to what we need to do:

set up systems to generate occultation predictions that flag stars as being a Kepler2 target star – and encourage people to obtain occultation light curves of those stars;

set up a reporting system to report light curves and associated data, for analysis;

identify past occultation observations involving Kepler2 stars, and wherever possible retrieve any video recordings and/or light curves.

A practical situation is that lunar occultations will provide the most frequent source of occultation opportunities of Kepler2 stars. However the observations will be limited by the brightness of the moon, and the rate of motion of the moon (about 0.3"/second) – which limits the spatial resolution. Asteroidal occultations will generally provide much greater spatial resolution, but the frequency of occurrence will be very much less than for lunar occultations.

Predictions

I have made a range of changes in Occult to implement the K2 program. The details differ for lunar and asteroidal occultations, as follows:

Lunar occultations:

These include:

a routine to match the Kepler2 target catalogues (as they become available) to the XZ80Q lunar occultation catalogue. This leads to a file containing the Kepler2 basic details of Kepler2 stars that are in the XZ80Q catalogue – which must be updated whenever the targets in a Kepler2 field are finalised (that is, about every three months);

adding a flag in the XZ80Q catalogue when a star is in the Kepler2 catalogue - so that details can be retrieved when needed. This results in a regular need to update the XZ80Q files;

when an occultation prediction involves a star in the Kepler2 catalogue, generating a message in the predictions – like:

*** A light curve is desired as X 85235 is in the Kepler2 program {ID = 202062458}

This will allow observers to identify lunar occultations of relevant stars – so that they can make a special effort to video-record the occultation.

Include a facility to obtain Kepler2 details when a star is flagged.

Asteroidal occultations:

These include:

Maintaining a file of ALL Kepler2 target stars, to match against predicted asteroidal occultation stars. This file will need to be regularly updated.

When generating an asteroidal occultation prediction, check whether the star is a Kepler2 target star – and if so, include a flag in the occultation elements

Include a message on asteroidal occultation predictions of the fact that the star is a Kepler2 target star

Reporting observations

At this time no mechanism or process has been established for reporting observations. We still need to establish the exact details of what needs to be included in such a report – although it can be assumed that a light curve in some manner or form will be required. It is likely that for lunar occultations the reporting process will be similar to the current process for reporting double star observations. For asteroidal occultations the issues are more complex, as the orientation of the limb for an observer can only be determined using the results of other observers.

Past observations

An important element of this exercise is to review past occultation observations, and wherever possible, retrieve light curves from past

Past observations

An important element of this exercise is to review past occultation observations, and wherever possible, retrieve light curves from past observations. Based on Kepler Fields 0 to 3, the number of past observations of Kepler2 stars is:

- Lunar occultations with a video or photoelectric recording: 1,693
- Asteroidal occultations 33, with three being in 2014

We will be trying to make contact with the relevant observers, in the hope that at least some recordings are still available for fresh analysis. This identification of past video observations will be ongoing as new Kepler2 input catalogues are released – so don't throw out any old video recordings!

WHAT NEXT

An ongoing situation for the next year or two (until the Kepler2 mission comes to an end) will be the regular updated on the XZ80Q catalogue and associated files. It is essential that these updates are downloaded, as they contain the flagging of the stars that are in the Kepler2 target catalogues, as well as a new file called XZinKepler2.dat (which lists the XZ stars in the current Kepler2 input catalogues.)

Most importantly, when you see a lunar occultation prediction, or an asteroidal occultation prediction, flagged as a Kepler2 star, make special effort to obtain a video recording of the occultation. Then make sure that record is retained for future reporting.

And if you have old video recordings of occultations – do not throw them out. It is just possible that some of your old recordings are of stars yet to be specified as Kepler2 target stars – in which case you will want to go back and analyse the recoding using current software tools.

Journal for Occultation Astronomy

Southern EXposure Timing Array SEXTA

Dave Gault, Tony Barry and Greg Bolt

The time of an occultation event is the fundamental measure of an occultation observation and we need to ensure the stated time is correct. This is done by ensuring our equipment operate within a known standard or category. There are basically two methods we can use to categorise our equipment; 1) use equipment that has been categorised by others and use the methods outlined by them during the observation, or 2) categorise your own equipment.

Fortunately the video equipment commonly used for occultation observations, are made to the Composite Baseband Video Signal (CVBS) standard, be it; CCIR (PAL), EIA (NTSC) or SECAM all have a defined modes of operation, so all it needed is for someone to test all commonly used equipment and publicise the results. Gerard Dangl performed testing and has produced comprehensive test results on his website1, thankyou Gerhard. So, as long as we used CBVS equipment and referred to Gerhard's tables, we could be assured our equipment was categorised, and we could state our event times with certainty.

However CBVS is a technology that was developed in the 1950s, when 'electronics' meant vacuum tubes, and today's microchip equipped devices simply mimic the workings of vacuum tubes of the 1950s. Looking to the future we may well find access to CBVS standard equipment becoming harder and harder to acquire, Also to utilise the full potential of microchip technology we find the CBVS standard has become a limiting factor, so different video formats, progressive frame scanning and deeper pixel bit depth has become desirable. Add in differences in data transfer technology, like USB2, USB3, GigE, FireWire,Thunderbolt or HDMI mean that categorising the accuracy of frame time-stamping will become a task to be done by the observer on their own equipment. The problem is how can one do this task within a reasonable budget? We think the answer is SEXTA.

The need for the development of SEXTA arose during the development of ADVS2 (Astronomical Digital Video System). ADVS is an all digital, progressive scan, 12 or 14 bit video system, that operates over FireWire, and we needed to assure ourselves that the frame timing shown by ADVS was correct. We looked longingly at Gerhard's EXTA3 device and we asked Gehard if he would share his design with us, but alas he foresaw difficulty, stating "...Because of the relative complex design required for this functions and the big display with a large number of LEDs the goal was not to develop this device for reproduction. So at the moment it will stay as a very useful prototype device." Although we were disappointed, I think Tony looked relived, not having to hand solder over 1000 LEDs and deal with 4 microprocessors. The solution was to develop a suitable device of our own. We named our device Southern EXTA to pay respect to Gerhard and his device.

SEXTA has two components.

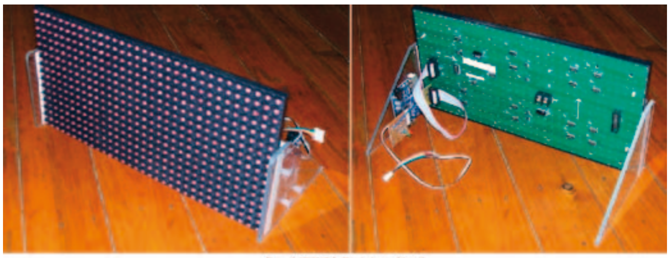

Fig. 1 SEXTA Prototype No. 1

Component One is an array of 32x16 LEDS (512 total of which only 500 are used) that was controlled by a GPS receiver and an Arduino Duemilanove microcontroller. Tony selected an off-the-shelf signage array and wrote code for the Arduino that would flash the 500 LEDs in turn over the duration of a second. See Fig.1

Component Two is GPS-ABC4 which is a device with a GPS receiver, and has 7-Segment, 8 character array of LEDs, all controlled by a Arduino MEGA microcontroller.

When a camera (See Fig.2 in the case a WAT-902) is pointed at the SEXTA array and GPS-ABC, only the LEDs of the array that were lit during the exposure are shown as white dots, and so the exposure timing can be determined by reading the GPS-ABC time display and by counting the LEDS of the SEXTA array. So the exposure timing can be determined independently of the Camera Timing System, which in this case is IOTA-VTI.

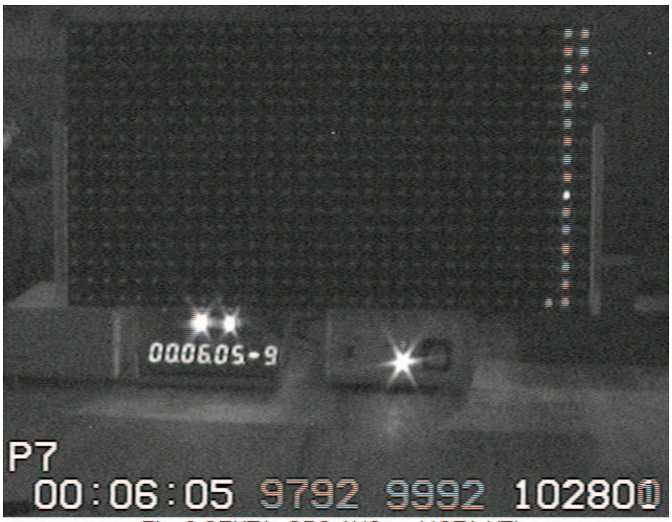

Fig. 2 SEXTA, GPS-AVC and IOTA-VTI

In this case the central time of the exposure is;

00:06:05.979 UT +/-0.002 sec.

Greg Bolt built a SEXTA array and a GPS-ABC to categorise the timing of S-BIG CCD cameras and controlling software. In the process Greg confirmed the accuracy of the lighting of the array LEDs and helped to improve the performance of the SEXTA Array.

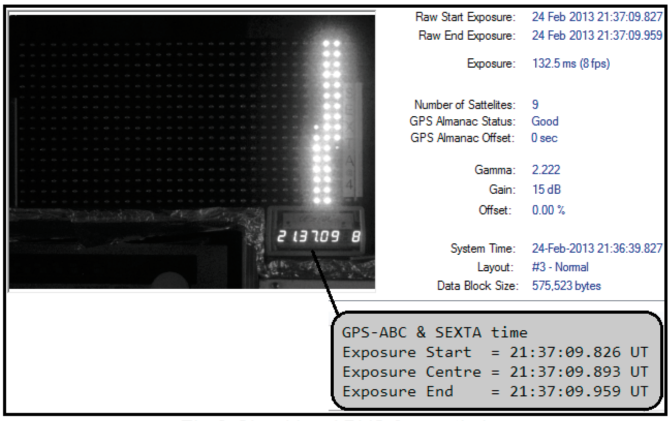

Fig.3 Checking ADVS frame timing

Development of ADVS was able to continue because we were assured that the accuracy of the ADVS time stamps were correct. In fact during ADVS development an error was accidently introduced into the ADVR code that resulted in significant dead-time between exposures, and this error was detected by the regular use of SEXTA. The error was quickly found and eliminated from the code and development could continue.

During the development of ADVS, it came apparent that SEXTA was a valuable tool and we decided that the following should occur;

develop SEXTA further to make it more useful by enabling a boarder range of camera types to examined.

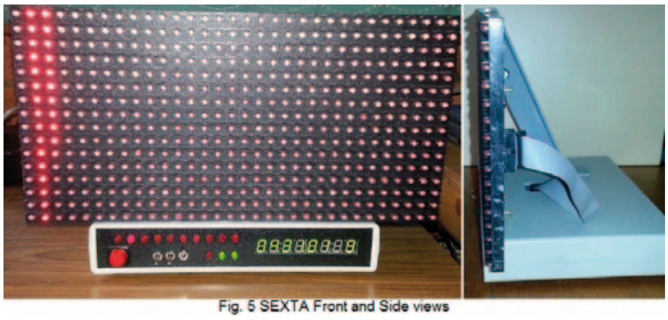

Fig. 5 SEXTA Front and Side views

create a SEXTA Reader application to improve the task of LED counting that was necessary to determine the frame timing. This helped to remove the possibility of count errors.

make the design open source so other researches can purchase the components and make their own SEXTA device.

write a paper to be published in a peer reviewed journal that describes SEXTA and it's uses.

The current design has all the electronics housed in a single plastic case, with the array mounted on top and coplanar with the front. The front has the 7-Segment arrays as well as a row of 10 LEDs that count to 0-9 seconds, as well as a 1pps LED, a Lock LED, an Almanac OK LED as well

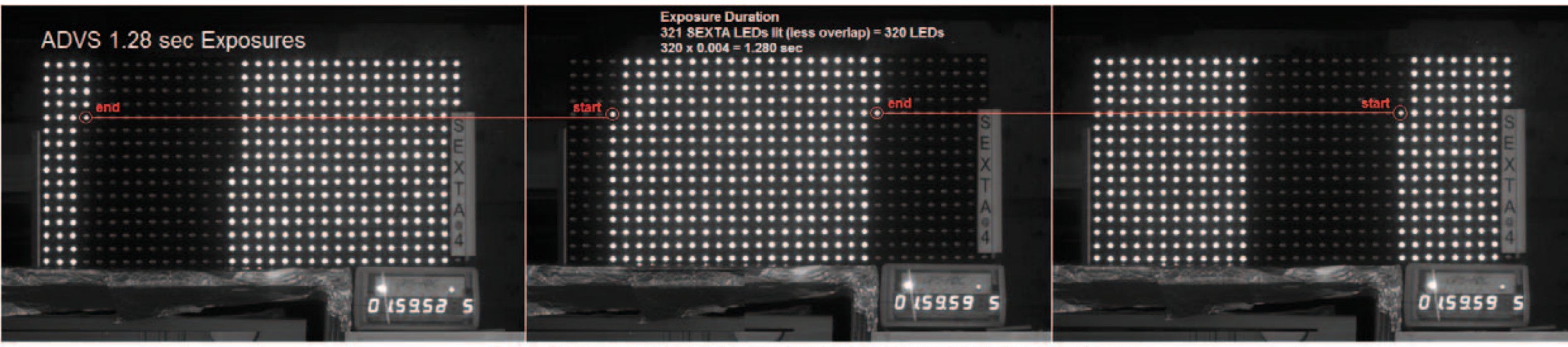

Fig. 4 Consecutive ADVS frames showing zero dead-time between frames

as a reset button and two switches that control the sweep times and a switch to clear error messages.

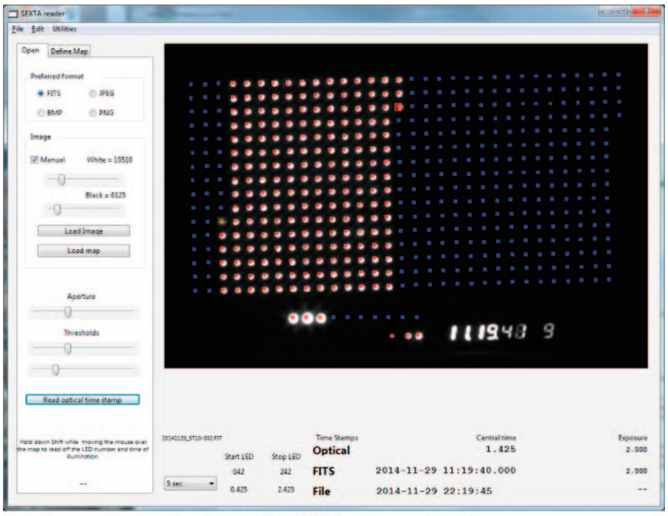

Fig. 7 The SEXTA Reader application

Clockwise from top-left.

homemade power supply based on a 7805 regulator.

Global Top PA6H GPS receiver.

Arduino MEGA 1280 for GPS-ABC.

7-Segment Arrays

0-9 and status LEDs and switches.

Arduino Dumilanove for the SEXTA array.

All components and circuit diagrams are detailed in the Bill Of Materials which is available at the Author's website(s)5, along with the Arduino code for both controllers as well as all necessary information.

The SEXTA Reader application will run on computers with Macintosh, Windows or Linux Ubuntu Operating Systems. It will read FITS image files and will display the header time. It will also load other common image formats. Once calibrated it will display the SEXTA time and allow direct comparison with the Camera-system timestamp.

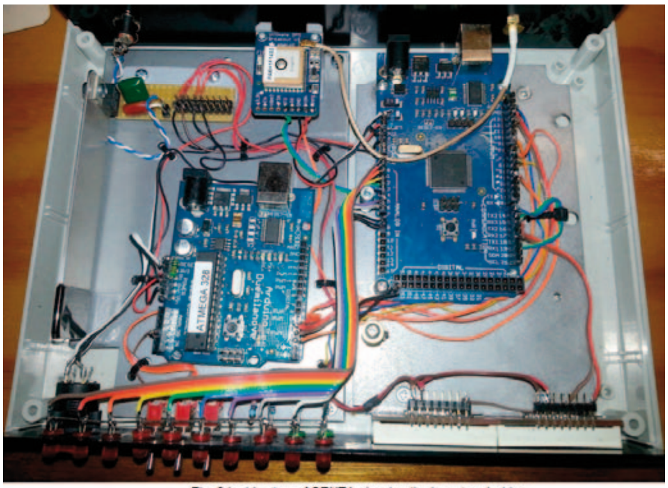

Fig. 6 Inside view of SEXTA showing the layout and wiring.

A peer reviewed paper6 has been published in the Publications Astronomical Society of Australia (PASA) that describes SEXTA and it's uses.

Now a video calibration tool is within reach of anyone who has the desire to own and use it to test their own equipment. All necessary documentation is available for download at Dave's or Tony's websites5.

Wishing you clear skies; Dave, Tony and Greg.

References:-

http://www.dangl.at/

http://www.kuriwaobservatory.com/ADVS.html

http://www.dangl.at/exta/exta_e.htm

JOA 12-3 and http://www.kuriwaobservatory.com/GPS-ABC.html

http://www.kuriwaobservatory.com/SEXTA/SEXTA.html

http://www.tonybarry.net/TB - Homepage/SEXTA.html

http://arxiv.org/abs/1503.05705

After having recorded successfully the Venus-Transit

Giuseppe Erico Beniamino Caminiti

passed away on July 15th 2015.

He had been always engaged as an IOTA-ES member, helping at his home at Sicily, when ever it was necessary for southern European observations.

We shall miss him.

Hans-J. Bode

European Symposium on Occultation Projects

Hannover, Germany, August 28-30th, 2015

We are pleased to invite all members, friends, and others, who are interested in occultation phenomena, to attend the 34th European Symposium on Occultation Projects which is taking place in Hannover, Germany.

ESOP is an annual Symposium held at a different European country each year and it is a forum for advanced amateur, semi-professional and professional astronomers specialising in occultation work. The Symposium language is English.

The International Occultation Timing Association / European Section (IOTA / ES) is a non-profit scientific organisation with about 140 active members.
It occupies itself with the observation and the analysis of occultations and eclipses of celestial bodies of our solar system.

Programe

Saturday, August 29th – Lecture-Day 1

09:00 - 09:15: Opening ESOP34 by IOTA / ES-President

09:15 - 10:30: The GAIA space mission, (E. Riedel)

60 Stefan Jordan
The Gaia-Project - A Milestone in Space Astrometry
Discussion: The impact of GAIA on occultation work

10:30 - 11:00: Coffee break

11:00 – 12:30: The Basics: Time and Catalogues, (K. Guhl)

25 Dirk Piester
Atomic Clocks, Time Transfer and Coordinated Universal Time

25 Mike Kretlow
Current star catalogs. Comparison and their application to occultation work.

30 Mike Kretlow
On the accuracy and uncertainty of asteroidal occultation predictions.

12:30 - 14:00: Lunch

14:00 - 15:30: Lunar Occultations, (E. Bredner)

30 Eberhard Riedel
The recent developments of the GRAZPREP software

30 Dietmar Büttner
The lunar profile basis of the IOTA / ES graze prediction program

15 Marek Zawilski
Observation of the graze of Aldebaran on April 21, 2015

15 Marek Zawilski
Top twelve of occultation observations in Germany in the past

15:30 - 16:00: Coffee break

16:00 - 16:55: Exploring Asteroids I, (O. Kloes)

25 Henk de Groth
The occultation of Chaliapin

15 Carles Schnabel
Latest works of the Sabadell Group

15 Baba Aissa
Statistical study of observable asteroid occultations in Algeria and Arab World

16:55 - 17:15: Coffee break

17:15 - 18:05: Exploring Asteroids II, (A. Pratt)

30 Eberhard Bredner
Anna, Mateusz and "Max und Moritz" -
An extraordinary observation site for Minor Planets

20 Oliver Kloes
Occultations by Binary Asteroids, Europe, 2016

18:00 - 18:15: End day 1, organizational remarks

19:30 - open ended: Social Dinner at the "Bistro Schweizer Hof"

Sunday, August, 30th - Lecture-Day 2

09:00 - 10:10: Special Projects I (tba)

15 V. Priban
Technical solution for evaluation PHEMU events close to Jupiter´s limb

40 A. Pratt
Experiences of participating in PHEMU 2014-2015

15 Bernd Gaehrken
PHEMU observations with satellite Amalthea involved

10:10 - 10:30: Coffee break

10:30 – 11:15 Special Projects II (K. Guhl)

20 Costantino Sigismondi (by video)
The next transit of Mercury in 2016 May 9th after the lessons learn from the transits of Venus in 2004 and 2012

20 R. Kostenko
Annular eclipse in Tanzania, prospects for 2016
Discussion

11:15 - 12:30: The Outer Solar System, (W. Beisker)

50 Bruno Sicardy
Exploring the outer solar system with stellar occultations

25 TBA
Results of the most recent TNO occultations

Discussion

12:30 - 14:00: Lunch

14:00 - 15:00: Technology and Outreach, (C. Schnabel)

30 W. Beisker
A CCD Camera System for Occultation Work Combining High Sensitivity, High
Timing Accuracy and Cost Effectiveness

30 TBA
Outreach activities - Discussion

15:00 - 15:30: Coffee break

15:30 - 16:15: Universe and Gravitation, (W. Beisker)

45 Benjamin Knispel
Gravitational-wave Astronomy

16:15 - 16:45: Next ESOP35 (Tim Haymes), organizational for the excursions

16:45 - 17:00: Final remarks, closing ceremony, End day 2

Left over: A. Kilcik
20 Solar diameter after space dedicated missions

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The Gaia-Project - A Milestone in Space Astrometry

Prof. Dr. Stefan Jordan

For more than one year the astrometric satellite Gaia, launched by the European Space Agency on December 20, 2013, is routinely scanning the sky. Its goal is a stereoscopic census of our Galaxy through the measurement of high accuracy astrometry, radial velocities and multicolour photometry. Over the course of its five year mission Gaia will measure positions, distances and motions for more than 1 billion stars and a few hundred thousand solar system objects. It is already certain that Gaia will produce the most accurate star catalogue ever aiming at a positional accuracy of about 25 microarcseconds at fifteenth magnitude in the final catalogue. The talk will describe the Gaia mission in detail and discuss what data can be expected during the coming years, starting with the first Gaia data release in mid 2016.

The recent developments of the GRAZPREP software

Eberhard Riedel

The use of high resolution lunar limb data considerably improves lunar occultation observation planning and the success of grazing occultation expeditions. The GRAZPREP-software now is making use of the high resolution limb data as calculated from the Kaguya data by Dietmar Buettner, Germany (LUNLIMB). In the next step the even much denser limb data of the LOLA-mission is implemented after recalculation by Dietmar Buettner. With this precise data higher graphical magnifications and stretching of the lunar limb features are allowed. It is shown how it is possible now with GRAZPREP's graphic abilities to easily and reliably find the best observing sites to measure preselected regions of the lunar limb, only being limited by the precision of the stellar position. This technique will also be used by the software for direct observation reductions.

The lunar profile basis of the IOTA / ES graze prediction program

Dietmar Büttner

GRAZPREP is the actual grazing occultation prediction program of the IOTA/ES.

Its predecessor GRAZEREG mainly used the IOTA profile data bases ACLPPP and MOONLIMB which were based on previous occultation observations. The GRAZPREP profile plots are taken from more accurate lunar topographic data derived from measurements by the Japanese lunar probe Kaguya. GRAZPREP started with a low resolution Kaguya data set provided by Dave Herald a few years ago. In January 2015 Eberhard Riedel incorporated the new limb model LUNLIMB. This was created in December 2014 by Dietmar Büttner from the original Kaguya data having a much higher resolution.

Meanwhile another set of highly accurate topographic data provided by the NASA lunar probe Lunar Reconnaissance Orbiter (LRO) is available. This enables to get even more precise lunar limb profiles.

Dietmar Büttner is currently working on a data set designed in such a way that the limb profiles derived from LRO can be displayed in GRAZPREP without any noticeable answering (and henceforth waiting) time to the observer.

This needs considerable programming efforts because the number of LRO topography points is much higher than that of the Kaguya data. So, intelligent algorithms for selecting and processing the LRO data are to be developed.

It is the aim of the author to provide highly accurate and reliable profile data without any uncertainties resulting from approximations in processing the original LRO data.

A more comprehensive description of this work is planned to be published in the 'Journal of Occultation Astronomy'.

The occultation of Chaliapin

Henk de Groth

On 2014 March 24 there was a possible occultation of a star by the asteroid (2562) Chaliapin.Ten observers observed the star, but only 2 observers saw an occultation. After the observation results were computed, it appeared that these results were inconsistent with the predictions, and also difficult to explain on some points. In the presentation the results will be presented. Also I will show some possible explanations, but at the end not all answers are satisfactory.

Occultations by Binary Asteroids, Europe, 2016

Oliver Kloes

Observing the satellites of asteroids are a difficult task. Many of the knows satellites have just a few kilometres of diameter and therefore are hard to detect at occultations. Their shadow paths are narrow and the duration of occultations are less than one second. Ephemerides for the satellites of 18 asteroids are available at the Miriade Ephemeris Generator at IMCCE (Institut de mecanique celeste et de calcul des ephemerides) and can be used for path predictions with Dave Herald's Occult V4.

This lecture will present predictions of the occultations of binary asteroids, which are at Steve Preston's predictions for 2016 and orbital data for the satellites are available from Miriade. The paths of these occultations have to be observable at Europe.

The path predictions of the satellites were calculated by the presenter using Dave Herald's Occult V4 and the paths were shifted to match Steve Preston's predictions of the main body.

In 2016 ten events fitting these criteria and will be presented with path maps.

Some events are hard to observe but there will be a series of occultations by (22) Kalliope in the second half of the year 2016. Linus, the satellite of (22) Kalliope, was the first satellite of an asteroid, which profile was measured during an occultation (Japan, Nov. 2006). The moon has a diameter of about 28 km, which will give occultations with durations of up to 4 seconds at the upcoming European events.

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These occultations by (22) Kalliope and Linus are good opportunities to improve the orbital elements for this interesting asteroidal system.

Technical solution for evaluation PHEMU events close to Jupiter´s limb

V. Priban

Some mutual events occured very close to Jupiter´s limb. Planet Jupiter was very bright object and disturbed evaluation by Limovie. Central ring jumped immediately on Jupiter and it was impossible to obtain light curve. Contribution describes technical solution how to hide Jupiter, see picture, and thus to eliminate its disturbing effect.

Experiences of participating in PHEMU 2014-2015

A. Pratt

Every 6 years Jupiter's equatorial plane is so aligned that its moons take part in a series of mutual eclipses and occultations as seen from the Earth.

The worldwide campaign to observe these mutual phenomena (PHEMU), specifically of the 4 bright Galilean moons, is organised by IMCCE - Observatoire de Paris - Bureau des Longitudes - CNRS.

During the 2014-2015 PHEMU campaign Jupiter was very favourably placed, with the planet at a high declination and at opposition in February 2015.

This talk describes the predictions used to plan for the observations, the equipment used to record several PHEMUs, the software used in their analysis and reporting the observations to the IMCCE

Exploring the outer solar system with stellar occultations

B. Sicardy

The solar system beyond Neptune's contains largely unaltered material from the primordial circum-solar disk. It also kept the memory of the early planetary migrations, and thus contains essential information on the origin and evolution of our planetary system.In that context, the stellar occultation technique is a very powerful tool to study Trans-Neptunian Objects (TNOs), revealing their shapes, atmospheres and rings.

In the last decade, our group led the field by discovering rings around the asteroid-like object Chariklo, detecting sub-km TNOs and drastic variations of Pluto's atmospheric pressure, and setting upper limit for the presence of atmospheres around the largest TNOs.

In this talk I will review a few of our recent campaigns and findings, from the discovery of Chariklo's rings to the monitoring of Pluto's atmosphere, before and after the NASA/New Horizon flyby. In that context, the ESA/GAIA mission will revolutionize our approach to stellar occultations, providing amazing accuracy for the predictions, thus boosting by orders of magnitudes our success rate.

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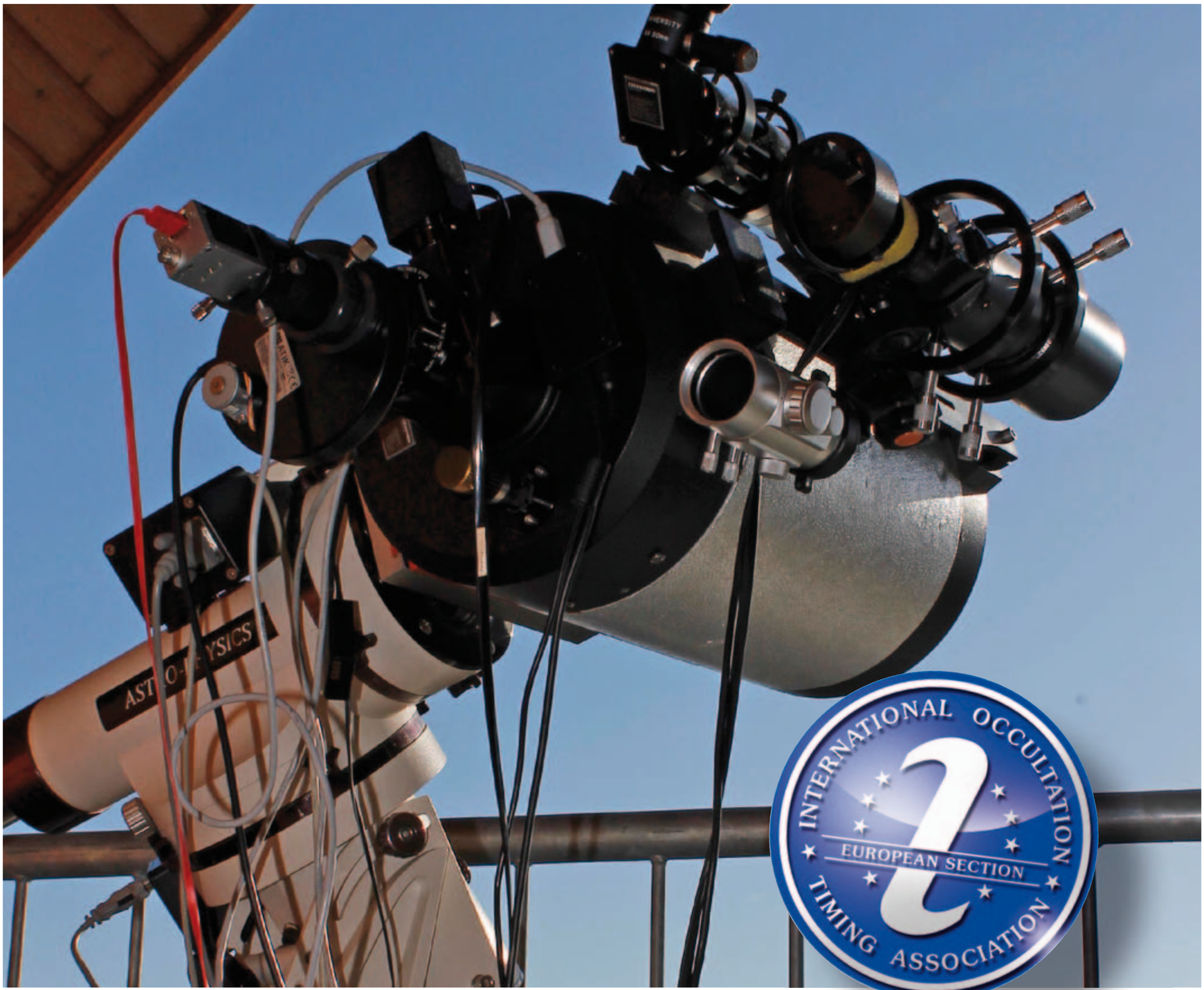

A CCD Camera System for Occultation Work Combining High Sensitivity, High Timing Accuracy and Cost Effectiveness

W. Beisker

The development of a camera package including a GPS receiver for timing and a dedicated laptop will facilitate occultation measurements for mobile stations and/or fixed site observatories. The camera is based on a module from the Canadian company Point Grey(c), who produces many different camera modules for industrial use. Because it is a large company, it guarantees that modules will be consistantly improved and will not stop delivery in the next few years like with other companies.

The module used in the development for a LINUX based camera package is the Chameleon module (either USB2 or USB3), which is build around the ICX445 (1/3 inch) chip made by Sony(c). The chip has a resolution of 1296 x 966 pixels. The pixelsize is 3.75 um square. For recording a 2x2 binning mode is used. Other modules of Point Grey are supported by the SDK too. The Chameleon has a peak quantum efficiency of more then 65% at 600 nm wavelength. The average QE between 400 nm and 640 nm is around 60% and a readout noise of about 7 electrons. The ADC converter has 12 Bit resolution.

Many parameter of the camera can be controled by software. The camera itself is modified with an active air cooling by a small fan built in the back cover of the module (a 3D printer was used for this). The temperature is always around 8 deg C above ambient temperature, which is sufficient for exposure times up to 10 seconds and more.Using the software devolpment kit from Point Grey, a control software has been developed for LINUX, which generates uncompressed FITS frames with precise time stamps in the FITS header as well as in the file name. The software runs on a dedicated laptop with OPENSUSE 13.2 at the moment. A GPS receiver with 1 PPS signal is connected to the laptop and sets the internal computer clock to better than 10 µsec using the NTP protocol. The software can record up to 30 images per second to a ramdisk. If the images are directly read to the harddisk, even on a slow system (AMD E1-2500 CPU) 5 images per second can be recorded. There is no delay, even if there are more than 20000 images in the recording directory (file system EXT4).

To test the accuracy of the time stamps, the 1PPS signal of the GPS receiver has been fed to an oszilloscope, which was imaged by the running camera. Analyzing the images of the 1PPS pulse it has been found, that the timing has an jitter of less than +/- 5 msec. This is far more than what is needed in asteroidal or TNO occultation work.In further tests the time gap between two adjacent images has been determined to be definitively less than 3 msec.Sensitivity data are presented which show, that with an 11 inch telescope (focal ratio 1/7) the limiting magnitude is between 15mag and 16mag with an exposure time of 1 sec. To give an example, even from a place only 5 km away from the city center of Munich, the central star of the ring nebula (M57) in the constellation Lyra could be seen in 1 second exposure time.

Including the camera, GPS receiver and a cheap laptop the system price is lower than 750 Euro. Even small observatories and private persons can afford such a package.

Gravitational-wave Astronomy

Benjamin Knispel

According to Einstein's theory of general relativity, accelerated masses emit gravitational waves. These ripples in space-time travel at the speed of light and are caused by energetic astrophysical events, such as colliding black holes, supernova explosions, and merging neutron stars. The direct observation of gravitational waves requires high-precision measurements with interferometric detectors such as GEO600 and compute intensive data analysis. 99 years after Einstein's initial prediction, gravitational waves still have not been directly observed. The second generation of interferometric detectors will come online in late 2015 and should make the first detections ever in the coming years.

Technical Solution For Evaluation PHEMU Events Close to Jupiter.

Vaclav Priban

Some events took place in sufficient distance from planet some was close to Jupiter.

Distance was only 10 arcsec from Jupiter for occulted moon Europe. I observed this event and made simultaneously two video records. One classical video VHS and second one direct to computer. For information I used telescope Newton diameter 30 cm, f. l. 150 cm, camera WATEC 120N installed in focus indoor in tube.

Event was visible very well by eyes.

When I tried to evaluate record by Limovie I found bad thing. Jupiter was very bright object. Central ring immediately jumped on planet and thus it was impossible to obtain light curve. I realized that I could not evaluate it.

But I did not give it up and made quite simple electrical circuit. This circuit derived pulse from Jupiter and allowed to switch video signal VHS on adjustable DC level only in place where Jupiter was. DC level was possible to change from white to black.

I adjusted it on dark level and created new avi file through this circuit.

Then I evaluated it by Limovie. I had to use regime "Off" and from time to time to stop measuring and adjusted central ring on occulted moon because there was other dangerously bright neighbour moon Io. I know it was not ideal but light curve appeared. I sent it to IMCCE with other 6 more comfortable events.

PHEMU observations with satellite Amalthea involved

Bernd Gährken

The PHEMU events in 2015 affected the 4 bright Galilean moons, but also the much weaker moons near the planet. These moons are so weak that the measurement of an eclipse is a real challenge. The biggest moon Amalthea has only a brightness of 14 mag. Jupiter is more than two million times brighter! Nevertheless the IMCCE has published some Ephemerides of the eclipses of the small satellites of Jupiter by the Galilean satellites. The speach presents 2 succesfull measurements and explains the observation technique.

Annular eclipse in Tanzania, prospects for 2016

R. Kostenko

As the next annular solar eclipse is due on September 1st, 2016, some advance research on the local conditions is presented. Out of all African countries in the central path, Tanzania has been selected as a preferred location. The results of a scouting trip done earlier, in July 2015, are used along with an analysis on the local conditions for a future eclipse expedition, including the climate, potential viewing sites, mobility options & the roads quality, possible travel itinerary etc. A proposal for a trip in cooperation with Astrosafari and UNAWE Tanzania will be presented.

Second, a quick story and photo report of a previous eclipse trip to Svalbard in March 2015.

Observation of the graze of Aldebaran on April 21, 2015

Marek Zawilski

This occultation was a chance to perform a valuable observation, for the first time since April 28,1998 when last graze of Aldebaran at the northern lunar limb was observed in Poland, on the outskirts of Lodz.

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The expedition to the recent spectacular graze has been organized in N-E Poland by the members of the Section of Observations of Position and Occultations of the Polish Association of Amateur Astronomers (PTMA). Wojciech Burzy ski, the team leader, representing the Białystok Division of PTMA, has chosen the observation region along a local road with a free view to the horizon (the event took place at the altitude of about 20 degrees). Finally, the observers were located at nine stations. One observer more independently went to another site situated at a distance of about 120 km from the main observation region.

At the main station situated near the local school, a live broadcast on the internet has been arranged by Karol Wójcicki. The phenomenon was preceded by a quite intense campaign in the Polish media. The live broadcast was watched by a total of over 17 thousand people.

Especially, the observers using CCD cameras with time inserters obtained very valuable results. Unfortunately, some of cameras not equipped with a control option turned out to be too sensitive and observers lost their results unless they decided to record the contacts using standard methods, e.g. "eye and voice" instead. The gradual D and R events could be easily noticed at some stations when single video frames have been analysed later on. Some of such events were remarkable directly on the screen during the recording, too.

The reduction of the results have been made using the Occult software version 4.1.5.2 (see the Figure below). In general, the results of observation show a very good agreement of the Kaguya ephemeris profile and the data resulted from older observations of different grazes. Small differences may be noticed only. Better agreement is typical for the most precise technique used whereas the greatest errors can be attributed to standard visual timing methods. However, even those data are consistent inside the whole set of results.

Top twelve of Occultation Observations in Germany in the past

Marek Zawilski

In the past, many interesting occultation phenomena were observed in Germany.

A selected twelve phenomena have been described and ranked.

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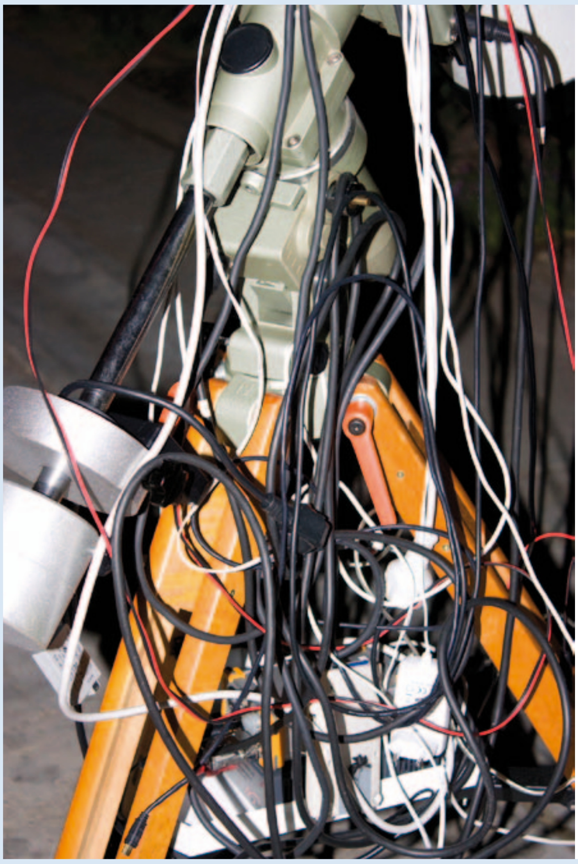

Sometimes it takes pathfinder innovative capabilities to find the camera or the controller in the tangle of cables. Here at a Regulus Occultation.

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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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