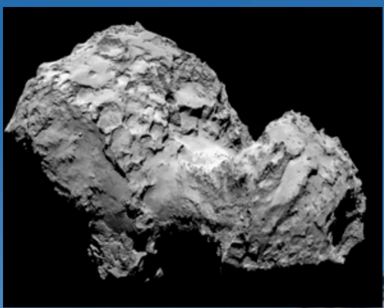
Journal for Occultation Astronomy
INTERNATIONAL OCCULTATION TIMING ASSOCIATION
2014–03
FORMERLY OCCULTATION NEWSLETTER

Comparison of Comet Churyumov Gerasimenko with downtown Los Angeles



On August 3rd, the Rosetta spacecraft's narrow angle camera captured this stunning image of the nucleus of Comet 67P/Churyumov-Gerasimenko. After 10 years and 6.5 billion kilometers of travel along gravity assist trajectories looping through interplanetary space, Rosetta had approached to within 285 kilometers of its target. The curious double-lobed shape of the nucleus is revealed in amazing detail at an image resolution of 5.3 meters per pixel. About 4 kilometers across, the comet nucleus is presently just over 400 million kilometers from Earth, between the orbits of Jupiter and Mars. Now the first spacecraft to achieve a delicate orbit around a comet, Rosetta will swing to within 50 kilometers, identifiying candidate sites for landing its probe Philae later this year.

Journal for Occultation Astronomy

Dear reader,

It is not the first time that I make a plea for recording a light-curve during an occultation of a star by a minor planet. But this time it is different!

On the 12th of March 2015 at about 1h06 UT the asteroid (216) Kleopatra will occult a rather bright star that will be visible from Central Europe!

As you may remember, the shape of Kleopatra resembles a brick or a bone, so it depends on the position of its axis whether during the rotation period a deep minimum of light will occur.

As a projection result the width of the path on Earth during an occultation too, can be obtained using the position of the planet's axis.

For next year's Kleopatra occultation it is of great interest to estimate the possible width of the predicted path in advance! Therefore it is necessary to determine the actual light-curve regarding its rotation period and corresponding epoch. Unfortunately, this minor planet position is still close to its conjunction-time-position so it will be very difficult to collect useful data for more than one extended cycle.

For variable star observers e.g. RR Lyr and WW UMa stars are under surveillance regarding their rotation period – it changes sometimes due to different reasons.

I don't believe this could happen to minor planets but checking it from time to time is better than doing nothing.

Hans-J. Bode

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In this issue:

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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.

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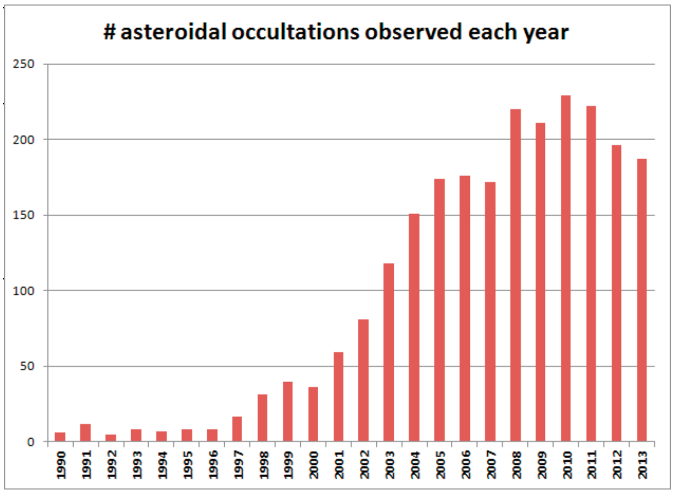
Accuracy of asteroidal occultation predictions

Dave Herald · Murrumbateman, NSW, Australia

For many years Steve Preston has been improving the predictions of asteroidal occultations by generating his own orbit solutions for the asteroid, using the latest available astrometric data. This resulted in a rapid increase in the number of successful occultations observed around the world. But in recent years the number of successful observations has been in slow decline. Why is this happening?



The problem we are currently experiencing has to do with the accuracy of star positions. The major increase in the number of successful occultations can be associated with the availability of the UCAC catalogue. The CCD images for the UCAC catalogues were taken between 1998 and 2004. Those images gave the positions of stars to high precision at that epoch. However to get the position of a star at current epochs, proper motion must be applied, and that proper motion is now for a period exceeding 10 years from the date of the images.

The big problem for us is that while the UCAC positions had high accuracy, the proper motions were not so good. The reason is that the determination of the proper motions in UCAC depends on older catalogues with two different problems. Either the older catalogues predated Hipparcos – with all the problems of pre-Hipparcos catalogues, or the older catalogue was created only a relatively small number of years before the UCAC images – with the proper motion uncertainties being relatively large because of the relatively short time base for proper motion determination. The result is that while the star positions were known quite accurately for dates about 10 years ago, the positional uncertainty is now much greater. Unfortunately, at the present time there are no other catalogues based on imaging taken at significantly more recent times.

To illustrate the problem of the proper motion uncertainty, figures 1-4 show plots of a number of star comparisons for current occultation events generated by Occult. These examples have been selected quite randomly. Figures 1 and 2 involve stars of mag 11.6 and 11.5 respectively. Figure 3 is of a mag 9.9 star, while figure 4 is of a mag 7.0 star

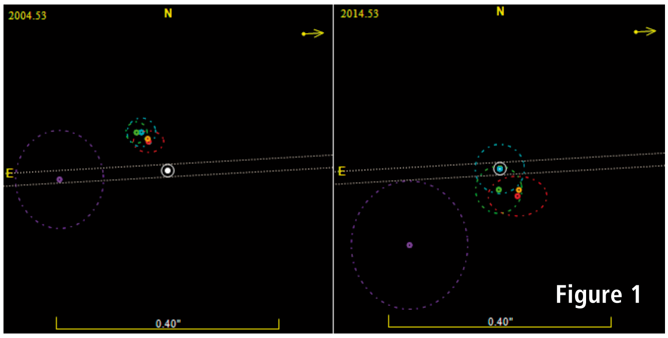


Figure 1

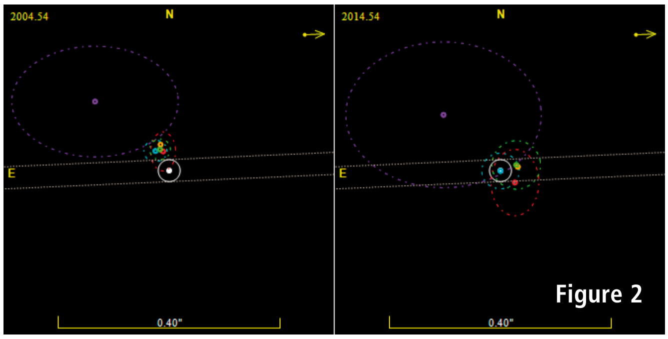


Figure 2

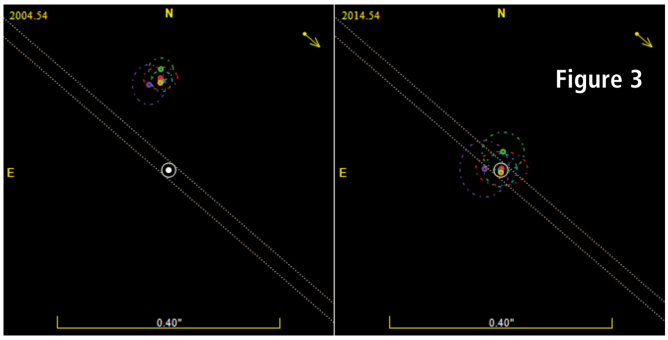


Figure 3

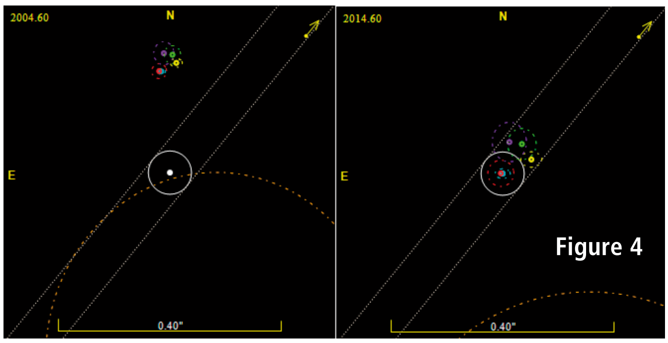


Figure 4

(Hip 90639). In these plots the uncertainty ellipse is shown as a dotted ellipse around the location of the star – and represents the 1-sigma formal uncertainty in the position of the star. [Note – the ability to draw the uncertainty ellipse is a relatively recent change in Occult.]

The plots show the uncertainty ellipses for the UCAC catalogues, PPMXL and Tycho2. (In these plots, the UCAC positions are in light blue (U4), red (U3), or orange (U2). Tycho2 is in purple, and PPMX is in green). The right-hand plot is for the date of the event (which is mid July to early August 2014), while the left-hand plot shows the positions and uncertainties for a date 10 years earlier.

The issue to look at is not the location of the stars (which are displaced in the left-hand images because of the proper motion going back 10 years), but the comparative size of the uncertainty ellipses. In all instances, the uncertainty ellipse for today is at least 50% larger than the uncertainty ellipse of 10 years ago. Simplistically, this means the probability of seeing an event from a predicted location has reduced by a similar amount over this 10-year period.

The growth in the size of the uncertainty ellipse is entirely due to the uncertainty in the proper motion. As we move further away from around 2000, there is a steady decline in the accuracy of the star positions, with a consequential reduction in our ability to accurately predict the location of asteroidal occultations. This will continue as a growing problem until we get a new star catalogue based on more recent imaging.

Many will immediately think the Gaia mission will be the solution to this problem – and in time that may well be the case. However it needs to be remembered that the first data release from Gaia is still some years away. Also there are potential issues with the accuracy of Gaia for stars brighter than mag 12 because of image saturation.

However a solution to our problem should become available from early 2015 – as a result of the URAT project at the US Naval Observatory. URAT stands for USNO Robotic Astrometric Telescope. It uses the same telescope that was used for the UCAC project – although with extensive improvements and a larger camera. An overview of the project and instrumentation is available at:

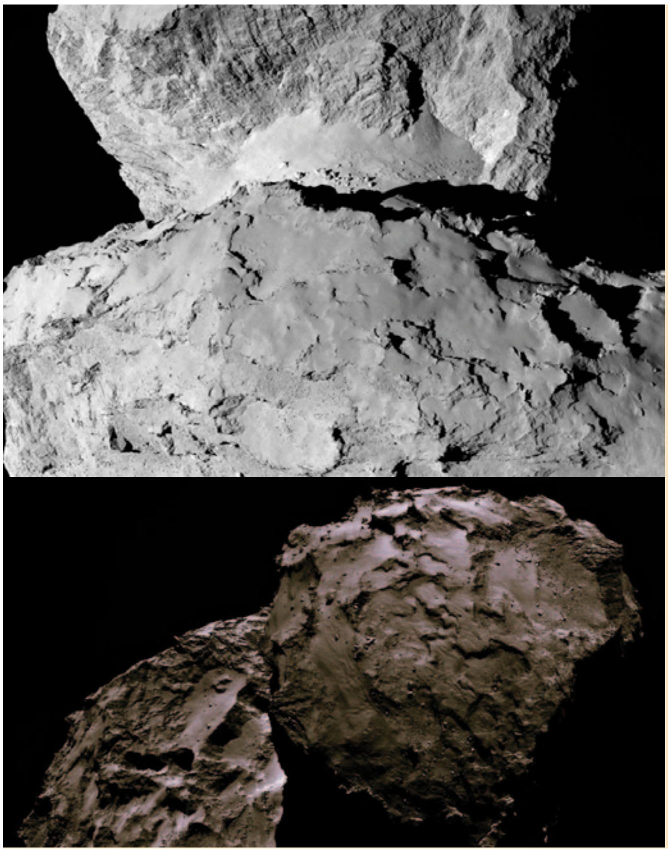
http://ad.usno.navy.mil/urat/

A poster paper for a recent meeting, that sets out the objectives and current status (most of the northern sky has already been well-imaged), is at

http://ad.usno.navy.mil/urat/DDAlowres.pdf

Of great interest is that USNO are anticipating the first catalogue release (URAT1) to occur by the end of 2014. Allowing for inevitable delays in projects like this, it would seem that by mid-2015 we should have access to current-epoch positions for stars north of the equator (and perhaps as far south as -20 deg). This will largely overcome the problems of the proper motion uncertainties in the UCAC catalogue, with improved prediction accuracy and increased success in observing events.

In summary, our predictions will continue to degrade in accuracy for the remainder of this year – but should suddenly improve sometime next year when URAT1 becomes available. However this improvement will be limited to northern hemisphere stars, and it will be several years before we have a similar improvement for southern hemisphere stars.



Contrasting Terrains on Comet Churyumov-Gerasimenko

Where should Philae land? As ESA's robotic spacecraft Rosetta circles toward Comet 67P/ Churyumov-Gerasimenko, a decision must eventually be made as to where its mechanical lander should attempt to touch-down. Reaching the comet earlier this month, Rosetta is sending back detailed pictures of the comet's unusual nucleus from which a smooth landing site will be selected. Pictured above, near the image top, the head of the comet's nucleus shows rugged grooves, while near the image bottom, the body shows a patch-work of areas sometimes separated by jagged hills. Some of the patch-work areas apparent on both the head and body seem to have fields of relatively smooth terrain. In the connecting area called the neck, however, visible across the image center, a relatively large swath of light-colored smooth terrain appears, punctuated occasionally by large boulders. Rosetta is scheduled to release Philae toward the dark mountain-sized comet nucleus with an anticipated landing date in November.

Image Credit: ESA / Rosetta / MPS for OSIRIS Team; MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

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Occultation Astronomy

Report on the Eighth Trans-Tasman Symposium on Occultations

By Jacquie Milner · Perth, Western Australia · milnerjacquie@gmail.com

TTSO8 PARTICIPANTS:

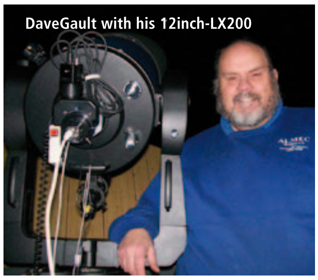
Back Row: Jacquie Milner, Darren Corbett, John Newman, (unidentified), (unidentified), Peter Skilton, Steve Russell, Bill Hanna, Terry Cuttle, Ken Wallace, Jeff Byron, Alan Gilmore, Dave Gault, Brian Loader
Front Row: Jim Blanksby, Albert Brakel, Peter Lowe, Hristo Pavlov, Dave Herald, Pauline Loader, Steve Kerr, Murray Forbes, Pam Kilmartin

Jacquie Milner presenting

The Eighth Trans-Tasman Symposium on Occultations (TTSO8) was held in Melbourne, Australia, as part of the 26th National Australian Convention of Amateur Astronomers. The meeting was held in two parts, with a half-day workshop focussing on occultation timing for beginners on Friday 18th April, then a full day of presentations on Monday 21st April, 2014.

The proceedings were webcast live over the internet so that interested people could listen in to the presentations even if they were unable to attend in person. As well as remote attendees from Australia and New Zealand there were visitors from the US, Canada, Spain, France, Germany and the Czech Republic. Many thanks are extended to Darren Corbett and Chris Douglass for their hard work behind the scenes to make this a success.

The workshop on Friday started with a look at some new developments for visual observers using timing apps for smartphones and tablets. These use Network Time Protocol via the internet, which leads to some delay in upload/download times as a result. But if this delay is noted and used as a personal equation (PE) then results can be considered acceptable. There is still work to be done on these apps but they appear to be a good start to utilising technology that many people will have on hand. Dave Gault spoke on the app for Android platforms called "Time the Sat" and Chris Douglass spoke on "Emerald Timestamp" for iPhones and iPads.



DaveGault with his 12inch-LX200

Dave Gault then gave a summary of the established timing equipment available, the IOTA-VTI, the GPS-ABC unit for visual observers and the Advanced Digital Video System (ADVS) that he, Hristo Pavlov and Tony Barry have been working on for several years. Dave Herald followed this, giving a live demonstration using his Occult software to generate personal lunar occultation predictions. A summary of sources for predictions of asteroid occultations was given by Steve Kerr. A new development here is the inclusion of Trans-Neptunian Objects (TNO) predictions from the RIO group in a feed to OccultWatcher.

After covering the equipment and predictions needed for occultation work we looked at the practicalities of making it all come together in the field. Dave Gault talked about setting up in an efficient manner – having good, reliable equipment, knowing how it works and using it regularly to minimise problems occurring at a crucial time. Establishing a personal routine can minimise mistakes, such as forgetting a piece of equipment or finding you have flat batteries. Regular practise is highly recommended! This was much the same view that this author put forward for her presentation on finding the target star for asteroid occultations. A commonly reported reason for not being able to observe an occultation is failure to find the target star in time. Establishing a personal routine for having the correct coordinate data on hand, an appropriate series of charts prepared and a good knowledge of how your equipment behaves also means that a well practised personal routine will help to increase your chance of success in the future.


The TTSO8 meeting room

Stephen Russell demonstrated how to analyse audio recordings of visual observers using Audacity software. One useful trick to know with this program is to adjust the speed of the recording (which can develop a lag during transfer from the recorder to computer) to make it easier to read and give the most accurate time possible. Brian Loader showed us how to analyse a video of a lunar occultation using LiMovie and then Dave Herald returned to show how to report lunar occultation results using Occult. First time users were reminded that there are examples to follow in the Help files of Occult if one forgets. This was the last presentation for the workshop and participants then dispersed to get ready for the welcoming cocktail party to be held that evening.

Dave Herald presenting his talk on AOTA

Several occultation presentations of a general nature were given on the Sunday afternoon of NACAA to let the wider audience know what is happening in our field of interest and perhaps even to entice them into occultation observing. Brian Loader opened with a look at how lunar occultations can help discover double stars and resolve their separation and position angle. This author then presented the manual that was co-written with RASNZ Occultation Section Director Graham Blow, "Observing Occultations Using Video: A Beginner's Guide." This manual was launched last year at TTSO7 and aims to guide beginners in selecting equipment, making observations, analysing data and reporting results. It can be downloaded as a pdf document from the RASNZ Occultation Section website at www.occultations.org.nz/videotime/manual.htm


Hristo Pavlov (left) & Steve Kerr

Steve Kerr then encouraged us to get more involved with observing TNOs. Predictions for these distant objects are becoming more common and while they rarely seem to approach bright stars, partly because they are so slow moving, this very fact combined with their large size makes for long event times, bringing these relatively large objects within the reach of integrating cameras that amateur astronomers use in their backyards. Currently predicted paths often have a huge uncertainty – Steve described them as "a bit of a lucky dip" at the moment - and capturing more of these events will help to reduce this. Following a break for afternoon tea, when some participants left on an arranged excursion to view progress on the restoration of the Great Melbourne Telescope, Dave Herald gave listeners an overview of current asteroid occultation knowledge, including profiles and 3D models. Dave Gault then finished the day by recounting some group efforts to record grazing occultations over the last couple of years.

The symposium convened for the last day on Monday 21st. John Talbot started the morning with his presentation via Skype from New Zealand summarising notable successful asteroidal occultations in our region over the past year. Twelve new observers have become active, which is great news, although we still have some noticeable "blank spots" on continental Australia where there are no active observers at present. Three occultations resulted in new double star discoveries, with two of them occurring on the same night. An occultation by the TNO (10199) Chariklo was attempted on 3 July 2013 but all observers reported misses. Brian Loader walked us through reporting lunar occultations of double stars and then Dave Gault recapped the information on the new Network Time Protocol timing apps available and their associated problems.

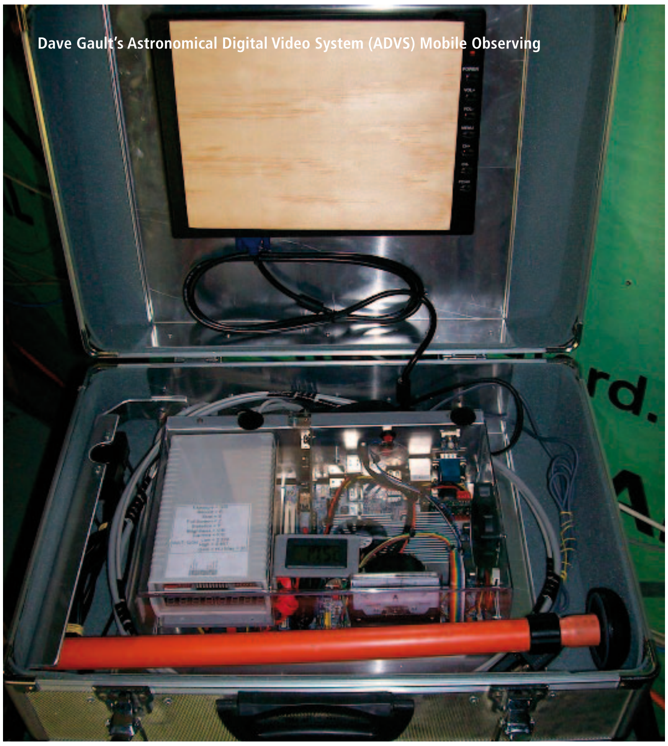
After the morning break there was an in-depth look at the latest Watec video camera, the 910BD. This PAL version is only available as a naked electronics board at the moment (the NTSC version, the 910HX, has a case), so the combined team of Dave Gault, Tony Barry, Hristo Pavlov and Dave Herald have worked together to make it more user friendly. Dave Gault designed an aluminium case to house the camera and Dave Herald has written a control program for it with a visual interface. Hristo Pavlov has also been developing new capture software called OccuRec. It does have some particular requirements and isn't suitable for all cameras, but you can read more about it at www.hristopavlov.net/OccuRec/OccuRec.html . It is still in early development and there are plans to extend its functionality to telescope control and remote recording. Hristo has also been working on some ASCOM controls for video to provide a generic interface for video cameras, but that too is still in early development.

Still on the theme of new software developments, after the lunch break Dave Herald spoke on the improvements made to AOTA, which is a part

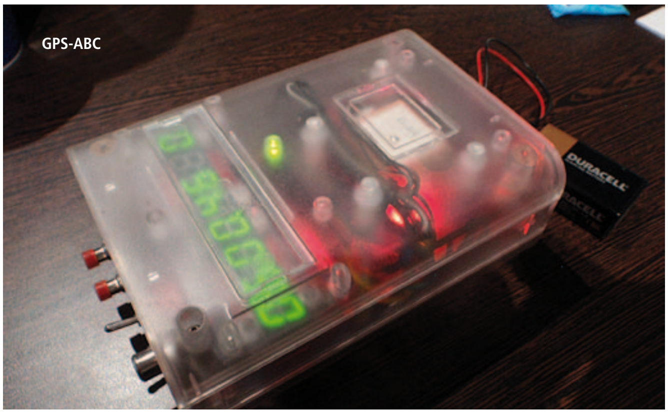
Hristo Pavlov

of his Occult program (you can find it on the Asteroid Observations menu page of Occult). Hristo and Dave have been working together so that a light curve can be exported directly from Tangra 3 to AOTA for analysis, with AOTA even telling you what event times to report. Tangra 3 is different to Tangra 1.4 and Hristo recommended moving to it unless you need to do astrometry. Once AOTA has determined the times of the event (if there is one) another click will send that information back to OccultWatcher to fill in the rest of the pre-populated report form (if you are using that OW add-on).

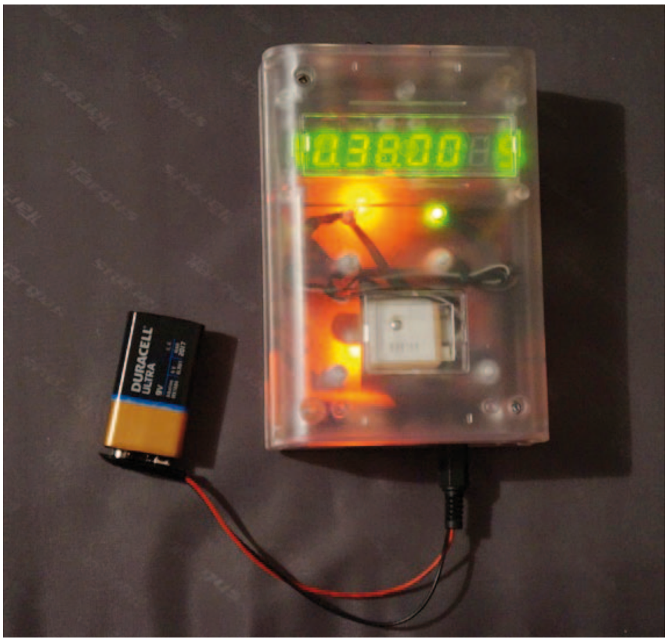
Dave Herald returned again to alert us to the upcoming series of Jovian Mutual Events that will start in September 2014, as the orbital plane of the Galilean satellites becomes edge on to our view from Earth for a 12 month period. With events lasting from 10 minutes to two hours a lot of hard drive space will needed for recordings. Hristo chipped in again saying that he hopes to have a special recording mode for these long events available in OccuRec soon. Results from any observations made should be sent to Paris Observatory. The day was rounded out



Dave Gault's Astronomical Digital Video System (ADVS) Mobile Observing



GPS-ABC

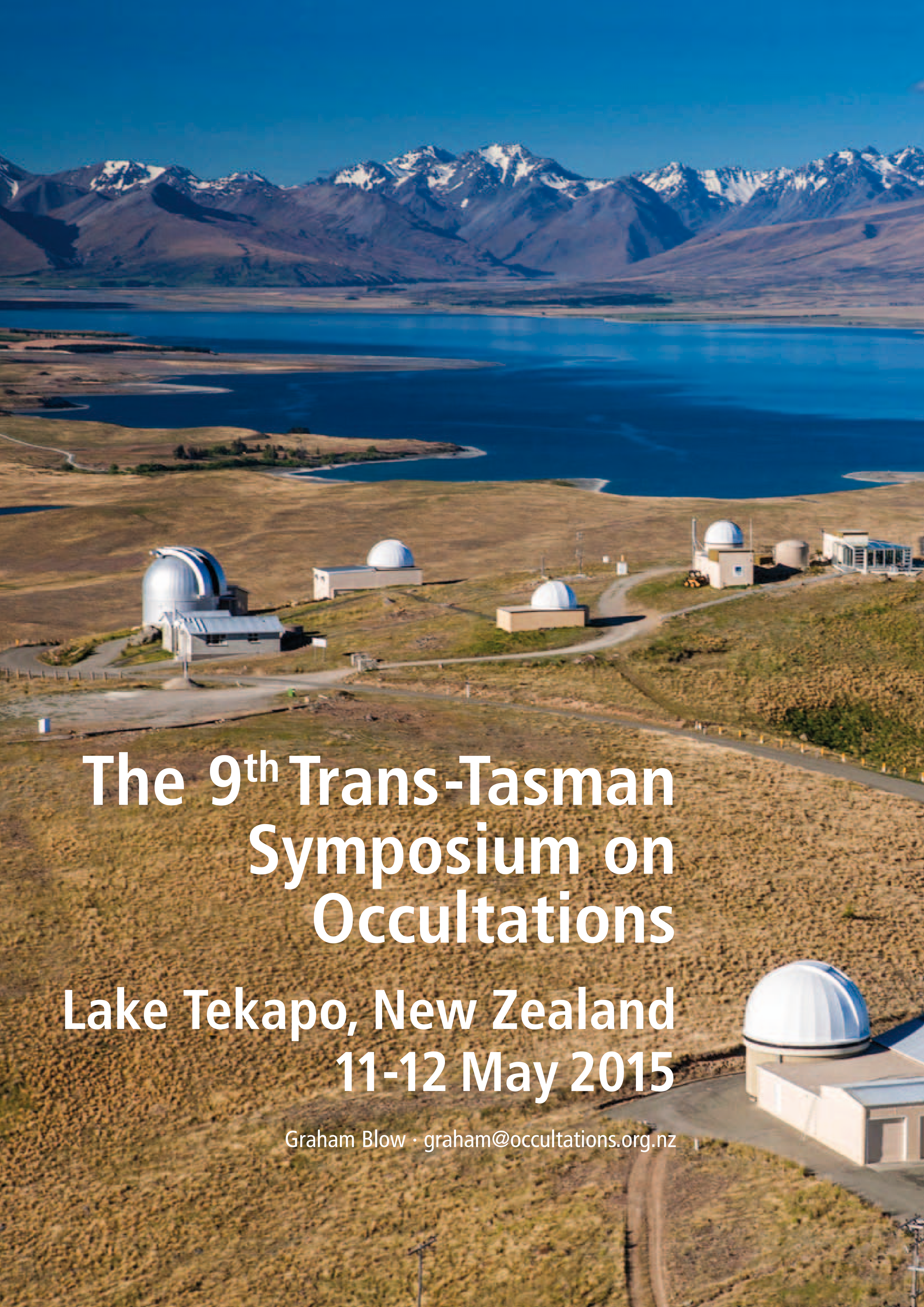


by brief mentions of the new TNO feed available in OccultWatcher with predictions provided by the RIO group, and a short update of the ADVS system that is still in beta testing. The new website for the ADVS is www.kuriwaobservatory.com/ADVS.html . The symposium was then officially closed.

PowerPoint files and presentation notes for most of the talks given over the weekend are available for download at www.occultations.org.nz/meetings/TTSO8/TTSO8.htm

The next symposium, TTSO9, will be held in conjunction with the RASNZ Annual Conference in early May, 2015, at Lake Tekapo, on the South Island of New Zealand. The TTSO9 and RASNZ meetings will follow a Symposium marking the 50th anniversary of Mt John University Observatory, New Zealand's principal professional observatory. This latter meeting is expected to attract a wide number of previous staff and students from the University of Canterbury (which owns and operates the observatory).

Details of the Mt John Symposium can be found at www.mjuo50.org.nz, of the 2015 RASNZ Conference at www.rasnz.org.nz, and of the TTSO9 meeting at www.occultations.org.nz .

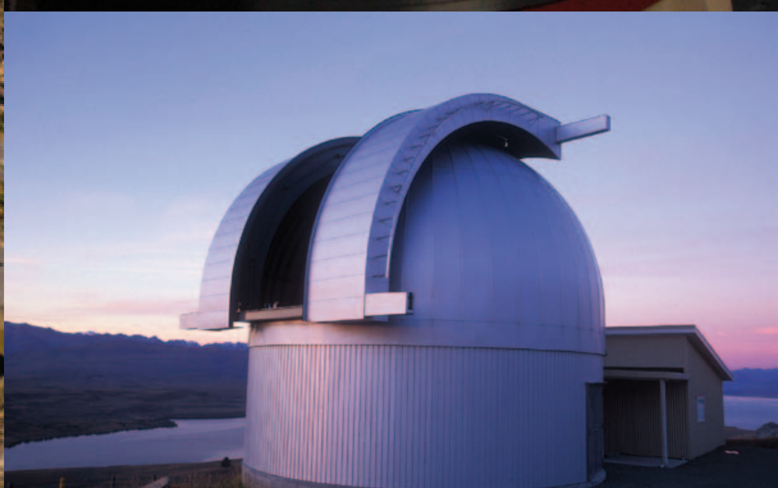


The 9th Trans-Tasman Symposium on Occultations

Lake Tekapo, New Zealand
11-12 May 2015

Graham Blow · graham@occultations.org.nz



The crescent moon sets behind the summit of Mt Cook, New Zealand's highest mountain.

The RASNZ Occultation Section is pleased to announce that the 9th Trans-Tasman Symposium on Occultations (TTSO9) will be held in Lake Tekapo, New Zealand, over 11-12 May 2015. The meeting will immediately follow two other scientific meetings in the same location, making for almost a full week of scientific astronomy activities. A record number of registrations for TTSO9 is expected.

The TTSO9 meeting will draw occultation observers and interested others from throughout Australia and New Zealand, and we hope from further afield. The meeting will cover two full days and will include updates on developments in occultation software, observing and reductions as well as the presentation of recent results. More details of the TTSO9 meeting are available at http://www.occultations.org.nz/

Lake Tekapo is the site of the Mt John University Observatory (MJUO) of the University of Canterbury. It is New Zealand's largest professional observatory and will be celebrating its 50th anniversary with a special symposium over 7-8 May which many former students and staff are expected to attend. Mt John is also home to 1.0 and 1.8 metre telescopes (the latter involved in the hunt for exoplanets), and from the astro café at its summit the views of the Southern Alps are spectacular. Tours of the Observatory will be available during the six days of the scientific meetings. More details on the MJUO 50th anniversary symposium can be found at http://www.mjuo50.org.nz

Between the Mt John Symposium and TTSO9 the Royal Astronomical Society of New Zealand (RASNZ) will hold its annual conference on Saturday & Sunday May 9-10. This is New Zealand's largest annual gathering of astronomers, and in recent years has also drawn many

Church of the Good Shepherd,
Lake Tekapo

participants from Australia. The feature speaker for 2015 is leading cosmologist Prof. Gerry Gilmore, Professor of Experimental Philosophy at the Institute of Astronomy, University of Cambridge, UK, and an alumnus of the University of Canterbury. More information on the RASNZ Conference is posted at http://www.rasnz.org.nz

With all three meetings being held near the beginning of May, this is an ideal time for those who would like to combine their astronomy with a holiday in the spectacular landscapes of southern New Zealand. Lake Tekapo lies in the Mackenzie Basin, a vast sheltered area in the lee of New Zealand's Southern Alps, an area whose skies are so clear that in 2012 it was designated the Aoraki/Mackenzie International Dark Sky Reserve. Its southern latitude also makes it ideal to examine sights not easily visible from the northern hemisphere, including the centre of our galaxy which passes directly overhead, and the Magellanic Clouds.

Mid to late April in the South Island of New Zealand is autumn, and regions around Lake Tekapo and to its south are renowned for their natural beauty and autumn colours. For those who wish to travel further, New Zealand offers a diversity of landscapes not seen together anywhere else on Earth. These range from the beautiful glacier-fed lakes in the foothills of the Southern Alps, Milford Sound and its adjacent majestic fjords, the semi-arid regions of Central Otago, stunning alpine and sub-alpine scenery, and the rainforests of the West Coast of the South Island – all within a few hundred kilometres. In addition New Zealand has some of the most spectacular walking tracks in the world, and the Lake Wakatipu/Queenstown region is acknowledged as the adventure capital of the southern hemisphere.

Visit http://www.occultations.org.nz/ for more information about the TTSO9 meeting and additional information about many of the locations mentioned above.

Journal for
Occultation Astronomy

User testing the UCAC4 catalog

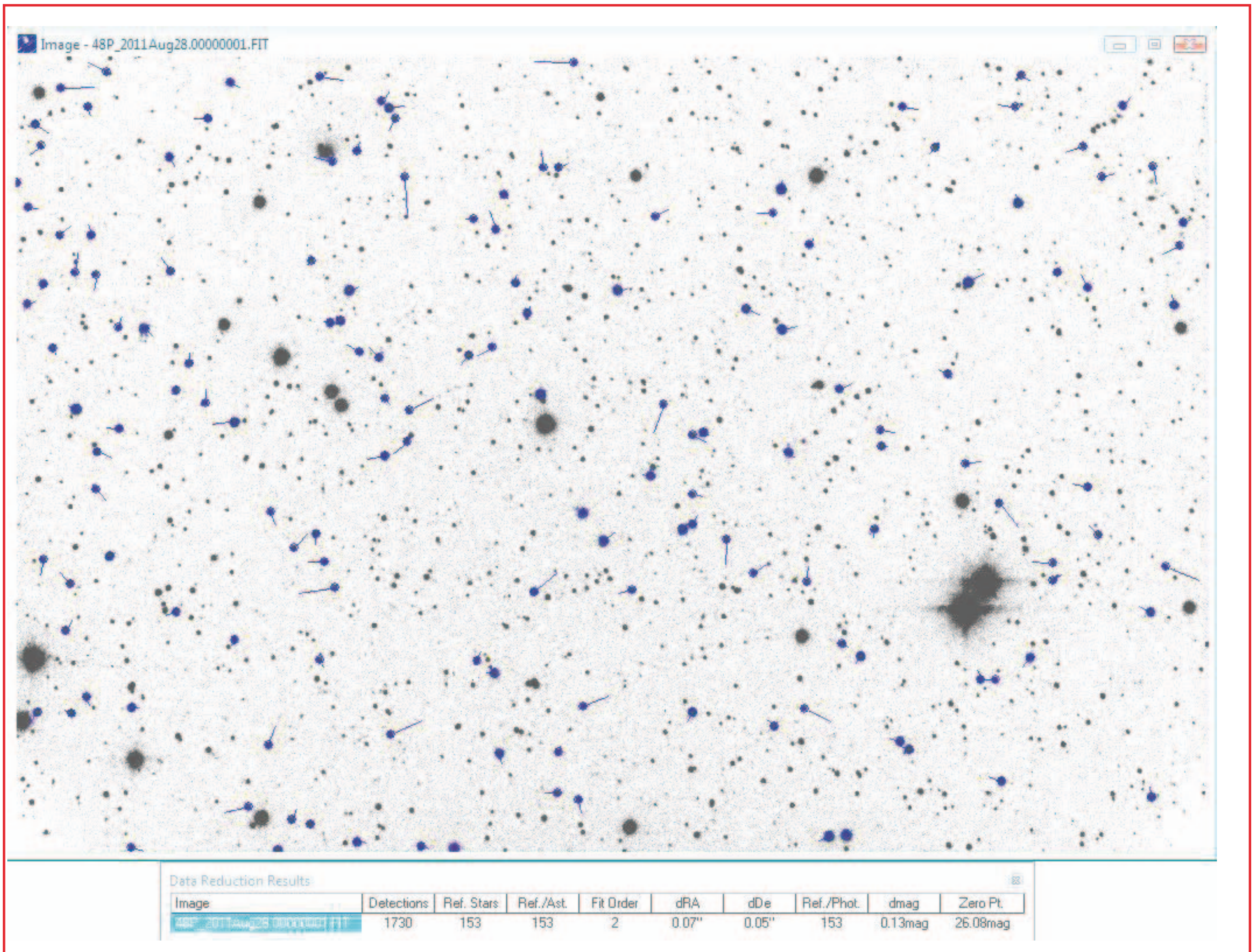
Dave Herald · Murrumbateman, NSW, Australia

Asteroidal occultations provide a strenuous test of a star catalogue. Firstly, we are seeking positions of the highest accuracy – since small errors in a star's position translate to large displacements of the occultation path on the Earth. [An error in a star's position of 0.1" results in a displacement of the occultation path of around 200km for a main belt asteroid, and about 2000km for a TNO asteroid.] Secondly, we want that precision for every individual star in the catalogue. [In contrast, when a catalogue is used for astrometry, 10's or 100's of stars are used in the astrometric solution, so that errors in individual stars are averaged out.]

The Hipparcos mission resulted in the Hipparcos and Tycho2 catalogues. These catalogues revolutionised astrometry as they provided high precision positions which were not affected by a range of problems with traditional star catalogues. However they have their limitations. The Hipparcos catalogue is limited to the brighter stars; the Tycho2 goes to about mag 12, but the precision is reduced and its proper motions are derived using traditional catalogues.

In the late 1990's US Naval observatory commenced a project to create an all-sky catalogue based on the Hipparcos reference frame, but extending to mag 16. [This would provide star positions on the Hipparcos reference frame at a density sufficient for small-field astrometry.] The project was based on CCD astrometry using images taken between 1998 and 2005. It achieved positional accuracies at the imaging epochs of about 0.015" to 0.020" for stars in the magnitude range of 10 to 14 (which equates to an occultation path uncertainty for a main-belt asteroid of around 40km.)

Steve Preston recognised the value of this project to asteroidal occultations quite early; before UCAC2 was released it was quite common for Steve Preston to seek an updated astrometric position of a star from the USNO.



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The first whole-sky version of the UCAC catalog was UCAC3. Unfortunately this version suffered from a range of defects – such as quite a few UCAC2 stars were missing, bad proper motions, and false double stars. This lead the USNO to subject the final version of the UCAC catalog to user testing – which may well be a 'first' for a star catalogue.

The purpose of this article is to record the involvement of our asteroidal occultation efforts in the finalisation of the UCAC4 catalog. It is important to note here that what we provided was input to the USNO about a range of issues; all decisions about the catalogue were made by USNO on the basis of their objectives, and having regard to the input of all user testers.

Astrometric check

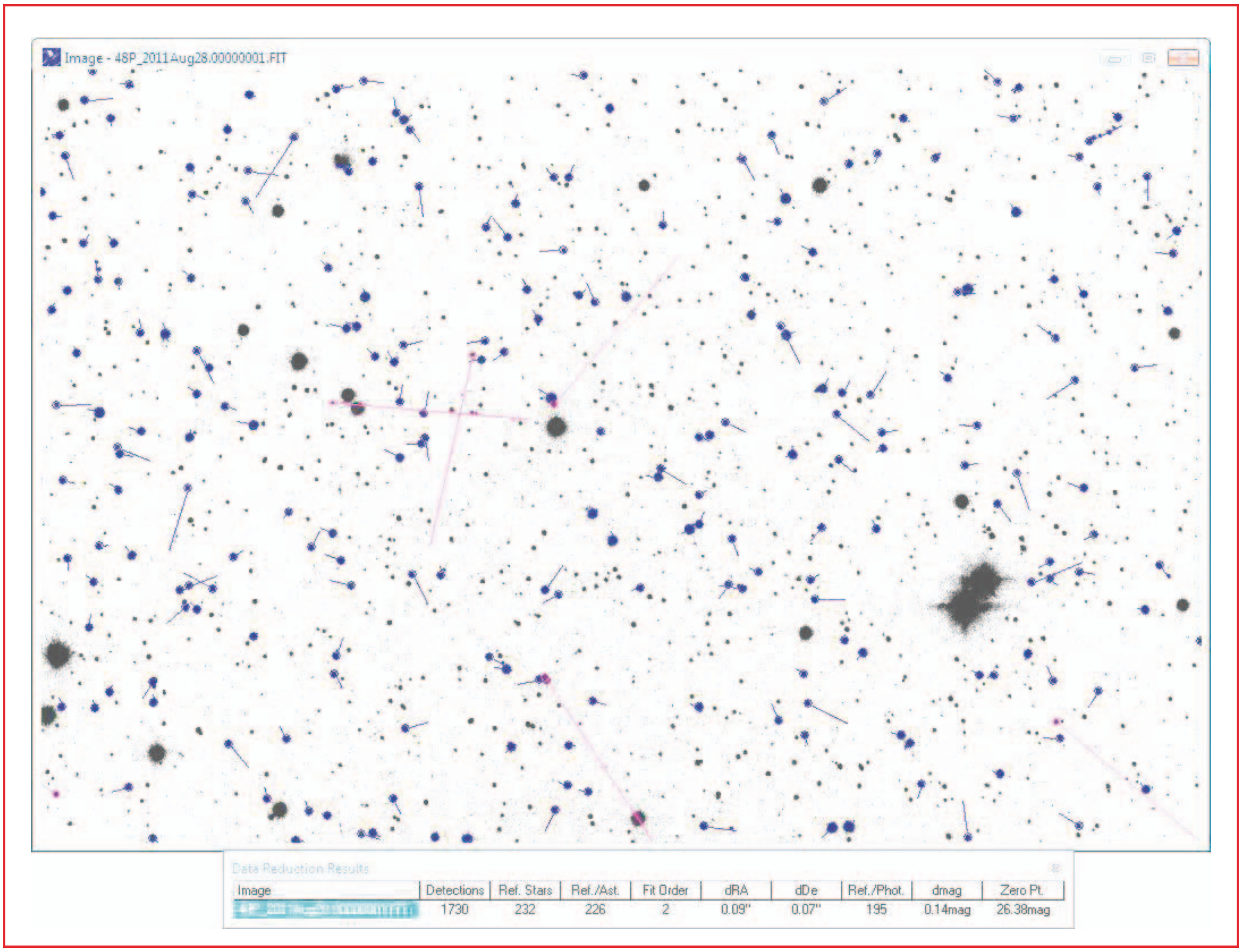
An initial test of the catalogue was to view the O-C residuals when the catalogue was used to generate an astrometric fit to a star image. For this purpose I took an image using a 40cm scope with an SBIG 6303 camera. The location was close to comet 48P – which is the 'fuzzy' towards the top left of the image. The image covers RA $20^h\ 12^m\ 40^s$ to $20^h\ 14^m\ 30^s$, Dec –26° 56′ 30″ to –26° 40′ 30″

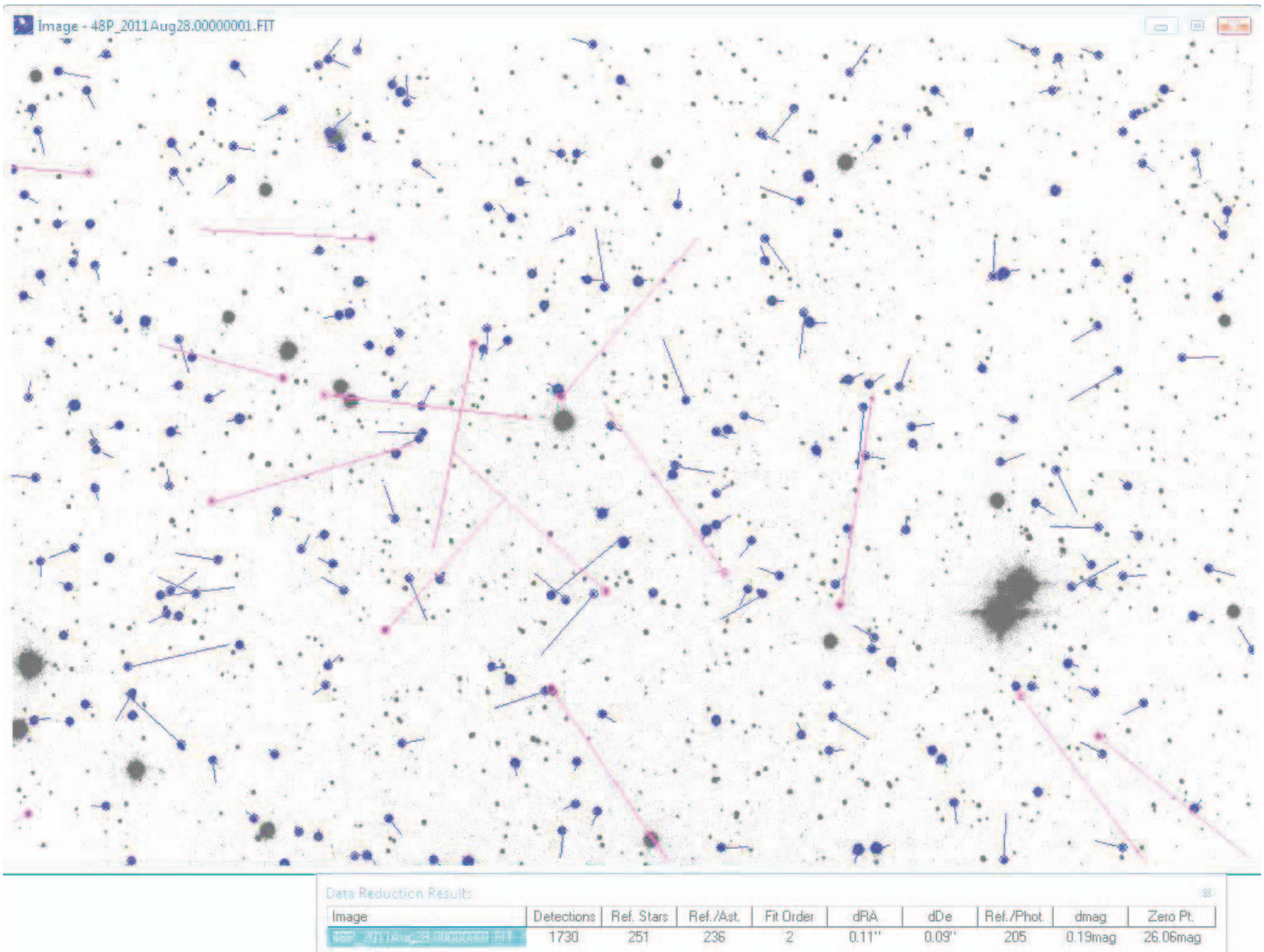
I used the astrometric package Astrometrica (which I highly recommend for astrometry!) using a quadratic fit. In the images below all catalogue stars matched to star images are indicated with a small blue circle. The O-C residuals are indicated by a short line, whose length is 120 times larger than the residual at the scale of the image. Where the residual is large and the star is not used in the astrometric solution, the line is shown in Fuchsia.

These solutions led to the following observations:

- Clearly U4 has more stars than U3, which has more stars than U2 [251:232:153]
- however the value of the fainter stars that have been added is not so great – as they generally appear to have larger residuals (which is not surprising)
- interestingly, no U2 stars were rejected in the solution, whereas U4 had 15 stars rejected
- the formal RMS fit in RA and Dec reduces in accuracy from U2 to U4. Specifically:

  U2 0.07″/0.05″
  U3 0.09″/0.07″
  U4 0.11″/0.09″





The fact that the RMS fit has become worse is 'interesting'. The most likely explanation is the inclusion of fainter stars with more accuracy 'issues'. To test this, I limited the faintest stars that could be used in the fit – to stars brighter than 15.0:

- U4 had 74 reference stars, used 68, and had rms residuals of 0.04"/0.03"
- U3 had 51 stars, used 49, rms 0.04"/0.03", and
- U2 had 68 stars, 68 used, rms 0.05"/0.03".

This confirms that the increase in the value of the rms of the fit is due to the inclusion of faint stars whose positions are less accurate.

I selected stars at random across the field, and measured their positions. UCAC4 differed from the UCAC3 positions by 0.1" in Dec most of the time, but rarely differed from UCAC2. In RA, UCAC4 rarely differed from UCAC2 (at the 0.01s level) but sometimes differed from UCAC3. This suggests that UCAC4 positions will be closer to UCAC2 than UCAC3, and the UCAC3 had some systematic errors.

I tried visually comparing the O-C lines on the three reduction images, in respect of reference stars that were common between the three fits. The impression I gained was that there was no significant general overall improvement. Rather some stars fitted better, and others fitted worse.

My conclusions from this single-field comparison were:

- UCAC4 has greater field density than UCAC2 and UCAC3.
- There does not appear to be a quantum leap improvement in the accuracy of catalogue relative positions at current epochs compared to UCAC3 or UCAC2.
- Astrometry performed using UCAC4 gives results that differ from UCAC2 and UCAC3 by no more than 0.1"

Accuracy from ast eroidal occultations

The astrometric reduction of an image gives information on the relative position of the stars in the field. However it gives little information on the absolute accuracy of a position. For example (as noted above) the positions measured using UCAC3 stars had a systematic shift in declination – and such systematic differences are hard to detect or quantify from astrometric analyses of small fields.

For our asteroidal occultation program we wanted to know whether UCAC4 was 'more accurate' in an absolute sense than other catalogues. To this end Dave Gault and I undertook a comparative assessment of the prediction accuracy of 4 catalogues:

UCAC2
UCAC3
UCAC4 and
PPMX

The methodology used for the comparison was as follows:

identify all successful occultations in 2010 and 2011 where the observations located the occultation path (that is, at least two successful chords that were well separated across the path);

■ use Steve Preston's prediction of the event as the basis for comparison – on the basis that those predictions used the best available position of the asteroid;

■ compute a 'post-diction' of the event using each catalogue, and determine the displacement from Steve's prediction – and from that, the displacement from the observed path;

■ make a subjective assessment of whether the prediction using each catalogue was close to the actual path location, differed by a small amount (up to about 1/2 a path width) or differed by a large amount; and finally

■ draw statistical conclusions.

This approach has some important limitations:

■ The main limitation is a significant selection effect, based on observers positioning themselves on the basis of the Preston predictions. By looking at successfully observed events, our focus is dominated by predictions which were 'about right'. If a Preston prediction was in major error, it would be unlikely for observers to be in the actual occultation path – and hence the actual occultation path would be undetermined. Consequently situations where the star position used in the Preston prediction was poor, with other catalogues giving better positions, are seriously under-sampled with this approach.

■ for each event, uncertainties exist in the position of both the star and the asteroid. For any one event, it is not possible to attribute the observed difference from the prediction to one or other of the star or asteroid. Rather the approach has to be to look at a large number of events, assume that the errors in the asteroid positions average out, and to compare the catalogues by looking at the 'average' result for each catalogue.

The effort involved in this analysis was quite considerable, with post-dictions for each event considered needing to be generated with each of the four catalogues being considered. Dave Gault is to be thanked for his tireless efforts at generating the post-dictions for analysis.

Results

All events in 2010 and 2011 (to about July) were considered. There were 93 events where the observations firmly located the position of the occultation path. The results of the analysis assume that the asteroid orbit had been updated by Steve Preston. They do not apply for predictions based on ASTORB or MPCORB, where the 'success rate' is inherently lower. The results can be summarised as follows:

1. Percentage of observed events where the observed path was close to the predicted path

UCAC2	UCAC3	UCAC4	PPMX
42%	38%	40%	33%

2. Percentage of observed events where the observed path was close to the predicted path, or off by up to about half a path width

UCAC2	UCAC3	UCAC4	PPMX
84%	69%	80%	76%

3. The corollary of #2 is the percentage of observed events where the observed path was significantly different to the predicted path – and that is:

UCAC2	UCAC3	UCAC4	PPMX
16%	31%	20%	24%

Conclusions

■ the UCAC3 catalogue is clearly inferior to the other 3 catalogues;

■ the PPMX catalogue is no better than UCAC for generating accurate predictions. Interestingly it is noticeably less successful than UCAC2 and UCAC4 for observed paths that were close to predicted.

■ the UCAC4 catalogue appears to be as good as UCAC2 for generating accurate predictions. However UCAC4 has whole-sky coverage, and includes many fainter stars.

Some other conclusions not apparent from the above figures are:

■ for every catalogue you can find instances where 'its' prediction is 'correct' and all the other catalogues are significantly worse. That is, the dominant factor in the accuracy of a single star position is the information concerning the particular star, rather than systematic issues with the catalogue. It follows that the question "which catalogue is the most accurate to use?" is the wrong question. Rather the relevant question that needs to be asked is: 'for this particular star, which catalogue appears to have the most reliable information...?'

■ the variation between the star positions as given in the various catalogues is generally smaller than the correction to the asteroid position derived from Steve's orbit improvements. That is, it is more important to update the orbit of an asteroid than it is to select the 'right catalogue' for the star position.

Other issues

In addition to the above testing, our involvement as user testers provided an opportunity to make suggestions. The more noteworthy suggestions which we put forward were:

the numbering system used in the catalogue needed to be one which allowed a star to be easily retrieved by its catalogue reference number. The final numbering system does this. In comparison, the USNO internal numbering system (present in the catalogue as the MPOS number) is based on a sort of the catalogue by declination (irrespective of RA), and is non-continuous.

Include bright stars in the catalogue. The UCAC project did not measure stars brighter than about mag 8. By supplementing the catalogue with bright stars from other sources, the catalogue could be made 'complete' at the bright end. This would mean that we could use one catalogue to conduct a comprehensive search - unlike UCAC2 and UCAC3, where a separate catalogue needed to be searched to find events involving bright stars.

For the bright stars, use the Hipparcos2 catalogue rather than the original Hipparcos catalogue. [Interestingly, the use of the Hipparcos catalogue created a problem with there being a number of instances where more than one UCAC4 star validly corresponded to a single Hipparcos catalogue entry.]

Make the Hipparcos parallaxes available, so that parallax corrected positions could be readily computed without accessing another catalogue.

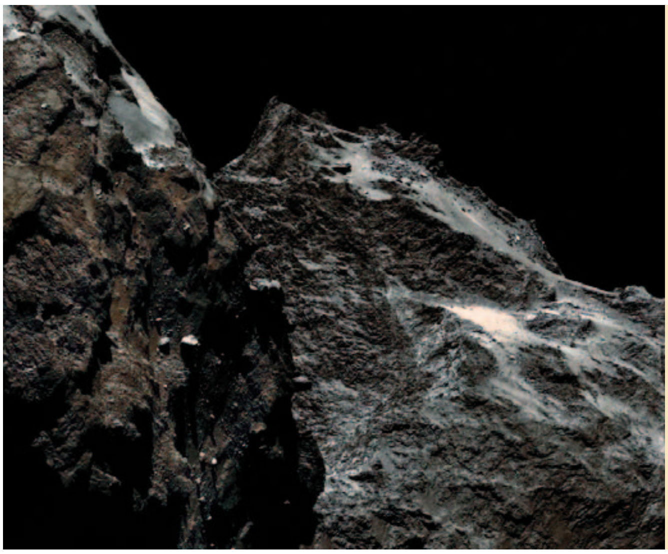
Support a small delay in the release of the catalogue, so that the full APAS pass 1 data could be included – thereby maximising the stars where decent 5-colour photometry was available.

Include an index to the catalogue that supported efficient searching for asteroidal occultations. [UCAC4 is indexed at increments of 1 minute of RA. UCAC3 had no index. UCAC2 was indexed at increments of 6 minutes in RA.]

Conclusion

Creating a catalogue with over 100 million stars is not an easy task. The challenge of getting accurate measurements from a CCD image is just part of the problem. Huge challenges also lie with matching positions obtained from several CCD images, plus matching stars to positions from older catalogues in order to derive proper motions. In years gone by where catalogues were derived by measuring photographic plates, every image of every star that went into the catalogue was 'observed' by the person measuring the plates – but even then false entries were created. In the modern catalogue creation environment the measurement and analysis of the data is fully automated – with many problems of interpreting the images (including distinguishing between stars and galaxies) - with the ultimate accuracy being very dependant upon the software solution. The user testing that UCAC4 was subjected to resulted in significant improvements to the final catalogue.

The US Naval Observatory is to be thanked for taking the approach of user testing UCAC4 – as it has resulted in a 'better' catalogue that meets the needs of the range of possible users.



62 Kilometers above Comet Churyumov-Gerasimenko

Explanation: Spacecraft Rosetta continues to approach, circle, and map Comet Churyumov-Gerasimenko. Crossing the inner Solar System for ten years to reach the vicinity of the comet last month, the robotic spacecraft continues to image the unusual double-lobed comet nucleus. The reconstructed-color image featured, taken about 10 days ago, indicates how dark this comet nucleus is. On the average, the comet's surface reflects only about four percent of impinging visible light, making it as dark as coal. Comet 67P/Churyumov–Gerasimenko spans about four kilometers in length and has a surface gravity so low that an astronaut could jump off of it. In about two months, Rosetta is scheduled to release the first probe ever to attempt a controlled landing on a comet's nucleus.

Image Credit: ESA / Rosetta / MPS for OSIRIS Team; MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA
Additional Processing & Copyright: Elisabetta Bonora & Marco Faccin (Alive Universe Images)

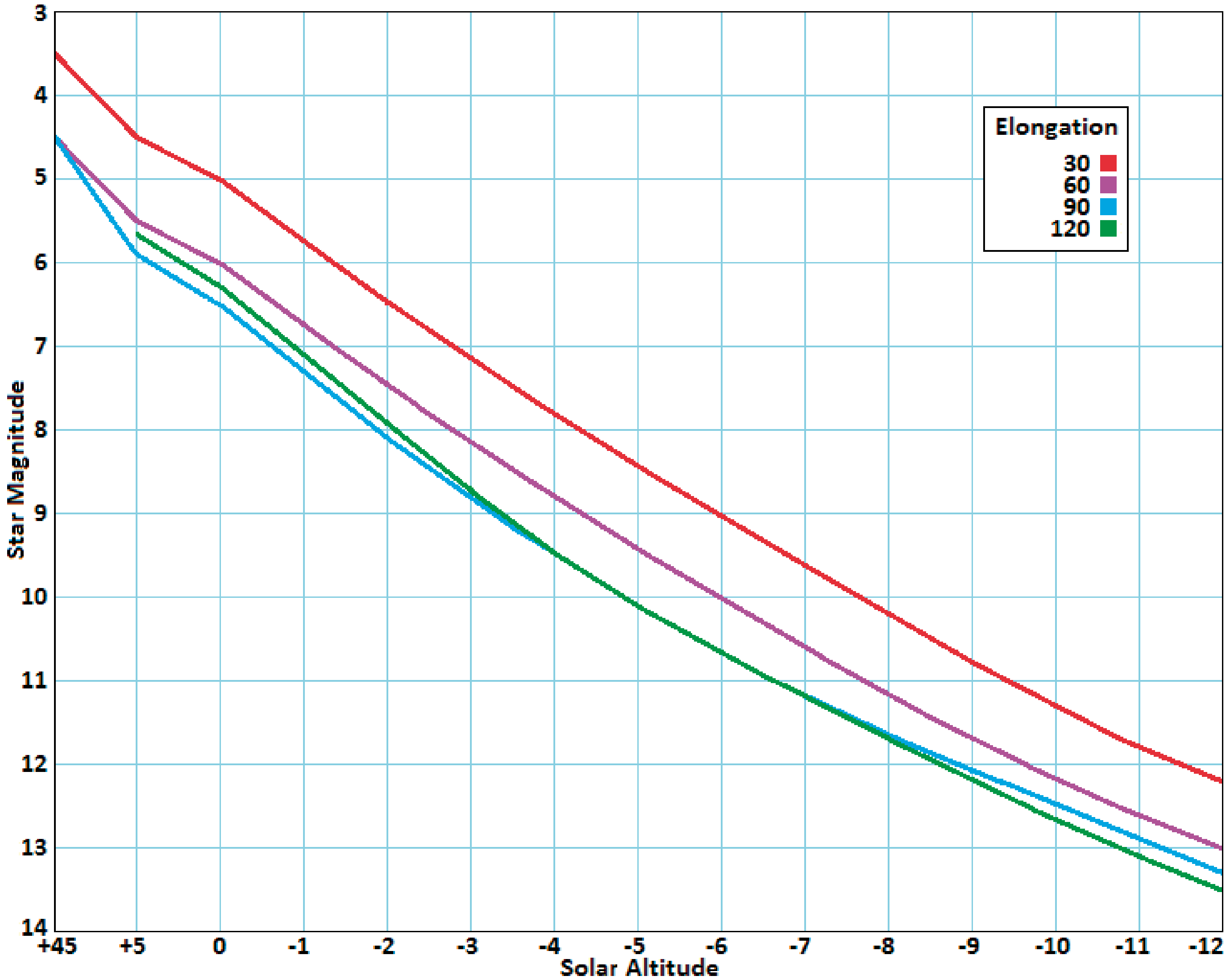
Journal for Occultation Astronomy

Twilight Magnitude Limits

J. Broughton - May, 2014

Stars associated with some occultations are bright enough to be visible during twilight and even in broad daylight on occasion. Under such circumstances, the visibility of a star depends on three major factors; solar altitude, star magnitude and elongation. Stars were imaged by a Watec 120N+ video camera through a 10″ f/6.8 SCT. A red filter aided observations during daylight and civil twilight. Progressively fainter stars were targeted until a limit was reached. The camera was adjusted to maximise star visibility without saturating the background. All sightings were made above 20 degrees elevation where atmospheric extinction is inconsequential. Results are set half a magnitude brighter than the faintest star visible on screen. Columns in the table represent different solar altitudes and rows signify elongation in 30-deg increments. Some extrapolation was required to fill gaps in the data and minor adjustments made to conform to fitted magnitude curves.

		Daylight		Civil Twilight						Nautical Twilight						
		Sun +45	Sun +5	Sun 0	Sun -1	Sun -2	Sun -3	Sun -4	Sun -5	Sun -6	Sun -7	Sun -8	Sun -9	Sun -10	Sun -11	Sun -12
ELONG	30	3.5	4.5	5	5.7	6.4	7.1	7.8	8.4	9	9.6	10.2	10.8	11.3	11.8	12.2
	60	4.5	5.5	6	6.7	7.4	8.1	8.8	9.4	10	10.6	11.2	11.7	12.2	12.6	13
	90	4.5	5.9	6.5	7.3	8.1	8.8	9.5	10.1	10.7	11.2	11.6	12.1	12.5	12.9	13.3
	120	-	5.7	6.3	7.1	7.9	8.7	9.5	10.1	10.7	11.2	11.7	12.2	12.7	13.1	13.5



Journal for
Occultation Astronomy

Optimised CCD Sampling for Occultation Timing

Jonathan Bradshaw, IOTA, jonathan@the2bradshaws.com

Introduction

This paper draws on lessons learned from astrophotographers in matching the focal length of the telescope to the pixel size of the video camera but with an occultation twist. It is suggested that observers with larger instruments imaging at correspondingly longer native focal lengths should endeavour to attain the suggested much shorter focal lengths required for the camera to operate most effectively. This will extend the reach of their occultation equipment by as many as three magnitudes and as a consequence minimise integrations for fainter events. Taking care to ensure that data is not over exposed, and ever mindful that some events may suit longer focal lengths, the author has employed the technique to record 19 positive events in as many months, with most in the 13-18th magnitude range using a 14″ telescope in semi-dark sky.

Some basic background on CCTV Cameras

The key tool of the amateur occultation observer is the CCTV camera and we are fortunate to share a common need with the security industry; the need to record events in very low light conditions. This gives us access to incredibly sensitive and inexpensive cameras whose job it is to turn light (photons) into a measurable signal (electrons).

These low light cameras have a high Quantum Efficiency (QE), the term used to describe, in percentage terms, the ratio of photons which are turned into electrons. There are many physical factors which influence whether or not photons are converted or not; many chips require a certain number of photons to strike a sensor before it will begin registering, for example; others have pixels with gaps in between them which are insensitive to light. The absolute QE for a chip is often not published by the manufacturer and instead a relative QE across the spectrum is shown. Chips such as the Mono ExView chips from Sony have an estimated QE of 65%, and for the purposes of this paper, this will be adopted as the standard for a very good chip.

CCTV cameras are restricted to a low number of very small chip sizes to ensure that they are interoperable with standard lenses and accessories. The two most common CCTV sizes are ¼ and 1/3 inch chips. Not that these relate to the true dimensions of the chip – hailing back to pre-CCD ages, the dimension relates to the outside diagonal diameter of the original analogue sensors and so our CCD chips are actually much smaller. A third format, 1/2 inch, is particularly popular in video astronomy due to the larger field of view it affords but can result in vignetting when coupled to a CCTV lens. Because the resulting AV signal is output generally in either PAL or NTSC formats, all chips have approximately 750x500 pixel arrays to accommodate the format. As all chips have roughly the same number of pixels, smaller chips must by definition have smaller pixels and Table 1 outlines the physical characteristics of these chips.

Chip Size	Actual	Pixel Size (approx.)
1/4 Inch	4 mm	4.3 µm x 4.6 µm
1/3 Inch	6 mm	5.6 µm x 4.7 µm
1/2 Inch	8 mm	8.6 µm x 8.3 µm

Table 1. Chip Physical Characteristics

Furthermore, these cameras output modified AV signals tailored to visual representation on a cathode-ray TV rather than for digital analysis, and as a consequence every camera modifies irreversibly the data before it is broadcast. This modification certainly involves stretching the levels and may include smoothing, averaging, gamma correction and noise reduction. This manipulation means that post processing techniques such as binning and further stretching are rendered much less effective.

By understanding the physical characteristics of the camera, it is possible to optimise the imaging setup used for occultation work.

Nyquist Sampling

Astrophotography camera choices are driven by their choice of subject and their imaging set-up with particular emphasis to the "Nyquist Sampling" of their telescope/camera combination. Nyquist was responsible for the early work describing digitising of analogue signals in relation to sound, and these theories tell us that a Sine wave must be sampled at twice its frequency. When adapted for light this means that to get a perfectly round star the light must fall on enough pixels. Too few, and the star may appear distorted.

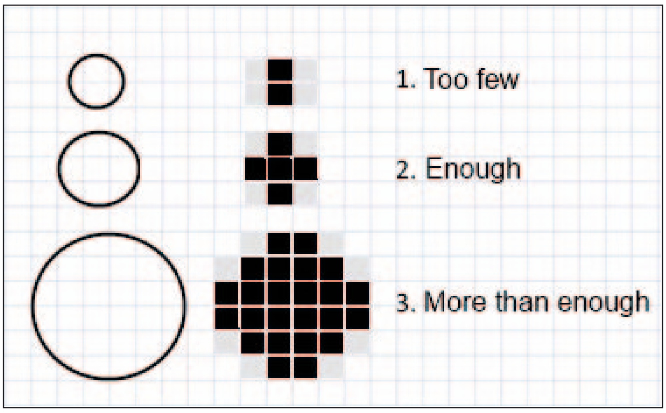


Figure 1. Effects of Sampling

The sampling for a star according to the theory suggests that the star size needs to be about 3.3 pixels, and is illustrated as the second example in figure 1.

Rob Kantelberg at http://www.astro-imaging.com/Tutorial/MatchingCCD.html suggests using this simple formula to determine star size:

Star size = (seeing x focal length) / 206.3

This formula takes into account atmospheric effects that play an important role as one of the most dominant forces in (ruining) imaging and allows us to work backwards with the data we know to work out the optimal focal length. Using:

Star Size x 206.3 / seeing = focal length

The optimum resolution of a ½ inch chip is 8.6μm x 3.3 = 28μm x 206.3 / 3 (moderate seeing) and is therefore in the region of 1925mm. This is something like an 8" SCT at its native focal length of f10.

Theory into practice

The above theory is for astrophotographers looking for perfect images; they can spread those photons across many pixels and compensate by taking a longer exposure to collect enough photons on each pixel to register a meaningful signal.

As a recorder of occultations, the converse is true. By concentrating the photons on as few pixels as possible, the aesthetic image of the star is degraded, but the signal that those photons leave is maximised in the shortest possible time.

It is proposed that optimum sampling for a faint star for occultation observing is not 3.3 pixels, but 1 pixel, and that for the commonly used ½ inch CCD this equates to 8.6 μ x 1= star size = 8.6 μm and an optimum resolution in moderate seeing as: 8.6 * 206.3 / 3 = 591mm fl, something like a small refractor.

Using this highly under sampled image does not come without issues. Images of brighter stars can saturate easily, and if the telescope is not steady, the moving image can appear blocky. Dense star fields can be a challenge when measuring the occultation where adjacent stars try to 'steal' the attention of the measurement aperture in Limovie or Tangra. Sub frame (field) measurement needs to be approached with caution as it is possible for a star to be recorded on one video field but not the other. This could make the timing of the event erroneous by the length of that field. This issue is easily checked by a visual scan of the video.

Practical example

The author's fixed observatory is equipped with an f10 14" Meade SCT and Gstar-EX camera with a ½ inch CCD. Utilising the Hyperstar system (http://starizona.com/acb/hyperstar/whatis.aspx) which allows it to operate at f2, or using a 0.5x focal reducer, this gives achievable focal lengths of this telescope of 3556mm (native), 1778mm (Focal reducer) and 710mm (Hyperstar) which conveniently gives us three frames of Nyquist reference; oversampled, optimally sampled and under sampled accordingly.

The Jewel Box cluster in Crux was chosen as an appropriate subject; a rich field open cluster with varying magnitudes. Camera settings were maintained identically throughout the duration of the experiment and images were taken with no integration. At each of three focal ratios, the data was analysed with Tangra which in figures 2, 3 and 4 is shown on the right, and compared to a theoretical distribution of pixels estimated by the author to assist in visualising how those photons are handled by the receiving CCD chip.

Oversampled

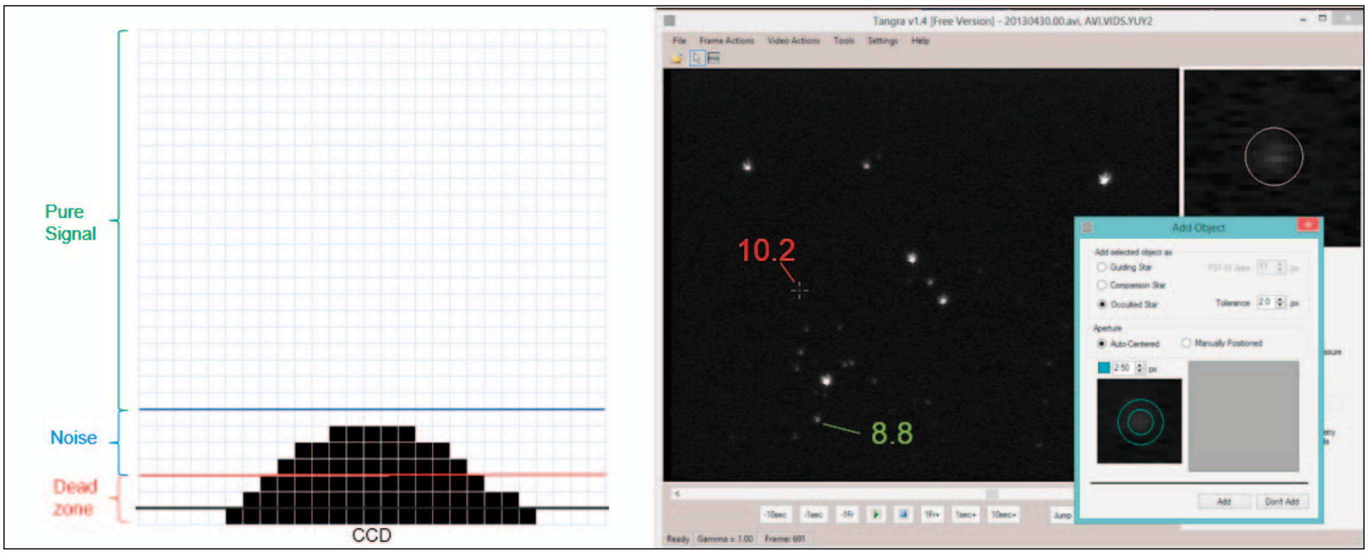


Figure 2. Oversampled Data

We can see that in theory, the photons are spread widely across the CCD. Many photons are lost as a product of the QE of the chip and the remainder are affected by the noise of the camera. Stars as low as Mag 10.2 can be seen but are very much buried in the noise. Brighter 9th magnitude stars can be measured reliably.

Optimally sampled

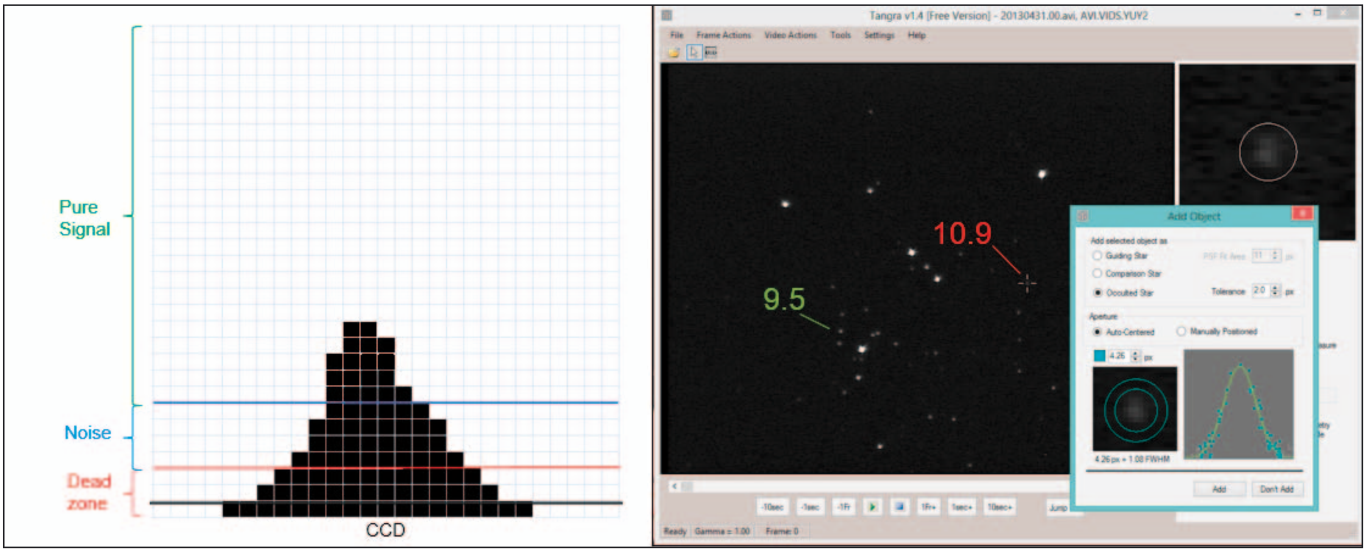


Figure 3. Optimally Sampled Data

Photons are now arranged with a 'text book' pattern. Star images are sharp and round and whilst some are lost to dark current and others are influenced by noise, a good many photons produce a strong clear signal.

11th magnitude stars are visible and very clear measurements can be made in the 9.5 to 10th magnitude range.

Undersampled

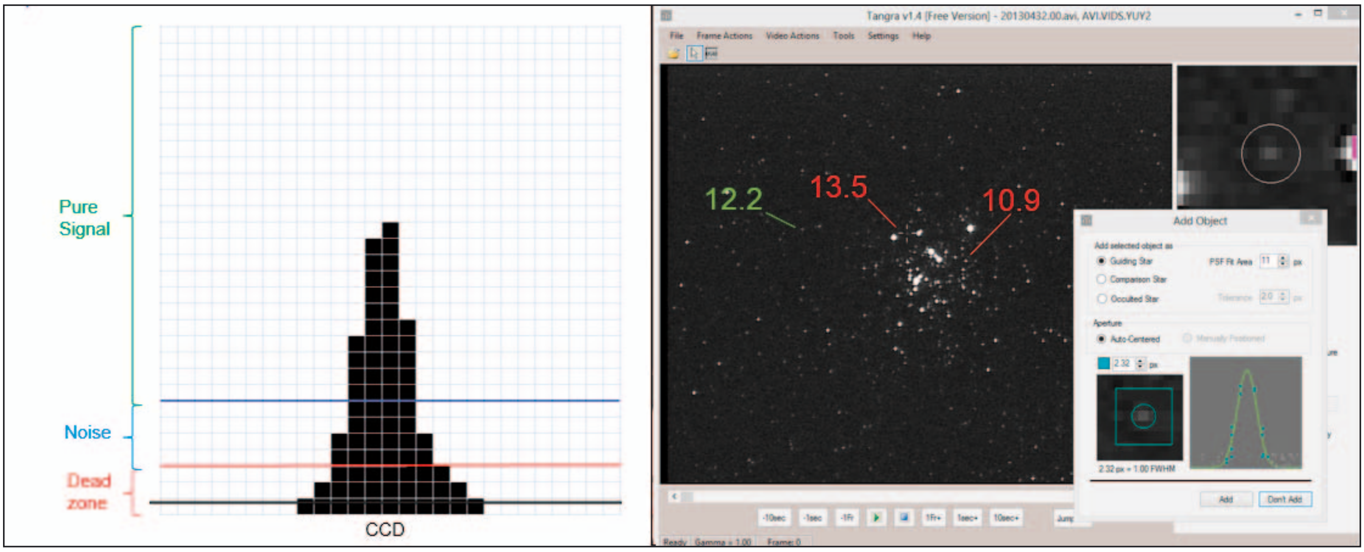


Figure 4. Undersampled Data

With photons striking the minimum number of pixels possible, hardly any are lost to QE issues or obscured by noise. Most become pure measureable signal. The star image is blocky and aesthetically far from ideal.

The image shows a significant increase in the depth of view with 13.5 magnitude stars visible and strong readings within the 12th magnitude range.

Conclusion

Sampling with a star size equating to 1 pixel in moderate seeing allows the occultation observer to capture very faint events with minimal or no camera integration. The beneficial effects of undersampling increase dramatically as the sampling rate reduces to 1, which in the author's case was an increase of over three magnitudes of star captured by video compared to the native focal length of the telescope.

Care must be taken to avoid over exposure though, and defocussing may assist in that. Where bright subjects need to be captured, longer focal lengths (larger star sizes) should be used.

For common chip sizes, the recommended focal lengths are:

1/4 Inch:	250-300 mm
1/3 inch:	300-450 mm
1/2 inch:	600-800 mm

Online resources:

http://www.astro-imaging.com/Tutorial/MatchingCCD.html

http://www.stanmooreastro.com/pixel_size.htm

http://starizona.com/acb/ccd/advtheorynyq.aspx

http://coursewiki.astro.cornell.edu/Astro4410/EstimatingPhotons

Project PHEMU: MUTUAL PHENOMENA OF THE SATELLITES OF JUPITER

These data are published by: IMCCE – Institut de Mecanique Celeste et de Calcul des Ephemerides

Mutual events of the satellites for Central Germany

Date	begin: h m s	end: h m s	Type	Dur(m)	Impact	m	Δm	limb(„)	dist(„)	h	Sun
2014 10 6	23 24 13	0 39 26	3E4	75.2	0.066	5.0	0.353	99.10	32.36	4	40
2014 10 15	7 5 32	7 8 54	4O3	3.4	0.943	4.9	0.012	134.29		55	12
2014 10 15	13 21 60	13 26 29	4O2	4.5	0.787	5.4	0.120	91.12		10	23
2014 10 16	6 16 57	6 20 5	4O1	3.1	0.827	5.2	0.081	-5.31		53	4
2014 10 21	2 1 30	2 3 45	2O3	2.3	0.968	4.8	0.003	129.33		24	-35
2014 10 24	5 9 2	5 12 6	2O4	3.1	0.875	5.3	0.016	37.40		50	-8
2014 10 24	8 24 58	8 30 40	1O4	5.7	0.044	5.2	0.249	13.48		48	19
2014 10 28	5 31 44	5 39 43	2O3	8.0	0.559	4.8	0.147	136.20		53	-5
2014 10 29	7 22 30	7 26 11	1O3	3.7	0.863	4.7	0.027	69.29		52	10
2014 10 31	2 33 13	4 48 27	4E3	135.2	0.041	4.9	1.393	231.06	48.02	50	-13
2014 11 1	8 11 47	8 15 10	3O1	3.4	0.794	4.6	0.073	24.35		46	15
2014 11 1	11 49 30	11 54 56	4O1	5.4	0.710	5.1	0.181	69.13		14	23
2014 11 1	22 38 11	22 42 46	4O2	4.6	0.649	5.3	0.262	-11.81		-1	-53
2014 11 2	5 52 41	6 11 29	4O1	18.8	0.268	5.1	0.867	33.71		54	-1

For more data and details have a look at the internet!

Journal for
Occultation Astronomy

Eclipses from 2015-2017

Hans-Joachim Bode · IOTA/ES

As you may remember at ESOP 2012 (Pescara, Italy) it has been decided to finish the "Variations of the Sun's Diameter" project with the solar eclipse of 2017 (USA).

The "simple" reason for this decision has been that the accuracy of our recording method does not match the quality of the Sun-recording satellite data.

The last chance to make careful measurements that could be used to determine the Sun's diameter using our eclipse method, which might yield results comparable to the satellite data, are the eclipses from 2015-2017.

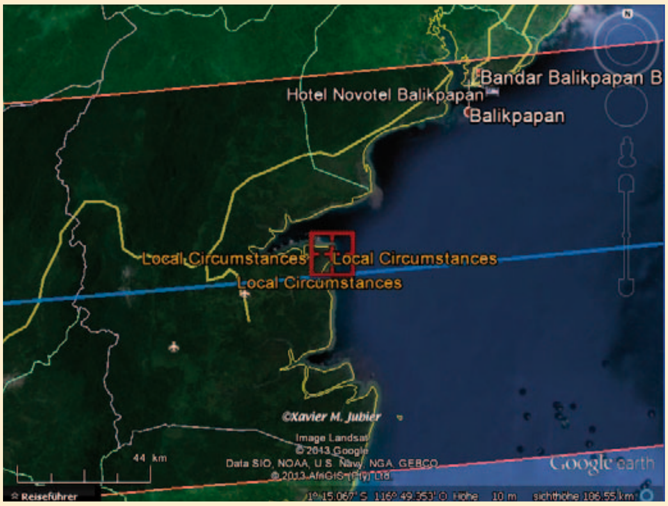
Members of the American IOTA have already had discussions and first preparations concerning their "2017-eclipse".

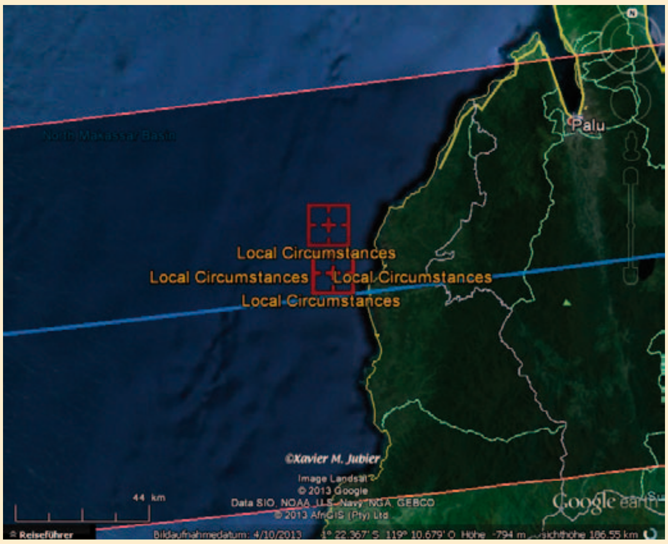
That is why it should also be very useful to start making plans for the next usable (regarding weather statistics) solar eclipse.

DATE	TYPE	AREA
2015-03-20	total	Faroe Islands
2016-03-09	total	Indonesia
2016-09-01	annular	Central Africa, Madagascar
2017-02-26	annular	Angola
2017-08-17	total	U.S.A.

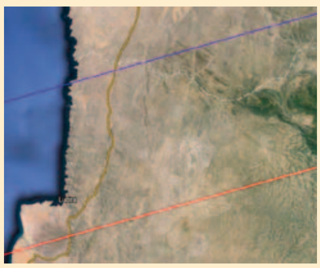
Total Solar Eclipse of 2015 Mar 20: No possibility to observe at both edges of the eclipse-path!

Indonesia 2016





Angola 2017



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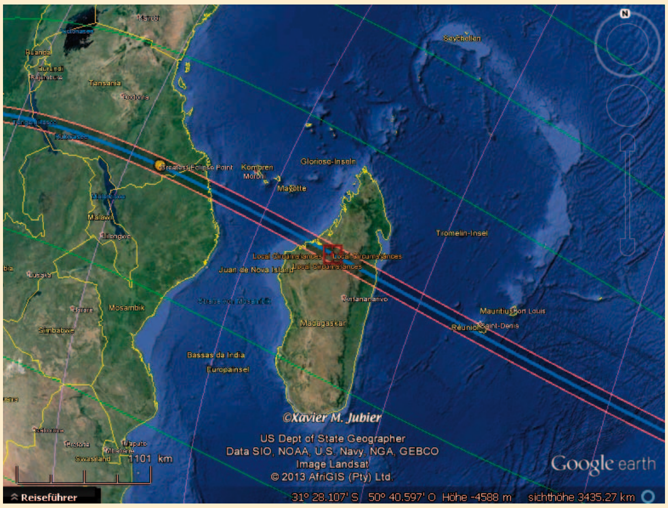
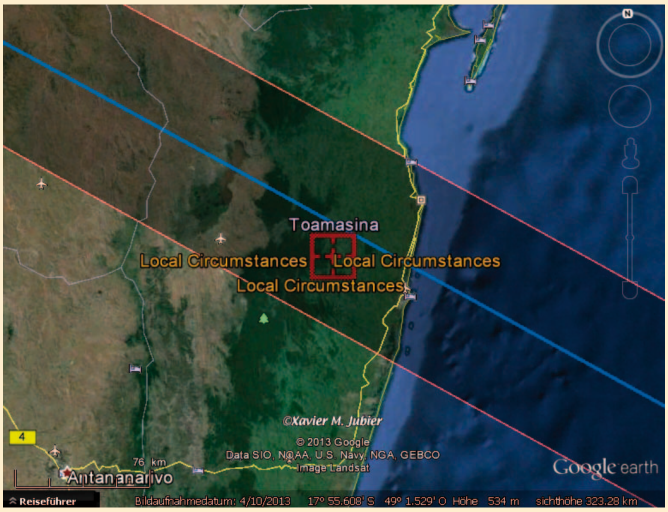
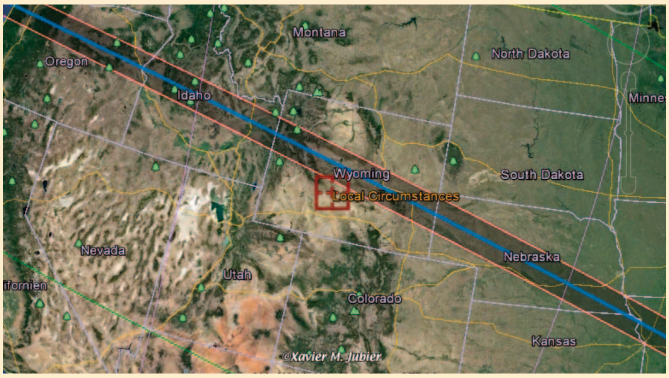
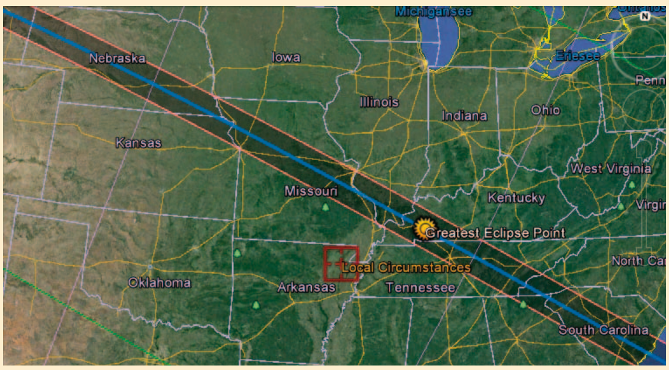




Central Africa, Madagascar 2016

USA 2017





Journal for
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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 Offices and Officers of IOTA

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