# ESOP XXXV – Report of the 35th European Symposium on Occultation Projects

## University of Guildford, Surrey, England

## 2016 August 19 – 21 (22 – 23)

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A total of 38 occultation enthusiasts from the Czech Republic, Germany, the Netherlands, Poland and Spain, including 18 from the United Kingdom, attended the 35th annual science meeting of IOTA-ES at the University of Guildford over the weekend of 2016 August 19 to 21, followed by social excursions on August 22 and 23.

Informal proceedings commenced with a buffet reception on the Friday evening and a visit to the observatory of the astrophysics department, housing a 406mm Optimised Dall-Kirkham telescope. The symposium presentations took place during the Saturday and Sunday. Accompanying persons were invited to join excursions to places of interest, such as Hampton Court, the Palace of King Henry VIII.

On the Saturday morning ESOP XXXV was formally opened by Tim Haymes and Dr Richard Miles of the local organising committee, and Dr Wolfgang Beisker on behalf of IOTA-ES. It was announced that in recent weeks the European occultation community had sadly lost regular contributors Alfons Gabel and Otto Farago. Tributes to their contributions to occultation astronomy were presented by Dr Eberhard Bredner and Andreas Eberle, and they invited the delegates to join them in remembering our absent friends.

The symposium continued with a most interesting and varied series of talks. The abstracts are given below:-

## Saturday session 1    Occultations and the BAA – past, present and future    (chaired by Oliver Klös, IOTA-ES)

### Gordon Taylor – an astronomical autobiography    (read by Tim Haymes, BAA, IOTA-ES)

Gordon Taylor sends his very best wishes to ESOP XXXV, but is unable to attend in person.

This presentation is a small part of his autobiography, written for this symposium, describing some of the many innovations he introduced into the prediction of lunar, asteroid and planetary occultations. This autobiographical account is supplemented by images from the presenter.

### UK occultation successes 1989 – 2015    (Richard Miles, BAA / Tim Haymes, BAA, IOTA-ES)

A summary is presented of the 1989 July 3 occultation by Titan of the star, 28 Sgr, which was exceptionally well recorded by UK and European observers. An account of the first positive asteroid occultation success in the UK will also be given (Richard Miles).

More recent occultation results observed from the UK are described, the most successful of which have been those of (130) Elektra in 2010 and (275) Sapientia in 2015. A relatively large observer base in England assisted by electronic communication and good weather favoured both of these events (Tim Haymes).

An account of the Sapientia result is reported in the BAA Journal

JBAA  2015 December Vol 125, No.6  Page 331. *Stellar Occultation by (275) Sapientia well seen.* – Author: Richard Miles.

### BAA occultations – future possibilities    (Tim Haymes, BAA, IOTA-ES)

The presentation reviews how the BAA can help observers in the light of improved predictions from Gaia. Current alerting methods are summarised.

The content of the BAA Handbook (occultations) will be described briefly.

The greater use of USB planetary web cams (CCD) is to be encouraged, since many potential observers use them.

In future workshops observing sections should include the ability to measure camera delays and discuss the accuracy of the many timing and recording methods that could be employed.

**Revisiting observations of the 44 Cap lunar graze of 1989 Aug 17     (Alex Pratt, IOTA-ES, BAA)**

In the early hours of 1989 August 17 Andrew Elliott recorded and timed the grazing occultation of 44 Cap (magnitude 5.9) during the umbral phase of a total lunar eclipse.

On checking Andrew's timings of the D-R-D-R sequence listed in Occult4's Historical Grazes module his O-Cs were small, except for a large value for the R1 event. Plotting the events against the LOLA lunar limb data showed this discrepancy, and a review of Andrew's original videotape confirmed that a mistake had been made either when submitting his observations or when they were added to the occultations archive.

The full story of these investigations is presented, including how the erroneous timing was corrected in the lunar archive, and it concludes with a discussion about record keeping, the problems of extracting data from near-obsolete media and future-proofing archival material.

Eberhard Bredner also observed this event with Andrew and he contributed his additional comments to the presentation.

Further details can be found in:- Journal for Occultation Astronomy, 2016-1, Jan-Apr 2016, page 20-22, *The Grazing Occultation of 44 Cap during the Total Lunar Eclipse of 1989 August 17*, Alex Pratt.


## Saturday session 2     Lunar occultations     (chaired by Jan Manek, IOTA-ES)

**Analysis of a Hyades double star occultation (70 Tau) using Limovie     (Tim Haymes, BAA, IOTA-ES)**

The Moon passed across the Hyades on 2016 Jan 19th in good conditions from the UK.  This presented a number of bright total occultations, some of which are known double stars.  FI 70 Tauri gave a clear step in the light curve.  I present the equipment and software used to analyse the result.

This example describes the basics of the analysis process with assistance and advice from Brian Loader and Jan Manek, and following some notes from Alex Pratt, who presented his results at ESOP32 Barcelona.

**An Historical Perspective: the Grazing Occultation of 139 Tau on 1972 March 21     (Richard Miles, BAA)**

An account of a successful lunar graze occultation from the early 1970s is presented. Based on predictions by Gordon Taylor, several expeditions were organised including one in the Bristol area by Dr Rodney Hillier, a Bristol AS member who passed away recently. A report of the occultation appeared in the BAA Journal. More recently, Tim Haymes utilised Occult 4 and *Kaguya* data to analyse the observational results.

**Occultation of the open cluster Hyades by the Moon.     (Vaclav Priban, IOTA-ES, Observatory and Planetarium, Prague, Czech Republic)**

First observation from a private observatory which I have constructed at my cottage near Krkonose mountains (Giant mountains, Riesengebirge).

This contribution describes preparing and equipping the observatory and shows the first observed occultations of the stars by the Moon in records and conditions under which they were obtained.

**A greeting from Harrie Rutten     (presented by Richard Miles)**

Very best regards from Harrie Rutten  - Arcen, Netherlands.

Unfortunately I cannot attend ESOP35 – I had a bad cycling accident which I will describe. Plans for the future include acquisition of a 16" ODK when my mobility and recovery have improved.

So all the best to you. Hope to see you next year.


**Group photograph     (taken by Janice McLean, annotated by Tim Haymes)**

**Construction and setup of a stand-alone Raspberry Pi time-server for computer time synchronisation     (David Briggs, Hampshire Astronomy Group)**

Recording of occultation video or CCD images requires an accurate UT time reference. This is often supplied via a continuous 1pps GPS time stamp overlaid on an analogue time signal from a video camera.  When using USB digital cameras, the time signal originates from the PC clock. Synchronisation is achieved via software such as Dimension4 and a wired internet connection.

The Raspberry Pi time-server receives the GPS signal directly, and does not require an internet connection. This is advantageous where no internet is available e.g. in an observatory, or in the field.

The stand-alone Raspberry Pi time-server is not original, as most of the information is freely available on the internet. However its application to occultation astronomy is probably new. The RasPi does require a basic knowledge of Debian Linux to set it up, as well as setting up the Meinberg Windows NTP software.

The system will be explained and hand-outs provided. (Live demonstrations took place during the coffee breaks and at lunchtime).

## Saturday session 3     Instrumentation     (chaired by Adrian Jones, BAA)

**Raspberry Pi time-server Question & Answer session     (David Briggs, Hampshire Astronomy Group)**

Further discussions took place about this time-server solution.

**A portable 20-inch telescope for IOTA/ES     (Konrad Guhl, IOTA-ES, ASTW)**

The observational work of IOTA is spread out across observation sites around the world. Due to focusing on occultation astronomy of TNOs and moons of the outer planets, the size of telescope necessary has increased over the years. The standard "travelling observatory" for many years – the C8 telescope (8 inch diameter) - doesn't fit the requirements of these observations any more. The signal to noise ratio of these rather small instruments cannot keep up with faint objects (up to 20th magnitude), even if highly sensitive CCD (or EMCCD) cameras are used for detection. An instrument with a diameter of 20 inches would solve this problem: from a dark observation site, with an exposure time of 1 second, an instrument of this size is able to detect occultations of stars fainter than 18th magnitude.

Therefore, IOTA-ES decided to buy a used 20-inch Dobsonian telescope in order to adapt it to the requirements of occultation work.  An instrument of this size balances research capability and transportability well. The presentation will show the different stages of the project and the instrument

in the final design. The first presentation about the instrument was given at ESOP XXXIII in Prague (2014). Within the last two years, the telescope was finished and improved. A first expedition was undertaken to the Alps for an occultation of a star by Pluto on July 19, 2016.

The instrument will be based in Hannover (Germany, headquarters of IOTA-ES) and will be made available to IOTA-ES members on request.


### A sensitive CCD camera with timing accuracy in the low millisecond range    (Wolfgang Beisker, IOTA-ES)

Based on a CCD camera from a large commercial camera company, a complete camera package has been developed and tested.

Because high timing accuracy is required in occultation observations, only a LINUX system is appropriate.  The time is read in from a GPS clock with a 1 pulse per second output. This output is fed into the computer by a RS232 to USB converter, controlling an NTP protocol. The time difference of the system clock and the GPS clock is generally better than 0.01 msec.

Using a commercial software developing kit, a GUI has been programmed, which integrates all necessary parameters, input and outputs, and other human interactions.

By direct comparison between the GPS 1 pps output and the camera images an accuracy of the time stamps written into the FITS headers of better then +/ 5 msec could easily be achieved. The system is ready to be used and can be set up together without large mechanical work.  Only the GPS receiver, a RS232 to USB converter, the camera, an electric fan and a notebook computer are needed.

The camera can operate with up to 30 images per second generating single FITS files. The read-out noise is around 7 electrons and the maximum quantum efficiency is around 70%.

The details of camera, hardware and software are presented.

### Atmospheric Dispersion Corrector - Useful for observing low altitude occultations? - A practical test    (Oliver Klös, IOTA-ES, VdS)

Light coming from celestial objects first passes through the atmosphere of our Earth before reaching the telescope.

The deviation of the light depends on the wavelength and the altitude of the object above the horizon. Blue light is deflected more than red light.

Planetary observers know this phenomenon very well. A red border appears at one side of the object, a blue border on the other side. An Atmospheric Dispersion Corrector (ADC) can compensate for this effect.

But what about low altitude occultations?

The light of stars is spread out in the same way as the light of other objects. Therefore a star at low altitude appears elongated perpendicular to the horizon. An ADC should focus the light of a low altitude star on a smaller area on the detector of the camera.

Could this improve our measurements of occultations? The results of a practical test will be presented at this lecture.

### Saturday session 4    Reports    (chaired by John Talbot, BAA)

**The Pluto occultations on 14th and 19th of July 2016 - Preliminary overview of observations (Wolfgang Beisker, on behalf of the European Pluto Occultation Team)**

Two occultations by Pluto on the 14th and 19th of July have been observed throughout Europe. The first one (stellar magnitude about 16) was aimed to be the pathfinder for the central flash of the second one (stellar magnitude about 14).

Because of the favourable weather situation, many stations throughout Europe were able to observe the occultations. In an unprecedented effort, it was possible by Bruno Sicardy and his team to calculate the central line of the occultation on the 19th. The publication of the first Gaia position of the target star on the 19th by the Gaia team allowed us, in combination with the observations on the 14th, to pinpoint the central line very precisely. As it happened, the line moved farther south to northern Africa and the Canaries.  In all parts of central Europe it was possible to observe the following occultation.

*This report will give just a rough overview of what has been observed, without a detailed analysis.*

**High resolution imaging of mutual events of the Jovian satellites during the 2014/2015 apparition    (John Sussenbach[1] and Willem Kivits[2]\*)**

*[1] Houten (The Netherlands) and [2] Siebengewald (The Netherlands)*

During the Jupiter apparition in 2014/2015 several mutual occultations and eclipses of the Galilean satellites took place. These mutual events occur every 5.93 years. A number of the mutual events have been recorded using 14-inch telescopes and different types of cameras. The current processing programs like Registax 6.1 or Autostakkert2! struggle to grade, align and stack the tiny images of the Jovian satellites. To obtain high resolution images, different processing procedures were employed to optimise the quality of the images, including hand selection of the master frames.  A number of occultations and eclipses were recorded at high resolution. In several eclipses the umbra and penumbra could be distinguished successfully. The most interesting mutual phenomenon was observed on 7 February 2016, one day after the date of opposition viz. the simultaneous occultation and eclipse of Ganymede by Callisto.

*\*Willem Kivits passed away on 23 February 2016*

**Occultation of 8th mag star HIP 54599 by (216) Kleopatra on 12 March 2015    (Bernd Gährken, Bavarian Public Observatory, Germany)**

The occultation of the 8th mag star by (216) Kleopatra was the most interesting occultation event in Germany in 2015. The weather was good and many observers got a positive result.

(216) Kleopatra is well-known from radar observations. The radar observations show an uncommon bone-shaped structure which is based on several assumptions. The occultation gave an opportunity to compare radar and reality.

**Mutual events of the binary asteroid (22) Kalliope in 2016 and 2017    (Oliver Klös, IOTA-ES, VdS)**

There are some very good opportunities to observe occultations by (22) Kalliope and its satellite Linus across Europe in the next few months, but other interesting measurements could be made while the binary asteroid reaches its equinox.

Several events can be expected:

Kalliope occults Linus

Kalliope eclipses Linus

Linus occults Kalliope

Linus eclipses Kalliope

This lecture presents the most favourable events for Europe, gives information about expected magnitude drops and accuracy in time and provides a link to the complete list of all events generated by Frédéric Vachier from IMCCE. http://fredvachier.free.fr/

## Saturday session 5    Evening workshop    (chaired by Alex Pratt, IOTA-ES, BAA)

### Informal software demonstrations / tutorials

Included a practical demonstration by John Talbot of OccuRec and AOTA software.

## Sunday session 1    Predictions and projects in the Gaia era    (chaired by Richard Miles, BAA)

### Gaia – the impact on asteroid occultations    (Dave Herald, IOTA, Murrumbateman, Australia – via Skype)

The current astrometric situation is compared with what we can expect after the Gaia data releases from September 2016 to 2020.  The parallax and proper motion of 1 billion stars is anticipated down to mag 20. The catalogues are also expected to contain a large number of new objects.  Occultation paths will become highly refined. For stars brighter than mag 12, the path errors will be less than 20km.  An observation strategy is suggested.

(This presentation was also given at a recent Paris conference, and to IOTA in July).

### On the uncertainty of asteroidal occultation predictions in the Gaia era    (Mike Kretlow, IOTA-ES, BAA)

The predictability of asteroidal occultations is limited by the uncertainty of the available ephemeris and by the error of the star position given for the occultation epoch. Typical star position uncertainties are about 10 - 100 mas for star catalogues mostly used in current asteroidal occultation work. For the first data release of Gaia (G1) a mean error of ~1 mas can be expected, the final catalogue will be about 100 times more accurate.

On the other hand the current ephemeris uncertainty of an asteroid is a complex result of the astrometric data used for the orbit determination and the (iterative) computation process itself. The astrometric observations are usually an inhomogeneous set of measurements made over years or decades by different observers with different techniques and reduced with different star catalogues, and thus are affected by a wide range of random and systematic errors and even not necessarily expressed within the same reference (catalogue) system.

Current uncertainties in asteroid ephemerides are often in the range of some 10 to 100 mas at the 1-sigma level. A 500 mas ephemeris uncertainty corresponds to ~360 km cross-track displacement on the Bessel plane for an object at 1 AU distance to Earth. To achieve a significantly better prediction quality we have to increase the ephemeris accuracy as well, e.g. by debiasing astrometric observations towards a Gaia catalogue system.

The talk will address these issues and looks at the prediction uncertainty and predictability which can be achieved now, in the near future (G1) and in the post-Gaia era.

**LUCKY STAR - An EU research project with Pro-Am collaboration    (Wolfgang Beisker, IOTA-ES)**

I will introduce and explain a new collaborative project involving professional and amateur observers.

**Gaia-GOSA An interactive service for asteroid follow-up observations    (Dr Toni Santana-Ros, Astronomical Observatory of Adam Mickiewicz University, Poznań, Poland)**

http://arxiv.org/abs/1505.03802

Gaia-GOSA is an interactive tool which supports observers in planning photometric observations of asteroids. Each user is able to personalise the observation plan taking into account the equipment used and the observation site. The list of targets has been previously selected among the most relevant and scientifically remarkable objects, while the predictions of the transits in Gaia's field of view have been calculated at the Observatoire de la Côte d'Azur. The data collected by the GOSA community will be exploited to enhance the reliability of Gaia's solar system science. The service is publicly available at www.gaiagosa.eu.

I present the Gaia-Ground-based Observational Service for Asteroids (GOSA).

**Determination of asteroid diameters from occultations    (Dave Herald, IOTA, Murrumbateman, Australia – via Skype)**

I have recently been developing tools to directly determine asteroid diameters from our occultation observations, by making use of asteroid shape models.

I am hopeful that we shall soon set about reviewing all our past observations for events where a shape model is available - so that we can generate 'direct' measurements of asteroid diameters for a good number of asteroids.

The presentation will describe the techniques and problems, and some of the challenges ahead.

(This presentation was also given at a recent US meeting).

## Sunday session 2    Practical techniques    (chaired by Konrad Guhl, IOTA-ES)

### New features of GRAZPREP    (Dr Eberhard Riedel, IOTA-ES)

With the LRO/LOLA lunar profile data as calculated by Dietmar Büttner, Germany, and provided for use in GRAZPREP it is now possible not only to increase the prediction quality but also to revise former grazing occultation reports. GRAZPREP has a special tool that allows an easy graphical checking of occultation timings against a highly enlarged lunar rim. The possibilities and limitations of this procedure are discussed.

Now shortly before the first release of the Gaia catalogue the stellar positions as well as the uncertainties related to stellar double and multiple systems are another obstacle to the precision of prediction and evaluation. According to a request of Gaia project officials, GRAZPREP will be used to confirm the precision of the Gaia positions once they are available.

### Using Occult4 to report and view light curves    (Alex Pratt, IOTA-ES, BAA)

A new feature in Occult4 allows the observer to submit light curves of asteroidal and lunar occultations to a publicly available dataset. Observers are encouraged to contribute the light curves from their latest observations and their work from previous years.

The processes involved in selecting light curve data and reporting the data files are presented and discussed, including the options for searching on star catalogue number, asteroid number or observer name to view light curves in the dataset.

(This presentation included additional slides contributed by Dave Herald).

### UKOCL  The UK occultation prediction feed for OccultWatcher    (John Talbot, Reading AS)

This feed was set up in 2014 using the URAT1 catalogue. Its purpose is to provide parts of Europe, and the UK in particular, with predictions for smaller bodies of which there are many. There are some false stars in this catalogue so potential observers should be made aware of this.

The presentation will describe the selection criteria used for predictions, how it can be accessed with OccultWatcher, and observing tips when selecting these targets.

### Using OccuRec - Occultation Recording Software by Hristo Pavlov    (John Talbot, Reading AS)

OccRec is a video recorder for Windows that has been specifically created to provide better options for recording asteroidal occultations with integrating cameras.

The settings provided in the software offer useful features, and should appeal to potential users. The recording format (AAV) is written by H Pavlov and the video can be read and analysed by Tangra 3.

The main features of the software will be described from this user's point of view, together with tips on how to set it up and record from the camera, and how the recording is used to obtain a basic light curve.

### Travelling and observing with small equipment    (Eberhard Bredner, IOTA-ES, DOA, Club Eclipse)

"From Mars to theta Librae and nothing".

This will be basic information on the use of portable equipment. I also hope to give some hints for the more experienced observers.

### Sunday session 3    Open forum    (chaired by Wolfgang Beisker, IOTA-ES)

General Question and Answer session.

Overview of the proposed location of ESOP XXXVI in 2017 and future ESOPs.

Closing remarks, acknowledgements and thanks to the Local Organising Committee.

Information about the social trips on Monday and Tuesday.

### Sunday session 4    Evening    (chaired by Tim Haymes, BAA, IOTA-ES)

Tim showed a documentary on recent excavations at Stonehenge, as a precursor to the visit on the following day.

### Occultation of a mag 10 star by (922) Schlutia

Tim had publicised this rare opportunity on Sunday night of observing an asteroidal occultation during an ESOP. The predicted shadow track passed near to the University. Poor weather conditions thwarted any plans to monitor the occultation.

**Monday social trip**

Delegates and accompanying persons enjoyed a coach excursion to the observatories of the Hampshire Astronomy Group at Clanfield. http://www.hantsastro.org.uk/ The visit lasted for about an hour, during which they viewed the large range of telescopes on site, including a 24-inch Ritchey-Chrétien reflector, a 7-inch Starfire refractor and the 16-inch Newtonian used by David Briggs for asteroidal occultations and astrometry. The group moved on to visit the famous Neolithic stone circle of Stonehenge, Wiltshire, a UNESCO World Heritage Site.

http://www.english-heritage.org.uk/visit/places/stonehenge/

In the afternoon the tour included sightseeing of Salisbury Cathedral, Wiltshire, and its original copy of the Magna Carta from the year 1215. http://www.salisburycathedral.org.uk/

**Tuesday social trip**

On the last day there was an excursion to Herstmonceux, East Sussex, to visit the old site of the Royal Greenwich Observatory (now transferred to Cambridge). As well as spending time in the interactive hands-on Observatory Science Centre http://www.the-observatory.org/ the visitors were given guided tours of the large telescopes in the Equatorial Group of domes. http://www.the-observatory.org/telescopes Amongst these is the 26-inch Thompson refractor, the 36-inch Yapp reflector and the 13-inch astrographic refractor which took part in the *Carte du Ciel* project.

**An excellent ESOP!**

Everyone agreed that ESOP XXXV had been a most enjoyable and productive symposium with a full social programme. The members of the Local Organising Committee, Tim Haymes, Anne Haymes, Richard Miles, Adrian Jones and John Talbot are to be congratulated.