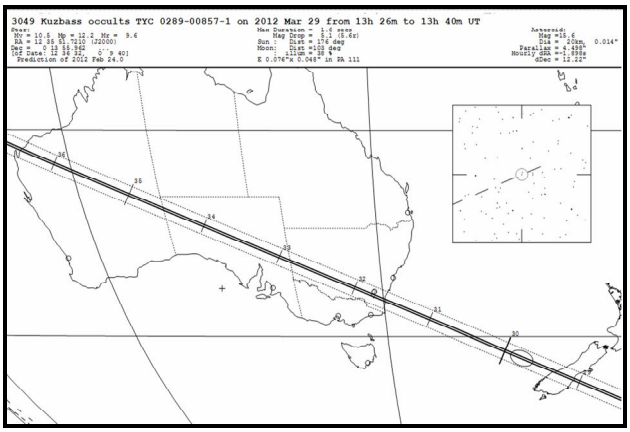
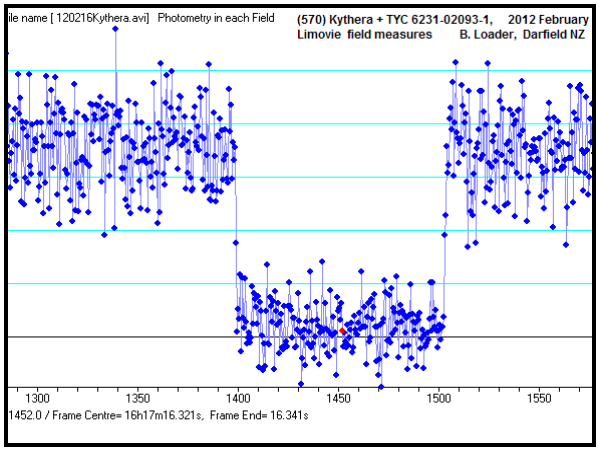
Royal Astronomical Society of New Zealand Occultation Section

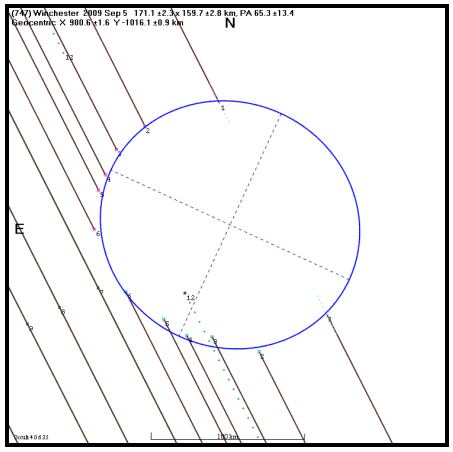
Observing Occultations Using Video:

A Beginner's Guide

For the Australia/New Zealand Region







VERSION 1.1

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ROYAL ASTRONOMICAL SOCIETY OF NEW ZEALAND

OCCULTATION SECTION

The Occultation Section of the Royal Astronomical Society of New Zealand was formed in 1977. Its role is to co-ordinate the observation of total lunar, grazing and planetary occultations throughout Australia, New Zealand and the South Pacific. In addition the RASNZ Occultation Section represents the interests of the International Occultation Timing Association (IOTA) in the Australasian region. We communicate with our members and others interested in occultations by three principal means:

- **Our website – *http://www.occultations.org.nz/***
  Our website provides easily understood information about occultations and observing techniques. You'll find the information there will be of benefit whether you are a novice or an experienced observer. The website also provides information about forthcoming events, and summarises results from previously observed events.

- **The RASNZOccultations Yahoo Group**
  To join this group go to: **http://groups.yahoo.com/group/RASNZoccultations/**
  The RASNZOccultations group (administered by Dave Gault) is a forum where any member can post any question or request for information regarding any form of occultation observing. It is used extensively by observers to discuss plans for upcoming events and to report observing successes. The group is also used for general announcements regarding occultations, including the availability of occultation software upgrades.

- **Occultation Section Circulars/Journal for Occultation Astronomy**
  The Occultation Section publishes regular Circulars which list observations made, provide analysis and feedback on events observed, give advance warning of upcoming lunar and planetary occultations, as well as containing news of occultation results from elsewhere around the world and background articles of general interest to all observers.

  In addition the Section provides its members with the Journal for Occultation Astronomy (JOA) published by IOTA. Both the Circulars and the JOA are only available to financial members of the Section.

You can support the work of the Occultation Section by subscribing to our publications. Membership information is available on our website http://www.occultations.org.nz/ We also strongly recommend that you join the RASNZOccultations Yahoo group. There is no charge for this and anyone can subscribe, whether they belong to RASNZ Occultation Section or not.

Graham Blow
Director

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INTRODUCTION

The universe is a dynamic place, often moving at incredible speeds. At a casual glance, though, nothing seems to be happening, or if change does happen it seems to be at a glacial pace when compared to our relatively short lives.

Occultations are a chance to observe the universe in action, and at the same time provide information about those distant bodies.

From refining the orbit of the Moon, discovering double stars and determining the shape of asteroids, to determining the angular diameter of stars, and studying the atmospheres of the planets and the orbits of their moons, occultations are a multi-faceted means of gathering information about the universe which surrounds us.

Occultations are also events that benefit greatly from the contribution of the amateur astronomer. Whether as an individual, or part of a team, an amateur has the flexibility and mobility that a professional astronomer often does not.

As we move into the 21st century the technology used in capturing these events continues to change. From using simple timing methods such as a radio and tape recorder, observers can now choose to use advanced recording methods such as ultra-sensitive video cameras with time insertion devices.

In the quest for higher accuracy the pace of change in equipment and techniques has left some people hesitant about how to get involved. This manual aims to address this and provide some guidance on what is involved in getting started with recording and reporting occultation events.

Section I

Before You Observe

Chapter 1: TYPES OF OCCULTATIONS

Occultations occur when one celestial body passes in front of another celestial body. For example, the Moon or a planet passes in front of (or 'occults') a distant star. In such cases the distant object casts a shadow of the occulting object, which sweeps across the Earth.

A solar eclipse is a special case of occultation where the two bodies, the Sun and the Moon, appear approximately the same size in our skies.

A transit occurs when the occulting body is very much smaller than the body it is occulting. (eg a transit of Venus across the face of the Sun).

The different types of occultations and their scientific value are described below.

1.1. Total Lunar Occultations

These occur when the moon moves in front of a star or a planet. Lunar occultations of stars occur almost every night and are relatively easy to observe.

Accurately timed lunar occultations, especially those where a double or multiple star is involved, are an especially valuable contribution to serious astronomy. These events help to determine the position of the lunar limb to high accuracy and can also aid in the discovery of binary star systems.

Occultations of known double stars are useful in determining the separation and position angle of the components. They can also be used to confirm the status of suspected double stars that are difficult to separate visually or are beyond the Dawes Limit of your telescope.



Figure 1.1: A typical situation for a lunar occultation while the moon is waxing. The leading limb of the Moon is dark and will move eastwards across the star field to occult the star.

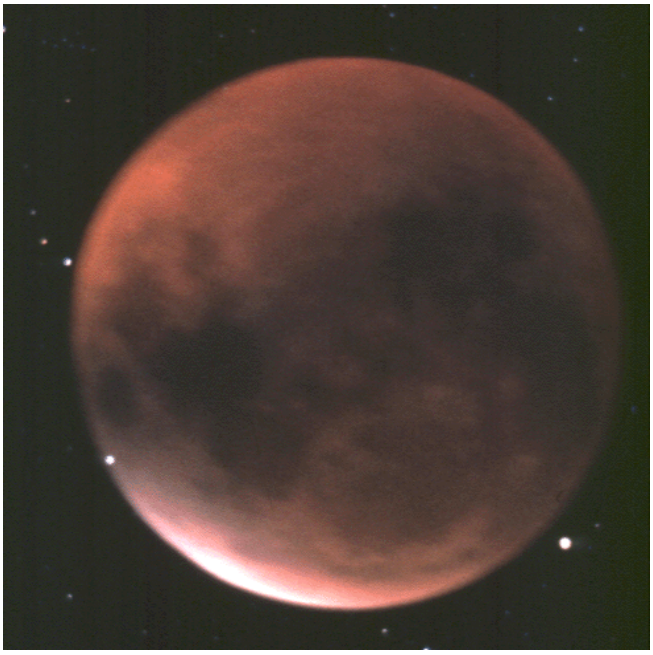


Figure 1.2: This image of the eclipsed moon was taken by Mr Harry Williams of Auckland, New Zealand, at the Lunar Eclipse of 30 December, 1982. Note the star on the left limb which appears to be *inside* the edge of the Moon, and that the Moon's edge does not seem sharp. A long exposure was required for this photo, and while the shutter was open the camera tracked the background stars. Because the Moon moves at a different rate from the stars, during the exposure the Moon moved far enough for the star to reappear from behind its limb.

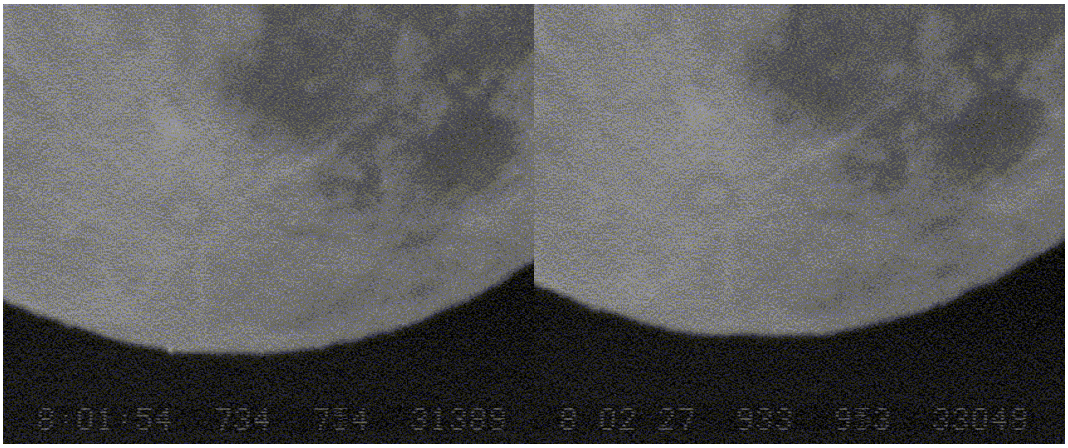


Figure 1.3: Two frames from a video of a lunar occultation. The star is visible in the first frame, but less than a second later it has been occulted. Source: John Talbot

1.2 Grazing Lunar Occultations

A grazing occultation (sometimes just referred to as a graze) occurs when a star is just occulted by the mountains in the polar regions of the moon. In a grazing occultation the star casts a shadow of the Moon's mountains onto the Earth, so that for observers situated across a band a few kilometres wide the star may be seen to blink off as it is occulted by lunar mountains, and to blink on again as it is uncovered in lunar valleys. Timing these events helps to refine the profile

of the moon, which is still poorly known, even after the Japanese Kaguya and NASA Lunar Reconnaissance Missions.

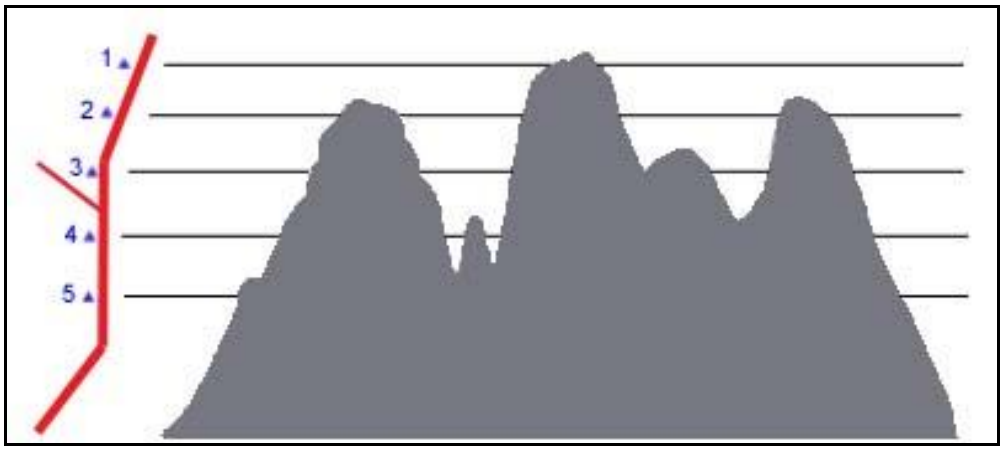


Figure 1.4: Grazing occultations can be a group activity, with several observers (represented by numbered triangles) placed at set distances, often along a roadside. Their combined observations help to build a picture of the profile of the lunar limb.

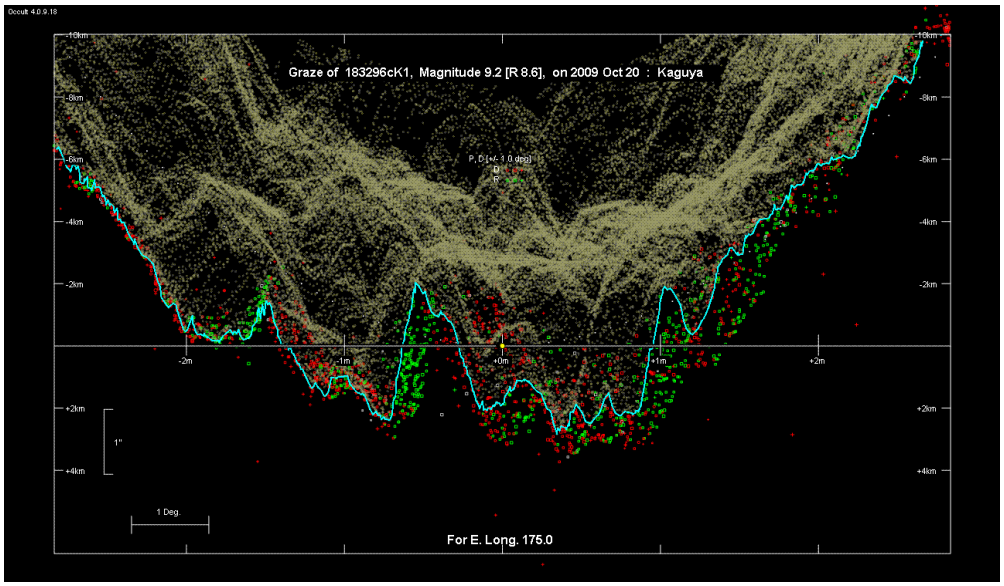


Fig 1.5: This *OCCULT* profile prediction used the Kaguya data to estimate the lunar profile at the time of the graze. Coloured dots represent previous observations of the same zone. Note the deepest gorge is more than 4 km below the highest peaks. Source: John Talbot, *OCCULT*

1.3 Planetary Occultations

These occur when a planet passes in front of a star. In most cases planetary occultations involve minor planets (asteroids), as there are many more of these than major planets. Occultations of stars by major planets have led to some spectacular discoveries, including the rings of Uranus in 1977 and the atmosphere of Pluto in 1986.

Occultations by minor planets can potentially yield information such as:

- The cross-sectional size and shape of the asteroid (where an event is observed from multiple sites). This information, when combined with ongoing photometry, can yield the three-dimensional shape of the asteroid (Figures 1.6, 1.7).
- The discovery of asteroidal moons, rings or double asteroids (Figure 1.8).
- Single occultation observations can also yield highly accurate astrometry of the asteroid which helps to refine its orbit.
-

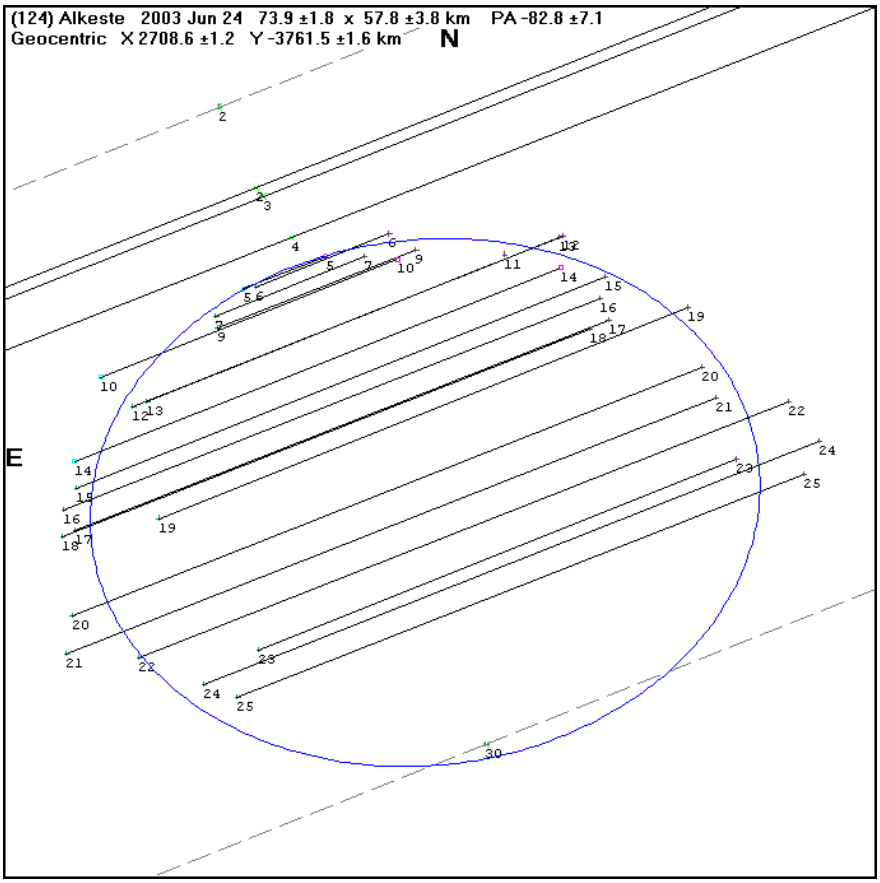


Figure 1.6: The result of multiple observations for (124) Alkeste on 24th June 2003. Each short line, or chord, represents the length of time the star was occulted for an observer. Note that the difference in some adjacent chord lengths results from some observers recording precise data by video, whereas the timings by visual observers are subject to each observer's individual reaction times.

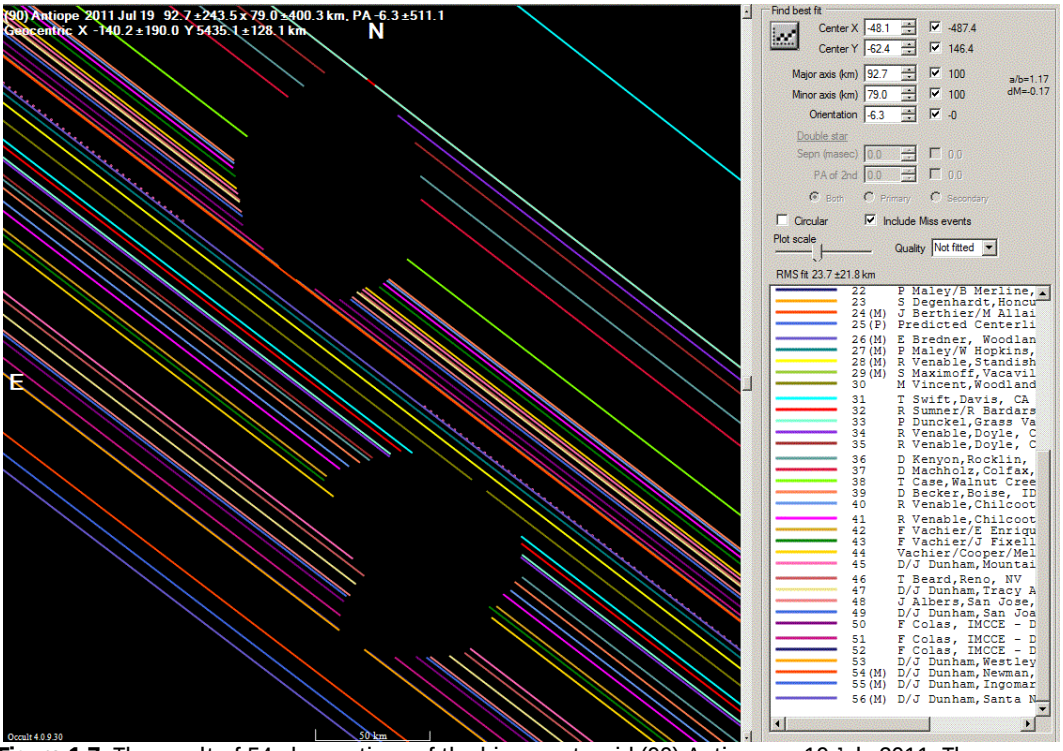


Figure 1.7: The result of 54 observations of the binary asteroid (90) Antiope on 19 July 2011. The resolution of the shapes of the two components is far more detailed that can be gained by imaging the asteroid directly by large telescope. Credit: IOTA, David Dunham

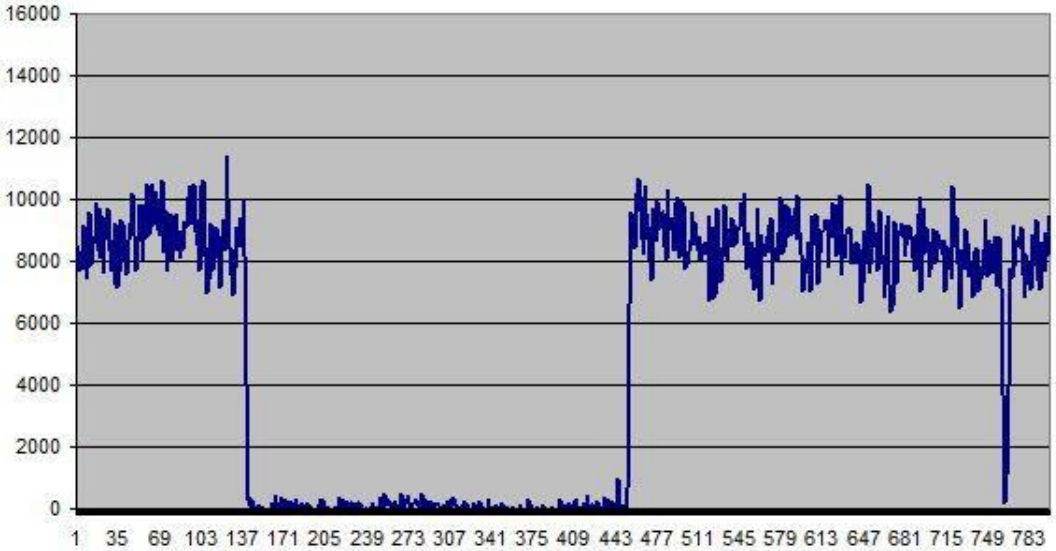


Figure 1.8: A light curve from an observation of occultation by (911) Agamemnon on 19 January 2012. The short secondary dip on the right of the curve indicates that there may be a satellite associated with this asteroid. Credit: IOTA

1.4 Further Reading and Information Sources

The following are good sources of information about occultations in general:

- RASNZ Occultation Section website: http://www.occultations.org.nz/
- IOTA website: http://www.lunar-occultations.com/iota/iotandx.htm
- IOTA-ES website: http://www.euraster.net/

A sample of videos showing what happens during an occultation include:

A collection of asteroidal occultations videos posted by Jonathon Bradshaw (Astrojunk);
http://tinyurl.com/bt6f5wy

An occultation by Pluto captured by Dave Gault on June 22nd 2008;
http://www.youtube.com/watch?v=WruS6own5qc

An example of a grazing lunar occultation that lead to the discovery of a double star.
http://www.youtube.com/watch?v=_S83iUfkC3Y&feature=related

Chapter 2: PREDICTIONS: OBTAINING, UNDERSTANDING AND PLANNING

Predicting both lunar and planetary occultation events has come a long way since the mid-20th century when, because of the complexity in predicting occultations, only a few might be predicted for any one location in a year. Today dozens of opportunities are available to observers each month, and there are several ways in which you can obtain predictions - both online and offline.

2.1 Obtaining or Generating Predictions

Predicting the time of an occultation is dependent on your latitude and longitude. Online total and grazing occultation predictions are available for standard locations (for example, some major cities) but for accurate predictions specifically for your own observing site it is recommended that you generate your own. Predictions for planetary occultations are somewhat less location dependent.

2.1.1 Online Predictions

2.1.1.1 Total Lunar and Grazing Occultations

The RASNZ Occultation Section website (http://www.occultations.org.nz) provides predictions of bright stars and known double stars for the major cities of Australasia.

Worldwide predictions of occultations of bright stars are available on the IOTA website at: http://www.lunar-occultations.com/iota/bstar/bstar.htm

2.1.1.2 Planetary occultations

Occultations visible from Australia and New Zealand are available on the RASNZ Occultation Section website. Two types of predictions are available:

1. Predictions by Edwin Goffin. These are usually prepared over a year in advance and provide an overview of what events may be seen from a particular region.

2. Updated predictions sourced from Steve Preston. These updates are usually available about a month before each event, and are based on the latest astrometry of the asteroid.

For a list of global occultations see Steve Preston's Asteroid Occultations website at http://www.asteroidoccultation.com/

For events specific to Pluto, its moons, other major planets and Trans-Neptunian Objects (TNOs) Bruno Sicardy at the Paris Observatory maintains a list of predictions at http://www.lesia.obspm.fr/perso/bruno-sicardy/

2.1.2 Generating your own Predictions

2.1.2.1 OCCULT

OCCULT is a free program dedicated to the prediction and analysis of occultations of astronomical objects, including lunar occultations, occultations by asteroids and planets, eclipses of the Sun and Moon, and mutual eclipses and occultations of satellites of the planets. It is written and maintained by David Herald. *OCCULT* can be downloaded from: http://www.lunar-occultations.com/iota/occult4.htm

The program has eight principal components, accessed from the opening screen:

- **Asteroid predictions** Access the routines for generating occultation elements, and then generate predictions of occultations using a wide range of selection criteria, and a wide range of output options.
- **Asteroid observations** Record observations of occultations by asteroids, analyse observations to derive the size and shape of asteroids, and access the file of all historical observations. This section also includes options to display summary results, and administrator functions for reporting and archiving results.
- **Eclipses and transits** Predict solar and lunar eclipses, and transits of Mercury and Venus. Predictions may be generated from the year -9999 to several millennia in the future. Analyse observations of Baily's Beads, and generate animations of an eclipse and the Baily's Bead phenomena.
- **Ephemerides** Generate general ephemerides of solar system objects, including all planets and their satellites. *OCCULT* can also generate star charts.
- **Lunar predictions** Generate total and grazing lunar occultation predictions. Predictions can be generated for selected sites, for selected objects, or for multiple sites and objects.
- **Lunar observations** Record and analyse lunar occultation observations, including grazing occultations. Optional data files allow for the investigation of the historical file of occultation observations going back to 1623.
- **Satellite phenomena** Generate predictions of eclipses/occultations/transits of the main satellites of Jupiter, Saturn, Uranus and Neptune with their planet. Generate predictions of mutual eclipses and occultations of the main satellites of Jupiter, Saturn and Uranus.
- **Maintenance** Area for maintaining various files and user settings.

To generate your own predictions, open *OCCULT* and choose "Asteroid predictions" at the top of the left hand side, then choose "Search for occultations."

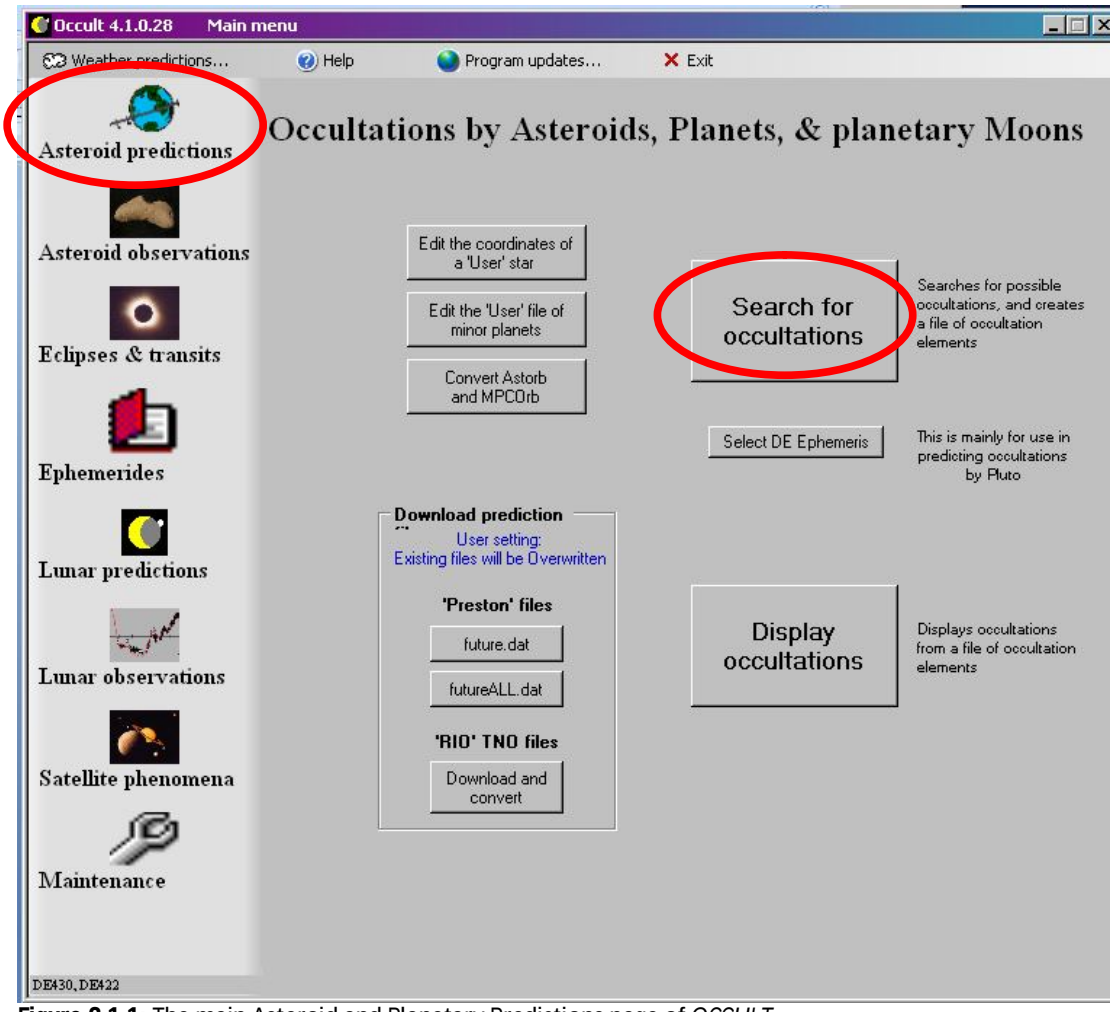


Figure 2.1.1: The main Asteroid and Planetary Predictions page of *OCCULT*.

A new box should open with a range of parameters for you set before a seach is made:

- Set the range of time you wish to search in months
- Whether it is minor or major planets
- If you have a small telescope you can set a limiting magnitude
- You could just choose a range of minor planets, but if no choice is made all will be searched for
- Make a note of the where the output file is going to be saved and what it will be called. Occult automatically appends it with the day's date.
- Press search – depending on your choices such as length of time, catalogue chosen or number of minor planets, the search may take several hours.

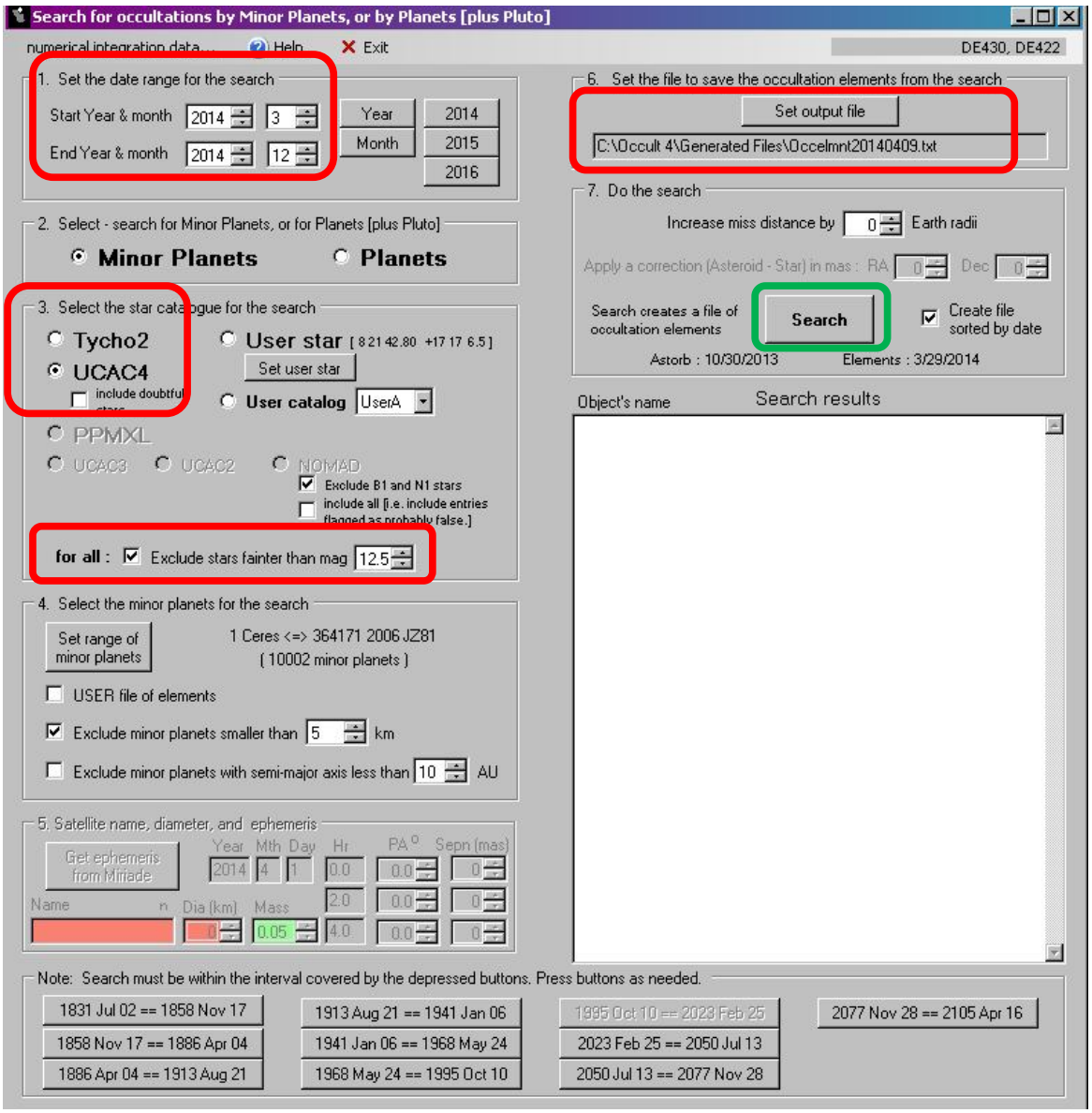


Figure 2.1.2: Search for occultations box

Once the search has completed you can go to the “Display Occultations” page.
Once again you can refine your output by choosing certain parameters, such as distance away from your location, the range of time, or the size of the asteroid. Once these have been chosen press the “Local events: Summary” button and chose the Occelmnt file that you last generated.

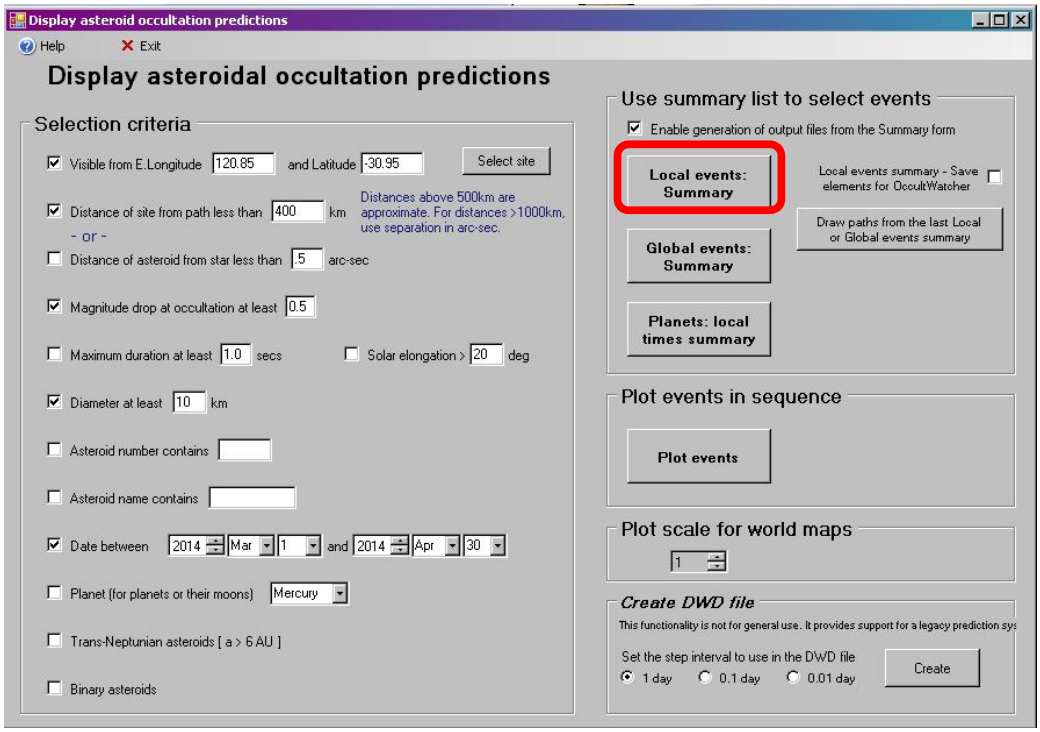


Figure 2.1.3: The display asteroidal predictions box.

A new box will open to display the predictions.
Double click on a line to bring up the world map for that event.

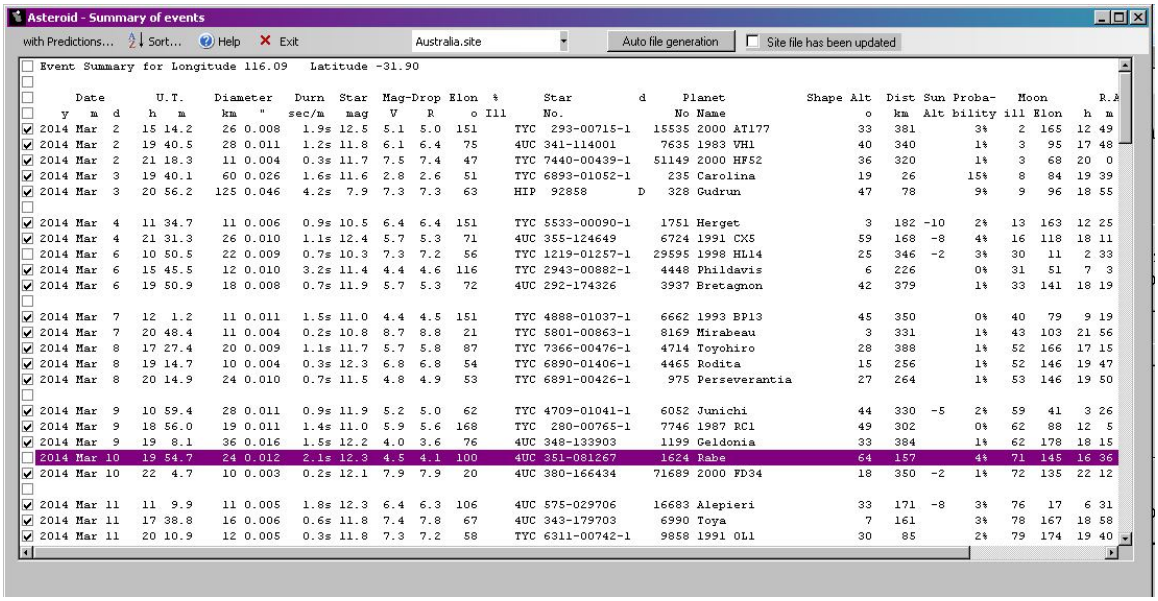


Figure 2.1.4: Summary of predicted events

2.1.2.2 Lunar Occultation Workbench (LOW)

The Lunar Occultation Workbench (LOW) is a program for lunar occultation events only. It is written and maintained by Eric Limburg and is in common use in Europe and other parts of the world. Once your location and telescope details are entered it will give you predictions for your location for the next 24 hours (and further into the future if required). It presents the prediction data in a more visual way than *OCCULT*, with a visual representation of the event shown, and time and star information tabled on the side of the window. It also aids in the coordination of grazing occultation events for groups. Once the occultation is observed it can generate a report in the IOTA2008 format for exporting.

LOW can be downloaded from http://www.doa-site.nl/

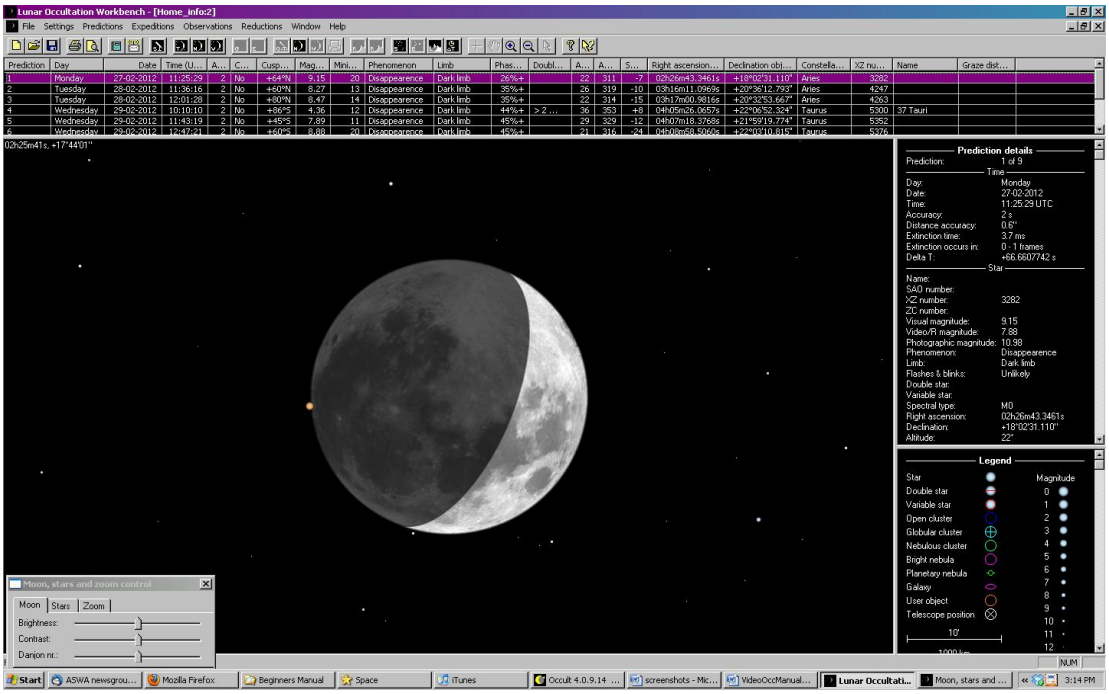


Figure 2.2: The main page of LOW, showing a predicted lunar occultation.

2.2 Reading and Understanding Predictions

A lot of information is given in shorthand with each prediction. Below are some sample predictions for both lunar and asteroidal occultations together with information on how to read them.

2.2.1 Lunar Occultations Generated by *OCCULT*

Below is an example of the output generated by a query for lunar occultations from *OCCULT*. It includes additional information for known and suspected multiple star systems, variable stars and nearby grazing occultations.

Right-clicking on a line will bring up a moon map with the location of the star on the limb and more information directly relevant to the event.

```
Occultation prediction for Melbourne
E. Longitude  144 58  0.0,  Latitude -37 49  0.0,  Alt.   20m;  Telescope dia 15cm;  dMag 0.0

       day  Time   P   Star  Sp  Mag  Mag    % Elon Sun  Moon   CA   PA  VA  AA
 y   m  d  h  m  s      No  D     v    r V  ill     Alt Alt Az   o    o   o   o
13 May 19 11 11 40 d  118536 K2  7.7  7.1   62+ 104     42 322  83N 104 314  81
13 May 20  9 13  3 d  138313wF9  7.6  7.3   72+ 116     52  22  61S 140 303 116
    138313 is double: AB 7.6 16.6 43" 321.0
13 May 21  9 14 26 d    1792SF2  7.4  7.1S  81+ 129     51  42  75N  96 244  72
      1792 is triple: AB 7.1 13.0 3.2" 277.2 : AC 7.1 13.0 16.1" 292.0
      1792 = NSV 19406, 7.36, , Type VAR:
13 May 27 15  1 25 r  161801 A*  7.4  7.4v  91- 145     60  57  75N 274  49 278
    161801 = V4404 Sgr, 7.43 to 7.48, Hp, Type ACV
13 May 27 15 59 12 R    2731cA1  6.6        91- 144     68  33  14S 182 335 186
      2731 is double: AB 6.87 8.14 0.41" 150.2
      2731 is a close double. Observations are highly desired
   Distance of 2731 to Terminator = 12.7"; to 3km sunlit peak = 2.6"
13 May 27 16  9 52 r  161834cB2  7.5        91- 144     69  26  62N 286  85 290
    161834 is double: AB 7.75 9.00 0.40" 153.5
    161834 is a close double. Observations are highly desired
13 May 27 18 46 17 r  161929 K4  7.6  6.7   90- 143     58 300  53S 221  87 226
13 May 28 11 15  7 Gr   2876SK1  5.3  4.7s  84- 133      6
       ** GRAZE: CA  8.4S; Dist.205km in az. 200deg. [Lat =-39.78-0.28(E.Long-144.97)]
13 May 28 11 24 55 r    2876SK1  5.3  4.7s  84- 133      8 105  34S 200 327 209
   R2876 = 54 Sagittarii
      2876 is triple: AC 5.4 7.7 45"  42.0 : AB 5.4 12.6 71" 273.0
      2876 = NSV 12275, 5.28 to 5.36, V
13 May 28 12 22 46 R    2880 F3  5.1  4.9   83- 132     18  96  70S 235   0 245
   R2880 = 55 Sagittarii
```

2.2.2. Header information for Lunar Occultations generated by *OCCULT*

Item	Meaning
Day	The day of the event.
Time	The predicted UTC, in hours, minutes and seconds.
P	The Phase of the event. Values are: • D - disappearance • d - disappearance, but star is less than 1 mag brighter than the predicted visibility limit. • R - reappearance • r - reappearance, but star is less than 1 mag brighter than the predicted visibility limit. • Gr - grazing occultation at site. At mid-occultation, or closest approach, the star is less than 4" from the limb of the moon (either above or below). • gr - grazing occultation at site, but star is less than 1 mag brighter than the predicted visibility limit. • M - miss. At closest approach, the star is more than 4" above the limb of the moon • m - miss, but star is less than 1 mag brighter than the predicted visibility limit.
Star No	• The star identifier. Three formats are used: • nnnn - A ZC star. When reporting occultations, the catalogue is identified with 'R' (for Robertson Zodiacal Catalogue.) • nnnnn, or nnnnnn - An SAO star. When reporting occultations the catalogue is identified with an "S." • X nnnnnn - an XZ star. When reporting occultations, the catalogue is identified with 'X'.
D	The double star code
Sp	Star's spectral type. Only basic spectral type information is provided
Mag v	The star's visual magnitude.
Mag r	The star's red magnitude. For observers using CCD video cameras, the red magnitude provides a better indication of visibility.
V	The variable star code.
% ill	The percent illumination of the moon. If followed by a +, values are for a waxing moon; - for a waning moon; and E for illumination during a lunar eclipse.
Elon	The elongation of the moon from the sun, in degrees. [Strictly, the quantity is calculated as the elongation of the star from the sun]
Sun Alt	The altitude of the sun. The field is blank if the sun is lower than -12 deg. (Nautical twilight)
Moon Alt	The altitude of the moon.
Moon Az	The azimuth of the moon.
CA	Cusp Angle – The angle of the event around the limb of the moon, measured from the nearest cusp. –'ve values indicate a bright limb event. The cusps are usually N (north) or S (south), but near full moon can be E (east) or W (west). If a lunar eclipse is in progress, CA gives the % distance from the centre of the umbra, and is followed by a 'U'. Values up to 103% are possible. Where an event occurs at more than 103% of the umbral radius, the usual Cusp Angle value is displayed

PA	Position Angle - the angle of the event around the limb of the moon, measured from true north
VA	Vertex Angle - the angle of the event around the limb of the moon measured anticlockwise from the vertex of the lunar limb - i.e. the point on the limb highest from the horizon
AA	Axis Angle - the angle of the event around the limb of the moon, measured eastward from the moon's north pole. Essential for a reappearance, as it locates the event with reference to lunar features. To use, mark the circumference of a map of the moon around at 10 deg intervals, starting at the north pole. Mare Crisium is at about 300 deg. [Note - the so-called Watts Angle differs from the Axis Angle by 0.21 deg. The term Watts Angle is limited to the context of accessing the Watts Charts. In all other situations, the term Axis Angle is preferred.]

Source: *OCCULT* Help files

Users of LOW will have a different and more simple set of headers, with their full titles available at the top (the column boundaries can be dragged to the right to expand the text), although there are some terms in common with *OCCULT*.

2.2.3 Goffin Predictions for Asteroid Occultations

Planetary occultation predictions prepared by Edwin Goffin are posted over a year in advance on the Occultation Section's website. See Figure 2.3 for an example of a planetary occultation prediction generated by Edwin Goffin. They consist of one page containing header information, a world map showing the predicted occultation path across the Earth, and two charts showing the occultation starfield.

The header information gives the (usually, minor) planet's number and name, and the name of the star to be occulted. The star's name is usually the catalogue name (e.g. PPM for the *Positions and Proper Motions Catalogue*) followed by its number within the catalogue. Immediately following the planet and star name is the date of the event (in Universal Time) together with the time of closest geocentric approach. (i.e. closest approach to the centre of the Earth). However, note that this time is NOT usually the time of occultation for your location - see 2.2.3.2 *Important Note about Given Times* below.

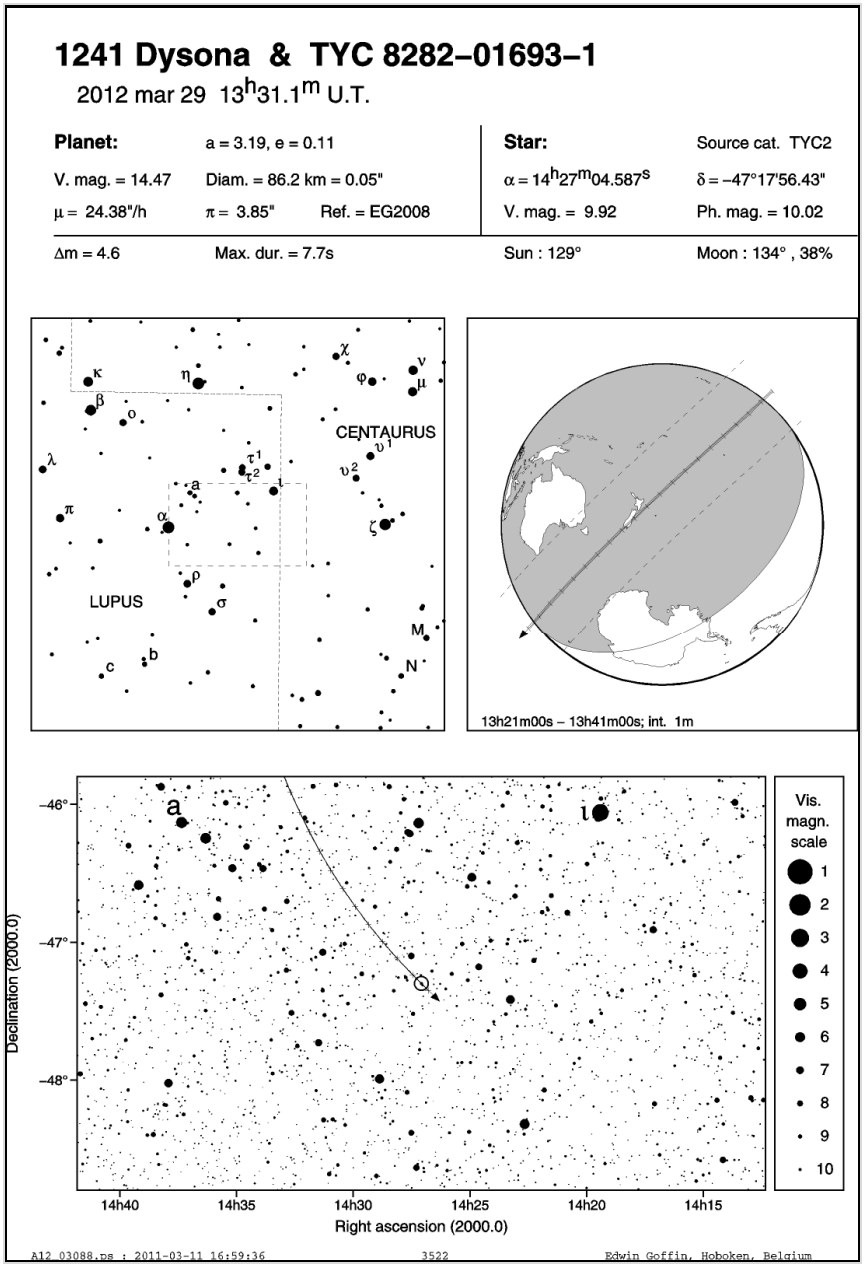


Figure 2.3: An example of a prediction by Edwin Goffin.

Under the heading "Planet" the following data are given:

- **V.mag** : Visual magnitude of the planet
- **Diam** : Estimated actual diameter of the planet in kilometres, and apparent diameter in seconds of arc
- **Greek Mu (μ)**: Motion at closest approach, in seconds of arc per hour
- **Greek Pi (π)**: Horizontal equatorial parallax in seconds of arc
- **Ref.** : Source for the orbital elements used. (e.g. MPC = Minor Planet Circular)

Under the heading "Star" are given:

- **Source cat** : Source catalogue used for the star position

- **Greek Alpha (α)** : Right Ascension (J2000.00) at the epoch of occultation
- **Greek Delta (Δ)**: Declination (J2000.00) at the epoch of occultation
- **V. mag** : Visual magnitude of the star
- **Ph. mag** : Photographic magnitude

The last line of the header contains information about the occultation:

- **(Greek Delta m) Δm** : Drop in magnitude if an occultation occurs
- **Max. Dur.** : Maximum expected duration for an observer on the central line (in seconds)
- **Sun** : Distance of the Sun (in degrees) from the star
- **Moon** : Distance of the Moon (in degrees) from the star, and illuminated fraction (in %) of the Moon

NOTE: For bright stars and faint minor planets the magnitude drop may be such that an observer with a small telescope will see the star disappear completely.

2.2.3.1 The World Map in the Goffin Predictions

The map in the centre-right of the prediction sheet shows the Earth as seen from the star, *i.e.* the centre of the disk is the point on the Earth's surface where the star is directly overhead. The night side is the part within the heavy lines and is shaded slightly.

The shadow of the minor planet as it sweeps across the Earth is indicated by the dark line across the globe. For large diameter minor planets (e.g. Pallas) you can sometimes see separate lines for the northern and southern edge of the track. The direction of motion is shown by an arrow on the end of the track. The dashed lines adjacent to the predicted track show the position of the central line of the occultation if there were to be a shift of one arcsecond perpendicular to the predicted shadow path. *i.e.* the dashed lines show what would be the path should there be a combined error of one arcsecond in the star's position and/or minor planet's ephemeris.

Tick marks appear at regular intervals along the track. The times written at the bottom of the chart give the first and last tick marks on the path, plus the interval between ticks.

2.2.3.2 Important Note About Given Times

The time given at the top of the prediction sheet is not usually the time at which you should expect the occultation to occur. This time is in fact the predicted time for a person in the centre of the Earth's hemisphere facing the star. If you are much distant from the centre of the disk, the predicted occultation time will also be different. Here's how to work out the time for your location:

- Note the text printed below the chart. It might say something like: "13h24m00s - 13h48m00s; int. 2m"
- In this, the first time (e.g. "13h24m00s") is the time of the start point of the track.
- The second time (e.g. "13h48m00s") is the time of the end point of the track.
- The third figure (e.g. "int. 2m") is the interval between tick marks along the track. This is usually in minutes, but can sometimes be 30 seconds.

- Now, note the direction in which the occultation shadow is travelling and count tick marks from the start of the track until you get to the part of the occultation band closest to your location. So now your predicted occultation time will be the (number of ticks) x (tick interval) + (start time).

For example, using the figures above, say you counted five tick intervals along until you came to the part of the track closest to your location. Your predicted time would then be (5) x (2 minutes) + 13h24m00s = 13h34m.

In terms of time, the predictions are now usually accurate to about +/- 0.3 minute so you should be most attentive during the predicted minute of the event for your location. However if intending to catch a potential satellite occultation you should start observing at least 10 times the predicted central duration before the predicted closest approach time for your location, and continue for a similar period afterwards.

2.2.3.3 The Star Charts in a Goffin Prediction

Edwin Goffin's predictions provide two star charts to help locate the target star; a wide view chart showing the region around the target star, which is in the centre of the chart; and a narrow view chart showing the target star circled. The path of the minor planet over several days prior to the event is shown, with tick marks indicating its location at 0 hrs UT on each day.

2.2.4 Steve Preston's Updates for Asteroid Occultations

Updated predictions by Steve Preston are generally posted on the Section's website a month or two before an event and are sourced from www.asteroidoccultation.com The data given in the header of the Preston predictions is similar to that given by Goffin and should be largely self-explanatory (See Figure 2.4 below). The path maps are generated by *OCCULT*.

For each prediction on the website, at the top of the page there is a link to a set of five finder charts of decreasing field of view (Wide field, 15 degree field, 5 degree field, 2 degree field and 30 second field), followed by a map of the predicted path and detailed information about the event.

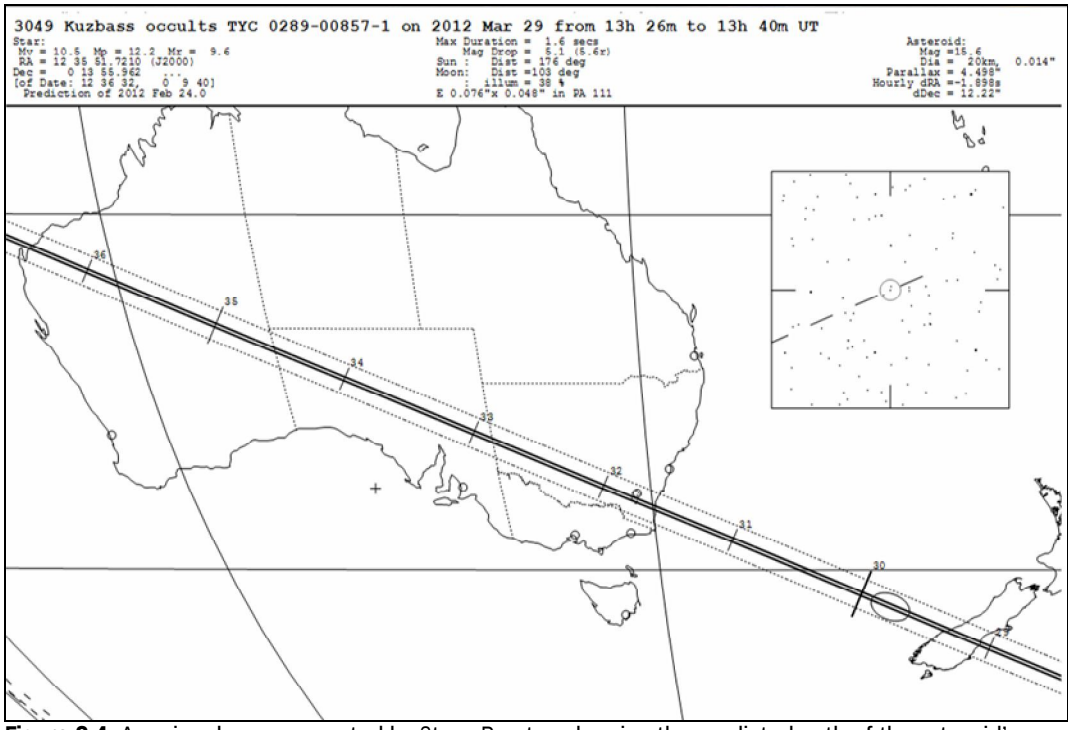


Figure 2.4: A regional map generated by Steve Preston showing the predicted path of the asteroid's shadow with ticks indicating where and when it is expected to cross the Earth. In this case observers in New Zealand would expect to see the occultation between 13h 29m and 13h 30m UT and observers in Canberra, Australia between 13h 31m and 13h 32m UT.

The data in the header to the map is as follows:

Under the heading "Star":

- **Mv:** Visual magnitude of the star (how it appears to the eye)
- **Mp:** Photographic magnitude of the star in blue light
- **Mr:** Photographic magnitude of the star in red light
- **RA:** Right Ascension of the star for epoch J2000
- **Dec:** Declination of the star for epoch J2000

Under the middle column:

- **Max Duration:** expected duration of the occultation if you are on the centreline of the track.
- **Mag Drop:** The expected drop in magnitude
- **Sun Dist:** Angular distance the star is away from the Sun at the time of the event.
- **Moon Dist:** Angular distance the star is away from the Moon at the time of the event. The percentage illumination of the Moon is also given.

Under the heading "Asteroid":

- **Mag:** Magnitude of the asteroid
- **Dia:** Expected diameter of the asteroid and the seconds of arc it subtends.
- **Parallax:** Parallax of the asteroid expressed in seconds of arc.
- **dRA:** Hourly motion of the asteroid in RA in seconds of arc
- **dDec:** Hourly motion of the asteroid in Dec.

2.3 OccultWatcher - A Program for co-ordinating observations of Planetary Occultations

OccultWatcher (OW) is written and maintained by Hristo Pavlov. It is currently in use by observers around the globe and is updated regularly. This program is mainly for planetary and asteroid occultations and helps observers to plan their observing program and coordination with other observers for a particular event (Figure 2.5) but it can also be configured to alert you to significant lunar occultation events.

The program can be customised to your particular needs and interests, as well as to show only specific types of asteroidal events. OW will also alert you when information about upcoming events is updated and – if you join the Observation Planning service – it will help you co-ordinate your site position with other observers to avoid duplicating chords and to improve the overall coverage of positive asteroidal events.

OW can be downloaded from http://www.occultwatcher.net

A comprehensive guide to the features and options available with this program is available on the website above and it is strongly recommended that you take the time to read through these pages once you have installed *OccultWatcher*.

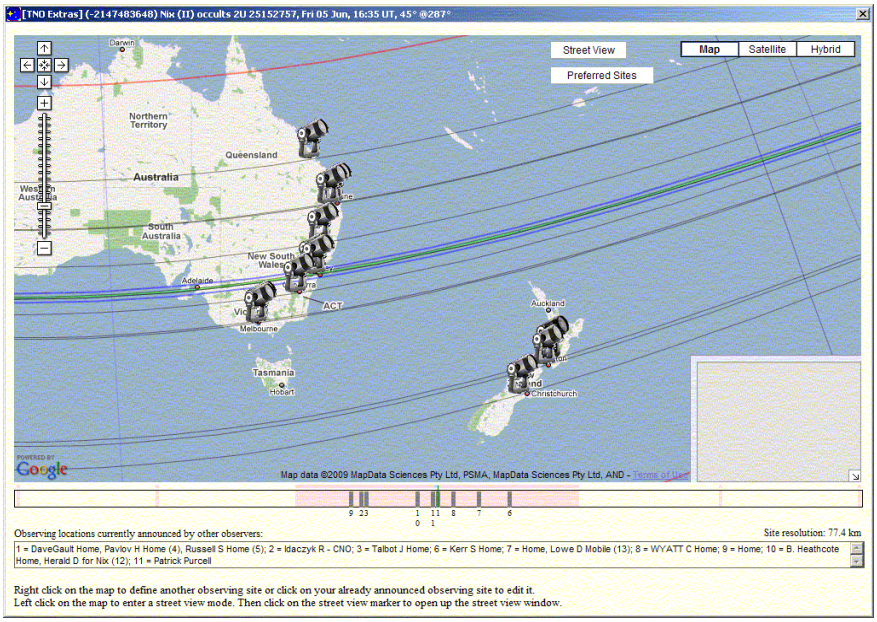


Figure 2.5: *OccultWatcher* helps coordinate observers spread widely apart geographically to see where the predicted path is being intersected by other observers.

2.3.1 Selected Features of Note in OccultWatcher

- On the events summary screen right-click on the column headings row then select "Choose Columns" to select which items of information to display for an event (Figure 2.6). This can also be done under the Configuration menu item.

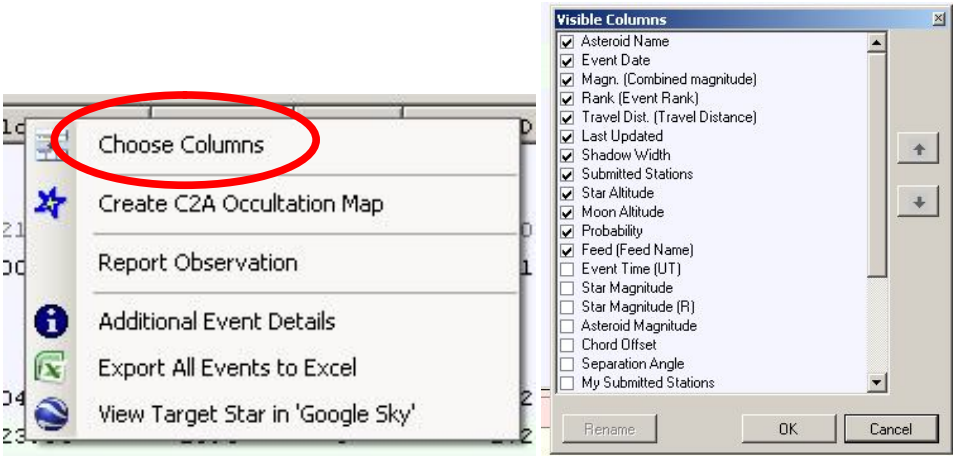


Figure 2.6: The" Choose Columns" feature

- All available information for the event can be accessed by right-clicking on the event line and selecting "Additional Event Details" (Figure 2.7). This will bring up a box with tabs to display information about the star, the asteroid, a summary of the event, magnitudes and if a positive occultation involving the asteroid has been observed before with the results and observers' chords.

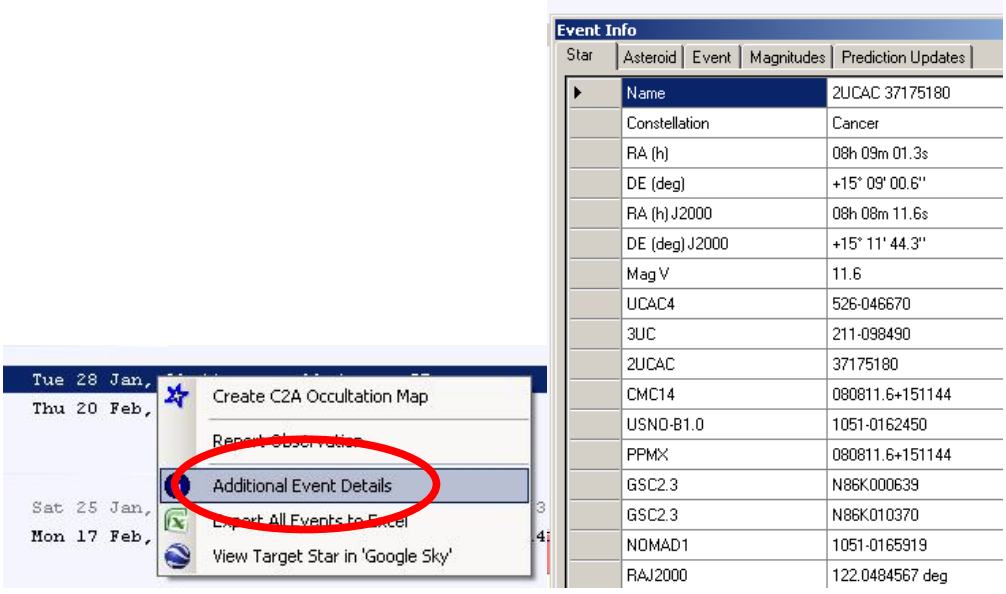


Figure 2.7: The Additional Event Details feature

- *OccultWatcher* displays the Combined Magnitude for the event, being the magnitude of the star and the asteroid when they appear as one object just before an occultation Figure 2.8). The combined magnitude can sometimes be significantly greater than the magnitude of the target star, so making the event visible within the limiting magnitude of your telescope. Look for it at in the lower section of the window where the event information is displayed once you click on an event.

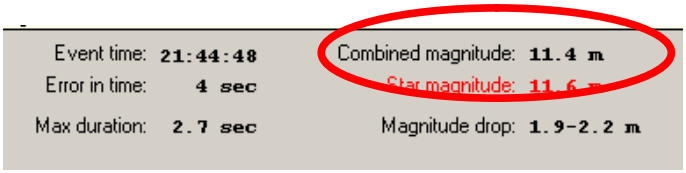


Figure 2.8: Combined magnitude for an event

- Asteroids known or suspected to be either double or to have a satellite are marked with a double blue dot in the shadow position indicator on the left of the event line (Figure 2.9). Even though the predicted path of the main body might lie thousands of kilometres from your position the event may appear in your event feed if you are within the possible range of the satellite.

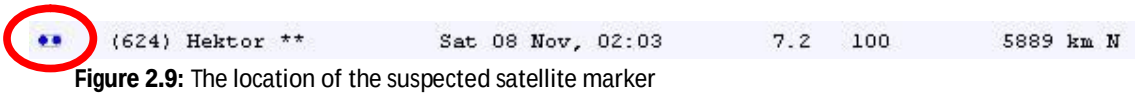


Figure 2.9: The location of the suspected satellite marker

2.4 Star Catalogues

Many different star catalogues are in use today but occultations need the most up to date and accurate star positions to produce accurate predictions.

Some of the catalogue prefixes you will see are UCAC2, UCAC3, UCAC4, TYC and HIP.

UCAC stands for USNO CCD Astrograph Catalogue and is published by the US Naval Observatory. UCAC2 was released in 2003, UCAC3 in 2009 and UCAC4 in 2012. UCAC4 contains data on about 113 million stars.

HIP is short for Hipparcos, a mission operated between 1989 and 1993 by the European Space Agency to measure stellar parallax to high accuracy. It is a high-precision catalogue of 100,000 stars and was published in 1997. The lower-precision Tycho Catalogue contains more than one million stars and was published at the same time, while the enhanced Tycho-2 catalogue of 2.5 million stars was published in 2000.

Some of the stars listed may have an unfamiliar catalogue number that neither you nor your favourite star chart software recognises. In this case the Right Ascension and Declination for the star are given so you can locate the star no matter what software you are using and whether you recognise the catalogue or not.

2.4.1 Obtaining a copy of the UCAC4

The size of the UCAC4 is about 9GB. It can be downloaded from several sites on the internet. Alternatively you could ask through the RASNZ Yahoo discussion group if someone can help you with a copy via DVD or USB memory stick.
Download sites:

http://sourceforge.net/projects/skychart/files/2-catalogs/Stars/UCAC4/
or
http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/ucac

2.5 Finder Charts

Even with today's go-to technology, you will need a finder chart to confirm you have pointed your telescope to the right position. You can either obtain them from the internet or make your own.

2.5.1 On the Internet

- The RASNZ Occultation Section Website lists all the planetary occultation events expected in the region of Australasia for the current month, together with star charts prepared by Edwin Goffin and/or Steve Preston.

- Steve Preston's site http://www.asteroidoccultation.com/ shows predicted events and finder charts on a global basis.

2.5.2 Making your own

Many observers prefer to construct their own finder charts using their favourite software. There is no best program to use here, just the one *you* like best.

Some popular free programs to explore are:

- Cartes du Ceil: http://www.ap-i.net/skychart/start
- Stellarium: http://www.stellarium.org
- C2A: http://www.astrosurf.com/c2a/english/ (*OccultWatcher* has an excellent add-in interface to the C2A program)
- OCCULT is able to generate star charts for a chosen event as well.

There are numerous commercial software packages available. Some of the more popular ones include:

- MaxIm DL
- Guide (by Project Pluto) : http://www.projectpluto.com/
- TheSkyX (by Software Bisque) : http://www.bisque.com/sc/
- Starry Night Pro: http://www.starrynight.com/

A series of finder charts will be needed at gradually increasing scales. You should consider making a chart for each of the following:

1. The sky as it is to the unaided eye.
2. A chart to match the scale of your finder scope.
3. A chart to match the field of view of a low power eyepiece suitable for your telescope.
4. A chart to match the field of view of your camera.

Information on how to work out your field of view can be found below.

2.5.3 Calculating your Field of View

If you know the size of the chip in your camera, which is likely to be given in millimetres, then you should have enough information to calculate the field of view (FOV) for the camera. If you are using charting software the program may have a function that draws the FOV for you once you enter the chip size and the focal length of your telescope (Figure 2.10).

To calculate the FOV separately you can use: (135.3 x D)/L = FOV in arcminutes
Where D = chip size in mm
And L = focal length of telescope in inches, taking into account your focal reducer, if any.

If you do not know the size of the chip in your camera an easy way to work out your FOV is to centre a bright star as close as possible to the celestial equator i.e. declination close to 0 degrees. Then turn off your telescope tracking and let the star drift across the field from edge to edge, timing how long it takes to do so.

If you are using a video camera which has a rectangular sensor you should first align one axis of the camera with the East-West direction. After timing the star's drift, rotate the camera by 90 degrees and repeat the process. Since the earth rotates at 4 minutes of time per degree we can work out:

FOV (degrees) = T (minutes) /4
And if required:
FOV (arc minutes) = FOV(degrees) x 60

These can then be entered into your star chart program.

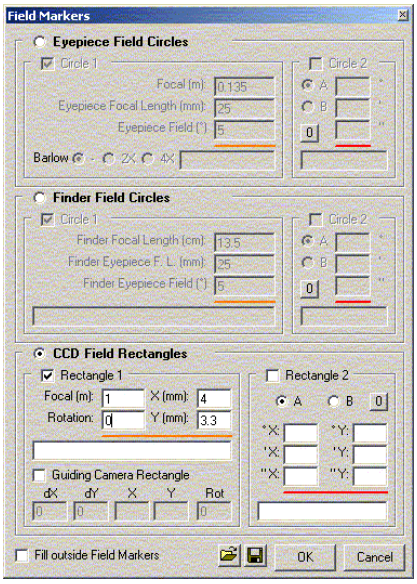


Figure 2.10: An example of a field of view generator from the C2A star chart program. Under the *Tools* menu is a *Field Markers* option. X and Y (width and height) for the chip size of the video camera can be entered here.

2.6 Considering Your Position

2.6.1 Choosing Your Observing Location

2.6.1.1 Total Occultations

Deciding where to place yourself for a total lunar occultation is generally not too critical. The Moon is such a large body that as long as the star is occulted from your site, your result will be useful.

2.6.1.2 Grazing Occultations

Choosing a location to observe a grazing occultation from however is much more critical. As the star casts a shadow of the lunar mountains a few kilometres wide onto the Earth, it is vitally important that your observing stations should straddle this narrow band, and that you are aware of their positions relative to each other. If you have arranged a team of people to record the event careful spacing of observers will be needed – perhaps every 50 to 100 metres across the graze path. Choosing the exact locations depends on the number of observers you have available plus the predicted lunar profile. More stations should be situated in regions of the profile which have the most interesting features.

More information on this detailed topic can be found at
http://www.occultations.org.nz/graze/grazoccs.htm

2.6.1.3 Asteroidal Occultations

As is the case for a grazing occultation, it's desirable that you observe an asteroidal event from within the shadow cast by the asteroid as it sweeps across the Earth. But while the region over which a grazing occultation may be visible can be predicted with high accuracy, this is not necessarily the case for asteroidal occultations.

It is also a common misconception on the part of the beginner that the only useful result for an asteroid occultation is a 'positive' one – that is, you were within the shadow of the asteroid and timed the disappearance of the star. However asteroidal "misses" are just as important as "hits", as they help determine the limits of an asteroid's track (see Figure 2.11 below).

Unlike grazing occultations, **the true track of an asteroidal occultation may often differ from its predicted path making it imperative that you observe the target star even if the prediction places the event some distance away**. The shift in a track can be due to the inaccuracy of the star position and/or asteroid ephemeris used, or the shape of the asteroid. (Almost all asteroidal predictions are made assuming the asteroid's profile is circular, which is frequently not the case.) This uncertainty makes it most important that asteroidal occultation predictions not be taken as "gospel" but rather as general indications only of where an asteroid's shadow may pass. Many an observer has reported a positive event when the prediction has indicated they would see a miss!

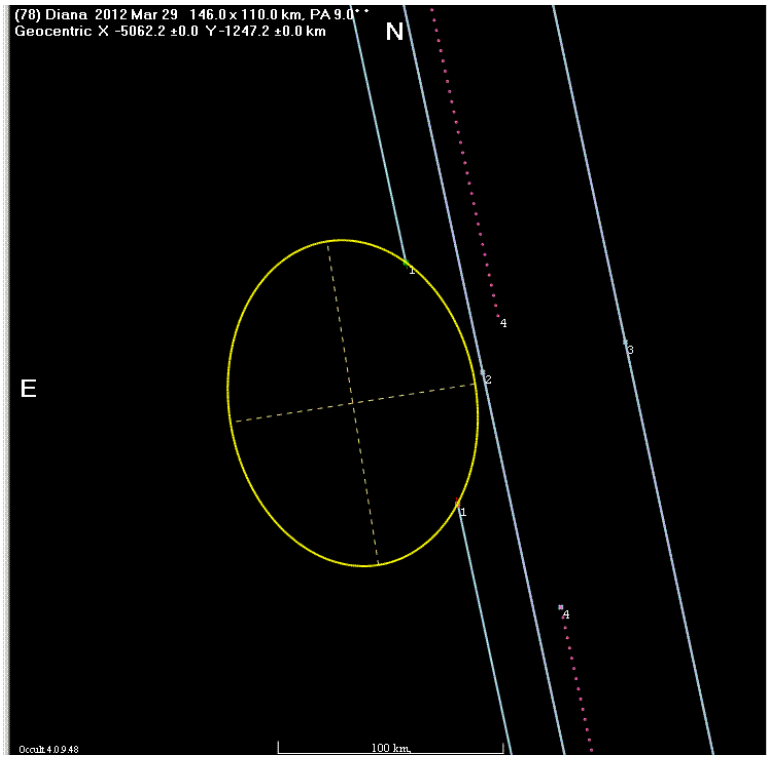


Figure 2.11: The results from three observations (one positive, two negative or "misses", represented by the solid light blue lines) of an occultation by asteroid (78) Diana on 29th March 2012. Despite there being only one positive result, without the two negative observations we would not be able to tell to which side of the predicted centreline (pink dashed line) the asteroid (yellow oval) had shifted . We can even tell that the asteroid is elongated in shape due to the constraining negative observation.

The following factors should be taken into account when choosing an observing location for an asteroid occultation:

- On the predictions by Edwin Goffin the dashed lines to either side of the asteroid's predicted shadow indicate the path the shadow would take if there were a shift of one arcsecond perpendicular to the predicted shadow path. *i.e.* the dashed lines show what would be the path should there be a combined error of one arcsecond in the star's position and/or minor planet's ephemeris.
- On Steve Preston's predictions, dashed lines to either side of the predicted track indicate the effect of a 1-sigma shift in the edge of the path. The 1-sigma line is the standard deviation in the prediction and, in theory, means that there is a 68.3% probability that the actual path of the asteroid's shadow will fall somewhere between the two 1-sigma lines. An "uncertainty ellipse" is also plotted somewhere on the path plot and shows the full orientation of the 1-sigma uncertainty in the path prediction.
  2-sigmas (twice the distance of the 1-sigma lines from the centre of the predicted path) indicate a 95% probability that the asteroid's path will fall within the 2-sigma region. 3-sigmas from the central line correspond to a 99.7% probability that the event will occur within the 3-sigma region.

- If you use *OccultWatcher*, the event graphic shows your specified location in relation to the 1, 2, and 3-sigma lines for an event. (The pink lines in Figure 2.6).
  In all cases, if you are within 3-sigmas for an event you should consider attempting an observation.

2.6.1.4 Regarding the "Rank" of an Event

At the top of the update predictions provided by Steve Preston the "Rank" of the event is also given. This is a number from 1 to 100 that gives an additional indication of the accuracy of the prediction. Strictly speaking, the event rank is the probability of at least one successful observation by a team of two observers spaced 1/8 path width just inside opposite sides of the predicted path. **An event rank of 100 indicates that the prediction is expected to be very accurate, while the lower the number the less accurate the prediction, and the greater the chance the actual track may shift. So the lower the rank, the more the event needs observing from locations well away from the predicted path.**

2.6.2 Determining Your Geographical Position

Whether you are observing from home or have travelled to some other location to observe an occultation it is of great importance that your geographical position be determined to high accuracy. Latitude, Longitude and Height may be determined using one of the following methods, presented in order of preference:

- Reading from a GPS that measures to an arcsecond of latitude/longitude or better. Most Video Time Inserter systems will display this information so it can be recorded with your observation.
- Local survey maps with contour lines – generally accurate to an arc minute or so, although sometimes they can be better.
- Google Earth – Look up your location and point the mouse to your precise location. The co-ordinates usually appear near the bottom. Google Earth uses the WGS84 datum but not all locations have good detailed pictures that you can point to with precision.

GPS satellites use the WGS84 datum as their reference, but some hand-held GPS units may display co-ordinates using alternative datums. Whether you have a hand-held GPS unit or you read the information off your VTI you should record the latitude, longitude, the reference datum used and the height above sea level of your position.

Important Note regarding Geodetic Datums

A datum is a reference system for geographical measurement. There are many datums in use around the world and it is important that you note which one you are using when you report your position. Co-ordinates can be converted from one datum into another, but it is critical that the datum you are using is clearly stated on your report.

Positions determined using a GPS are generally expressed in terms of the WGS84 datum. However check the settings of your GPS as it may be set to display coordinates in your local datum. The WGS84 datum is the preferred datum for the reporting of observations.

Australia also uses the Geocentric Datum of Australia 1994 (GDA94), which replaced AGD84. Positions expressed in GDA94 are very close to WGS84 positions and generally differ by less than a metre, so for most practical purposes GDA94 positions can be considered to be the same as WGS84.

New Zealand uses the New Zealand Geodetic Datum 2000 (NZGD2000). The previous datum was New Zealand Geodetic Datum 1949 (NZGD1949). NZGD2000 is essentially co-incident with WGS84. For most practical purposes NZGD2000 positions can be assumed to be the same as WGS84.

If you are using the Universal Transverse Mercator (UTM) system (i.e Eastings and Northings instead of longitude and latitude) you must note which zone you are in. Australia is covered by UTM zones 49 to 56 and New Zealand by zones 58 to 60.

A program to convert between UTM (and other datums) and WGS84 for New Zealand is available from:
http://www.linz.govt.nz/geodetic/software-downloads/nzmapconv

A conversion program for Australia is available from:
http://www.ga.gov.au/geodesy/datums/redfearn_grid_to_geo.jsp

Occult can also convert most older datums to WGS84 as well. The toggle button for this function is located at the bottom right of the menu page for “Ephemerides.”

Section II

Observing Occultations

3.0: RECORDING OCCULTATIONS: AN OVERVIEW

3.1 Observing Visually and Radio Time Signals

This technique is used less often as technology has progressed to allow a more precise timing of occultations. But making observations visually is still an acceptable way of recording an event so long as you can find a suitable time base.

Traditionally this has involved an observer stationed at their telescope with a voice recorder and an audible radio time signal (see Radio Time Signals below) in the background. A signal would be made on the disappearance (e.g. “off”) and the reappearance (e.g. “on”) of the star.

The disadvantages of visual observations include the inability to detect small drops in magnitude and very short duration events (<1-2 seconds).

Radio Time Signals

Radio VNG was Australia’s short-wave radio time signal service until 2002, when it was closed down. This has made it difficult for observers in Australia and New Zealand to use short-wave radio time pips as a background timebase for timing occultations.

Observers in New Zealand may be able to pick up the radio time signals still broadcast from station WWVH in Hawaii on the frequencies of 5, 10 and 15 MHz. In addition to WWVH signals are also broadcast by station BPM in China, but as BPM uses the same frequencies as WWVH this may add to the difficulty of making accurate timings.

3.1.1 Visual Timings and Your Reaction Time (Personal Equation)

A major problem when timing occultations visually is the amount of time it takes for an observer to react to an event. This Reaction Time is called the observer's *Personal Equation*. When queried, many observers will estimate their reaction time as only a few tenths of a second, whereas comprehensive studies have shown that actual reaction times are often considerably longer - sometimes by an order of magnitude.

An observer's Personal Equation depends on many factors, some of which are:

- Experience at timing occultations
- Magnitude of the star involved
- Environmental Conditions
- Level of comfort
- Length of the observation
- Tiredness
- Lack of certainty as to when the event will occur (or whether it will occur at all).

Human reaction time is the single largest cause of error in visual occultation timings, and its effects can have serious consequences, especially in the case of minor planet occultations where reaction times (which are usually different for Disappearances and Reappearances) can be a substantial fraction of the occultation duration. When minor planet occultations are observed from multiple sites, large differences in the reaction times of the observers lead not only to uncertainty in the actual length of the chords, but also to large offsets between adjacent chords. It is for this reason that we encourage observers to move to non-eyeball forms of observing (e.g. video).

The International Lunar Occultation Centre (ILOC) has determined, through the analysis of many tens of thousands of lunar occultation observations over many years that the average reaction time for a lunar occultation disappearance timed by an experienced visual observer is of order 0.4 seconds. Experienced observers timing lunar reappearances have an average reaction time of order 0.6 seconds. For less experienced observers, and also for minor planet occultations where there is no certainty that an event will occur at all, studies have shown that reaction times are frequently many times these values.

Nevertheless, visual occultation timings still have value and will continue to do so. (It was, after all, the analysis of tens of thousands of visual occultation timings that showed that the Moon is slowly spiralling away from the Earth). With practice, human reaction times can be minimised.

Various computer programs have been written to help observers estimate - and reduce - their reaction times. One such is available at
http://www.occultations.org.nz/software/software.htm

3.2 Observing using Video

Not every video camera is suitable for astronomical work. Some cameras are more sensitive than others. The minimum sensitivity of a camera's detector is given in lux so the lower the lux quoted for a camera, the more sensitive the camera will be.

Among video cameras sold for astronomical uses the most suitable will be monochrome (B&W) cameras as their sensors are generally more sensitive than those of colour cameras. In general cameras sold as night-time security video cameras are the most suitable.

In 2013 the most sensitive camera on the market was the Watec-120N+ which detects down to 0.00002 lux. See 4.3.1.1 *Video Cameras* below for more information about other models.

3.3 DriftScan Observing Using CCD cameras

CCD cameras do not work like video cameras. In a video camera a series of exposures is taken at high time resolution and the results output. In a CCD camera the charge-coupled detector stores up light for a defined exposure period, but then it takes some time to read the data out. This readout delay makes CCD cameras less suitable for occultation observing – but they can still produce a useful result if the star is allowed to drift across the field of view, rather like allowing a star to trail across a piece of photographic film to produce an image. If you are successful in recording an event using this DriftScan technique then you will see in the resulting image that the trail of the target star dims - becomes thinner and fainter, or even disappears completely – for the duration of the occultation. So long as the times at the beginning and end of the exposure are accurately timed the image can be measured to extract the times of any events recorded.

See the following website for a description of how CCD DriftScan observing works:
http://www.asteroidoccultation.com/observations/DriftScan/Index.htm

3.4 Timing

The essence of making scientifically useful occultation timings is to accurately time the instant at which an occultation occurs. In the case of total lunar occultations we are interested primarily in the time at which the disappearance or reappearance occurs (although one of these will not usually be visible as it occurs at the lighted limb of the Moon). In the case of minor planet occultations the real value is in accurately timing both the disappearance and reappearance of the star as it is occulted by the asteroid. In occultation astronomy all times should be reported in Coordinated Universal Time (UTC).

3.4.1 Time resolution required for a useful result

The following accuracy in your timing are considered acceptable for a useful result:

Grazing occultations, timed visually: +/- 0.5 seconds

Total lunar occultations timed using video under ideal conditions : +/- 0.02 seconds for PAL systems. For visual timings +/-0.3 seconds for disappearances and +/-0.5 seconds for reappearances has been considered acceptable for an *experienced* visual observer, but with the use of video you should aim for the highest time resolution and time accuracy possible.

Planetary (asteroid) occultations: +/- 0.02 seconds or +/- 2% of the predicted central occultation duration, but the minimum time resolution achieved may vary depending on the circumstances of the event and the integration time set on your camera.

3.5 Unattended stations

While one person can only be in one place at a time it is nevertheless possible for one observer to record multiple events from geographically different sites by setting up one of more unattended recording stations. Unattended stations can be set up to track the star, if you have the appropriate gear, or as a non-tracking station where the stars are allowed to drift through the field of view of such that the at the predicted time of the event the target star is centred in the field of view. See Appendix 4 for assistance on how to pre-point your telescope to capture an event while the telescope is unattended.

4.0 EQUIPMENT

One of the most basic questions for those interested in attempting occultation work using video is "What equipment do I need?" You need more than just a telescope and a video camera. This chapter discusses the options available and some of the pros and cons for each.

To successfully record an occultation via video there are a number of components that must be brought together. A basic schematic of these is given in Figure 4.1:

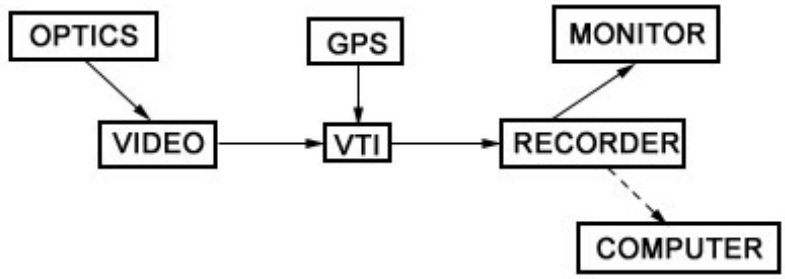


Figure 4.1: A basic schematic illustrating the components of a video capture system.

- **Optics** can be either a telescope or a telescopic camera lens
- **Video** is your video camera
- **GPS** is your Global Positioning System device that may be fed into your **VTI** (**Video Time Insertion)** unit if you are using one. A GPS can provide a reliable time base to time events
- **Recorder** is the storage unit used to record the video. This may be separate from the computer. Sometimes the recorder is the computer, in the case of a laptop acting as the recording device. An example of separate components here would be a Digital Video Recorder (DVR) to record the data which is later downloaded to a computer for analysis.
- **Monitor** so that you can see the event in real time. If the computer is the recorder this component may not be needed.
- **Computer** to download and reduce the data.

4.1 Optics

The range of optics that you could use for occultation work is quite broad and not just limited to telescopes. And big isn't always necessarily better either.

4.1.1 Telescopes

Just about any telescope is suitable for occultation work, from a small 3" (90mm) refractor to a huge 20" Dobsonian.

Many factors can affect the limiting magnitude of your telescope, such as:

- The local seeing (stability of the atmosphere)
- Light pollution
- Cloud
- Humidity

You may have to trial your scope for your location and local conditions to see what works best.

However if you plan to observe faint stars and small magnitude drops there really is no substitute for aperture.

The theoretical limiting magnitude for any given telescope under various conditions can be calculated at: http://www.cruxis.com/scope/limitingmagnitude.htm

4.1.2 Camera lenses

Rather than attaching camera to a telescope, camera or monocular lenses attached to video cameras may also be used, with a T-C adapter and/or a T-adapter needed to connect the lens and video camera together. As there is no rule as to what size lens will be effective, you will probably need to experiment with different lenses to find what field of view you get with your particular combination and what the limiting magnitude of the setup is. In general camera lenses may be best suited to occultations involving bright stars for both lunar and planetary events.

4.1.3 "Mighty Minis"

Scott Degenhardt of the USA has developed a system which attaches half of a 10x50mm binocular to a video camera to make a cheap but effective optical system for occultation work. To read more about the spectacular results from his work and how to make these systems go to: http://scottysmightymini.com/

4.2 Mounts

Any telescope mount is suitable. Factors such as field rotation of the image are not an issue when recording an occultation so alt-azimuth mounts are suitable for this work. Even a large Dobsonian with a tracking device (e.g. an Obsession with a ServoCAT motor drive system) is suitable.

The only caution is for fork-mounted Schmidt-Cassegrain telescopes, where the camera may interfere with the mount near the zenith when in alt-az mode, and near the pole for equatorial mode (e.g. mounted on a wedge).

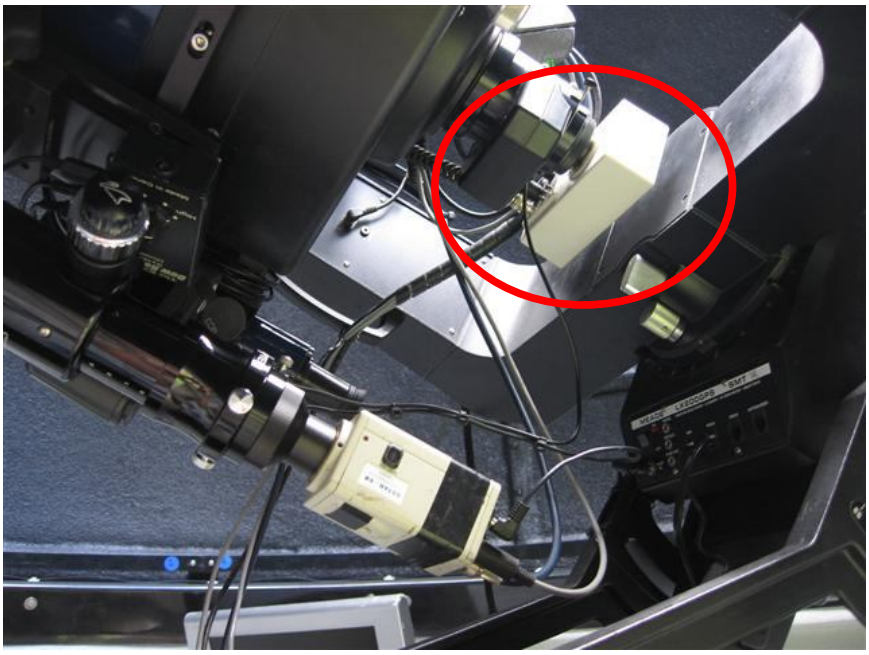


Figure 4.2: A modified video camera has been used with this fork-mounted Schmidt-Cassegrain telescope to avoid the video camera hitting the mount if the telescope points too near the south celestial pole. Source: J. Bradshaw.

Non-tracking mounts are also suitable if you allow the target star to drift through the field of view while recording. In this situation a focal reducer may be helpful as it gives you a wider field of view. This is especially useful if the expected duration of the occultation is more than 50% of the drift time across your recording field of view. You can also maximise the drift time by rotating the camera so that the drift line goes across the camera's field of view on the diagonal instead of on the square.

4.3 Video

4.3.1 Cameras

Two types of camera can be used: video and CCD (Charged Coupled Device).

Video is the preferred type for occultation work and refers to a camera that takes a stream of still images to create a video stream.

A CCD camera is more like a traditional film or DSLR camera, taking long exposures to produce a single image. They can be very sensitive but are not ideal for capturing motion or changes in brightness over time as the dead time (time taken to transfer the data from the pixels to the storage device at the end of each exposure) is often too long, thereby sacrificing time resolution. However the DriftScan method can be used to capture asteroidal occultations with a CCD camera (See 3.3 *DriftScan Observing using CCD Cameras* above).

Standard digital SLR cameras have been successfully used for drift-scan observation and may also be an option but are not generally used for occultation work.

4.3.1.1 Video Cameras

Video Cameras come in a several different formats, most notably NTSC and PAL. NTSC (also called EIA when in black and white) cameras are the standard in the North American market while the standard in Australia and New Zealand is PAL (also called CCIR in black and white).

PAL cameras capture 25 images per second such that, shown one after the other in quick succession, they make the video footage that you view on a screen. NTSC cameras, common in the US, operate at 30 frames per second. This is not to say that you can't use an NTSC camera in Australasia, just that you must be aware of its different frame rate and adjust your capture software (and sometimes your TV) accordingly.

In a video camera each video 'frame' is made up of two separate video 'fields', or exposures, which are interlaced together. In a PAL camera each field (exposure) is $1/50^{th}$ of a second. When two sequential fields are interlaced they make up one video frame whose total exposure time is $1/25^{th}$ of a second. In an NTSC camera each field is $1/60^{th}$ of a second, making one video frame $1/30^{th}$ of a second.

A more sophisticated kind of video camera is an integrating video camera. Integration occurs when the camera stacks frames on top of each other. An advantage of an integrating camera is that it makes fainter objects brighter and easier to see, but at the expense of time resolution. Thus the more frames integrated, the lower the time resolution. This has implications for the timing of occultations which are discussed in Chapter 6.

Having frame integration capability is not essential to occultation work (it is not crucial for lunar occultations, as an example) but it can allow much more flexibility in observing asteroid occultations where the object and target star can be relatively faint. Some of the advantages of integrating frames to increase the signal of your target star are:

- Stars which are otherwise near the limits of your optics can be made easier to see
- You can observe through light cloud
- You can see fainter stars from a light polluted area.

Some of the video cameras on the market at the current time (2013) include:

- Watec 120N+ - Integrating camera



Observers with Watec cameras are reminded that the controls of these cameras are not as intuitive as they might first seem. In particular, when setting slow shutter mode the numbers under "slow" on the hand control do not directly give the actual integration time. You need to refer to the table on the back of the hand controller to understand the correct settings for this camera.



Shutter Mode	Shutter Speed (Integration level)
Slow 1	1 Frames
Slow 2	2 Frames
Slow 3	4 Frames
Slow 4	8 Frames
Slow 5	16 Frames
Slow 6	32 Frames
Slow 7	64 Frames
Slow 8	128 Frames
Slow 9	256 Frames

Figure 4.3: The Watec-120N+ cameras have a "High" and "Slow" mode on the hand paddle control. Slow mode is the integrating mode, and must be interpreted using the table on the back of the hand controller.

- Gstar-EX – Integrating camera



Figure 4.4: The Gstar-EX

- KT & C KPC-350BH camera, otherwise known as a PC164 in the USA.
  A non-integrating security camera that works well for lunar occultations and minor planet events involving bright stars.

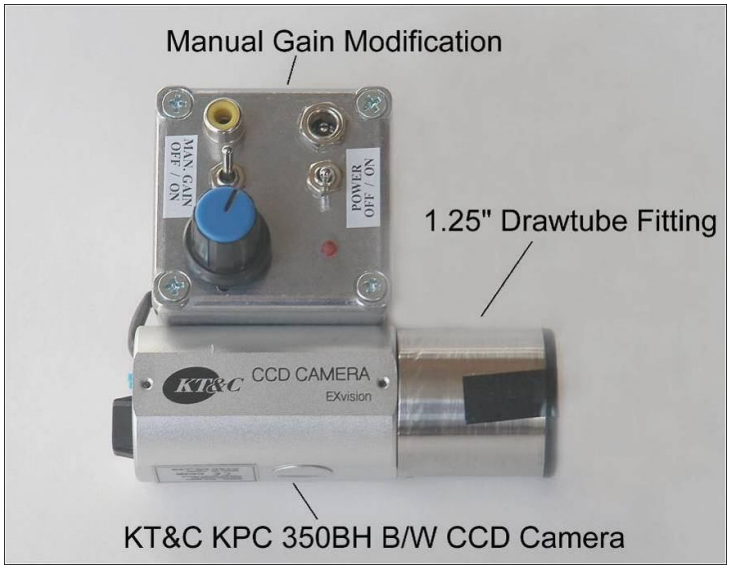


Figure 4.5: The KT & C KPC-350BH camera (with modification to provide a manual gain control).

4.3.1.2 CCD Cameras

Any model of CCD camera seems to be suitable for occultation work. The wider the field of view you have with your particular CCD/telescope combination the more flexible you can be in selecting events, as the field of view will limit your recording time. See 3.3 *DriftScan Observing using CCD Cameras* for more information on the DriftScan method for CCD cameras.

4.3.1.3 CCTV Adaptors

The camera you purchase may not have an adapter that allows it to be held firmly in the focuser (or at the focal point) of the telescope. If you need some ideas on possible solutions see Appendix 2: *CCTV Adapters.*

4.3.1.4 Focal Reducers

A focal reducer in the light path from the telescope to your camera will reduce the focal length of your optical system. This will increase your field of view, increase the brightness of stars in the field, and give you a lower limiting magnitude. There are a number of focal reducers on the market, popular ones being the Meade f/6.3 and f/3.3 focal reducers. An f/3.3 reducer will give you a wider field of view and a limiting magnitude between one and two magnitudes fainter than an f/6.3 reducer or no reducer. Note however that focal reducers will significantly change the point of focus of your system.

4.3.1.5 Parfocal Rings

A parfocal ring is a small circular device which fits around an eyepiece and can be fixed at any position on the barrel. The parfocal ring allows you to adjust the focus of your eyepiece so that it will be the same as your video camera. To use a parfocal ring bring a star to focus in your video camera. Then carefully take the camera out and insert the eyepiece with the parfocal ring loosely placed around it. Without moving the focuser, move the eyepiece in the drawtube until the star is in focus. Then fasten the parfocal ring until it is hard up against the drawtube. From then on, each time you insert the eyepiece it will come to a focus at the same place as your video camera, meaning that it is not necessary to refocus the camera each time you mount it.

4.4 Monitors

If you are planning on working from a home-based observatory then a television with an RCA Video input will be suitable. An old second hand unit with a screen of about 14 inches will be adequate. Either colour or black & white will do.

If you intend to be mobile then you will be better off with a small light unit that can be powered from a 12 volt power supply. While there were small 12 volt CRT televisions available in the past (you may still find one second hand) now there are small portable 12 volt LCD televisions that will probably be lighter and easier to find. Check your local electronics store for available models. (Alternative sources include specialist 12 volt shops and caravanning specialists).

4.5 Video Time Insertion (VTI) devices

Viewing and recording occultation using video can be an interesting experience. However it has little scientific value unless the time of the recorded event can be determined with high accuracy. A video time inserter is a device which will imprint the time (to millisecond accuracy) and other information on top of a video stream. It has an internal clock, usually synchronised to the GPS satellite network. The two models in common use at the time of writing this manual are the KIWI-OSD and the IOTA-VTI. Both are described in greater detail below.

Note that the time displayed by hand-held GPS units is unreliable and can be up to 2 seconds late due to the processing overheads in these units. For this reason it is not advisable to use hand-held GPS units for timing purposes.

Note also that some handheld GPS units may display the height relative to the datum reference geoid rather than the height above Mean Sea Level (MSL). If this is the case you must note which datum your co-ordinates are specified against so that they can later be converted to WGS84.

However issues can also arise when VTIs are used in conjunction with integrating cameras, especially the Watec and G-Star models. See 6.9 *Time Corrections for Integrating Cameras* for further information on these issues and how to deal with them.

Fields and Frames

Before discussing the KIWI-OSD and IOTA-VTI in detail it is important to more fully understand how the fields and frames in these devices are related. As described in section 4.3.1.1 one video frame is made up of two interlaced video fields. This can be demonstrated by looking at the on-screen display from a Kiwi-OSD. Below are two consecutive *frames* from a recording:



The numbers across the screen from left are the Universal Time (UTC), the decimal seconds of the end of the field, the decimal seconds of the beginning of the field, and the incrementing field count.

We can see in the second frame the field count is different by a count of 2, not 1. It's also a little blurry, as two fields have been combined to make the frames displayed. If we were to split this into the two fields we would see the numbers clearly and that they are consecutive.



4.5.1 KIWI-OSD

The KIWI-OSD (On Screen Display) is a VTI developed by Geoff Hitchcox specifically for video occultation work. The production of these models is now discontinued, but you may find one on the second-hand market. The KIWI-OSD displays the GPS-derived longitude, latitude, height and UTC date during its start-up process, and then displays the time accurate to one millisecond plus the video field (not frame!) count at the bottom of the picture. The time stamp is only displayed at the bottom of the screen and only in white text, which means visibility of the time stamp can be an issue with some lunar occultation work, as the bright limb of the moon can drown out the figures of the time stamp. This can usually be avoided by rotating the camera in the drawtube of the telescope so that the illuminated part of the moon is in the top half of the frame.

The websites below provide an overview of the operation of the KIWI-OSD:

http://sites.google.com/site/kiwiosd/

https://sites.google.com/site/kiwiosd/example

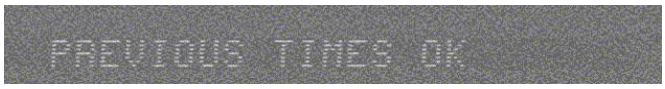


Figure 4.6: A Kiwi-OSD unit, without attached cables and GPS receiver.

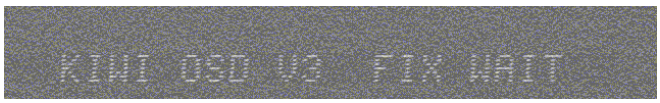
4.5.1.1 Reading Your Location Information from a KIWI-OSD

If you have a KIWI-OSD, after pressing the reset button the unit will run through a series of information displays.

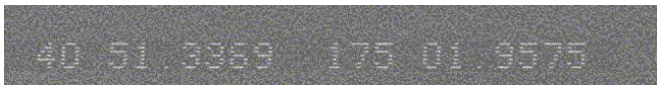
This screen confirms any previous times were OK.



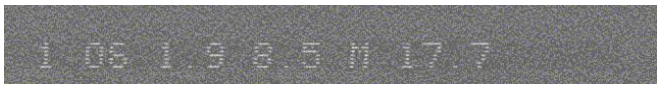
Press the Reset button again.



The unit now checks that enough satellites are visible.

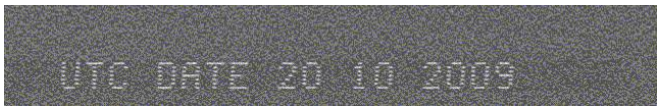


The Latitude and Longitude in dd mm.mmmm format are now displayed.

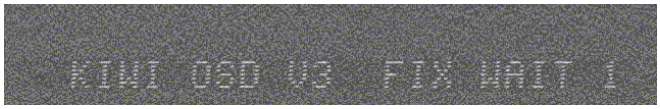


The unit now displays information about the Fix status (1, indicating it is a valid fix), number of satellites used for that fix (6), The Horizontal Dilution of Precision, or HDOP (1.9, indicating that the location given by the fix is pretty accurate, as the closer it is to 1.0 the better), the height above Mean Sea Level (8.5 M or metres) and the geoid correction for the location (17.7 metres).

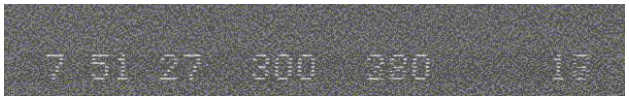
If the geoid correction is shown the previously given height will be above Mean Sea Level and you do not need to make any adjustment to the height for that location before reporting it.



The current UTC date is displayed in DD MM YYYY format.



Now it does another check that it can see at least 9 satellites –



- and then drops into the normal display of time and field count.

Ideally with the KIWI-OSD you should record this sequence at both the start and end of each recording but definitely at least once in each recording.

4.5.2 IOTA-VTI

The IOTA-VTI was introduced in mid 2011. Development was by Dave Gault and Tony Barry in Australia. The IOTA-VTI performs a similar function to the KIWI-OSD with some differences in performance. It can be set for either NTSC or PAL recording and contains an internal GPS unit.

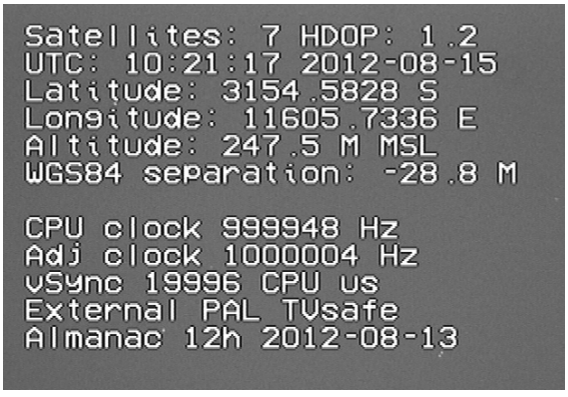


Figure 4.7: The front and back of an IOTA-VTI

For more information on the features of the IOTA-VTI or to order a unit go to http://videotimers.com/home.html

4.5.2.1 Reading Your Location from an IOTA-VTI

If you have an IOTA-VTI the screen will display your location information in this format:



- The number of satellites acquired at that time. You need a minimum of 4 for a fix.
- **HDOP** is the Horizontal Dilution of Precision. It is a measure of how accurate your horizontal location fix is. This value should be less than 2.0, and should improve with

the number of satellites available. The HDOP of 1.2 displayed in this example is excellent.

- The **UTC** time and date, with the date given as YYYY-MM-DD
- **Latitude** and **Longitude**. Displayed in ddmm.ssss format for both latitude and longitude. In the example above it is 31^0 54' 58.28" South and 116^0 05' 73.36" E
- **Altitude** in **M**etres above Mean Sea Level (**MSL**), given as 247.5 metres in the above example.
- **WGS84 separation** is the separation of the reference geoid from the given MSL

4.5.3 GPS-ABC

The GPS-ABC unit is a GPS based precision clock and occultation timer that can be used to provide an audible time signal for the visual observer or as back-up visual time signal for video observers (Figure 4.8). A description of this unit appears in Appendix 3 *Introducing the GPS-ABC*. At the time of writing the GPS-ABC is only available in kit form.

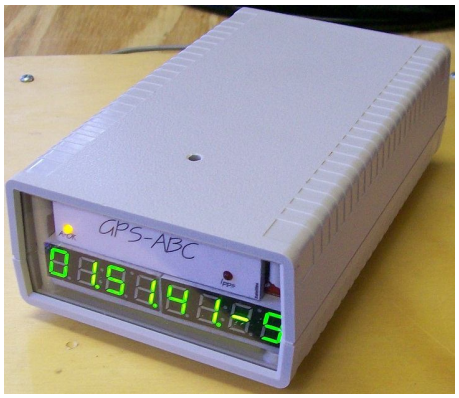


Figure 4.8: A GPS-ABC unit. Source: Dave Gault

4.5.4 Beeper Boxes

A Beeper Box is a small low cost 'standalone' portable unit generating accurate audible time signals which can be recorded in a similar manner to the VNG or WWV time signals. It was designed by Pauline Loader in New Zealand. It is useful when observing a grazing or minor planet occultation visually, and can also be used with a video camera via an add-on LED cable. The box is approximately 10cm x 8cm x 4cm and runs on four AA batteries. The audible signal is provided by a small piezo buzzer mounted inside the box. The buzzer emits a 'beep' of approximately 50 milliseconds duration at one second intervals. On every tenth second the 'beep' is slightly longer. The short beeps start at 51 seconds on the fifth minute. On the 55 – 58th seconds of each minute the 'beep' is very short. The 59th second is silent and the minute is marked by an extra long beep (500msec). This very closely emulates the former VNG time signals.

If a video system is being used to record events an accurate timestamp facility on the video is required to allow accurate time analysis of the events recorded. To this end, the Beeper Box also has provision for output to a LED. This provides light flashes with exactly the same timing characteristics as the piezo buzzer. The LED can be mounted in the telescope field of view so that the one second flashes are recorded on the video system. When playing back the video record in order to analyse the event(s) the one second

flashes are visible on the relevant frames. Using the slow playback or frame stepping facility of the video player it is possible to determine the time of each event to within 0.02 sec depending on the characteristics of the video player. Alternatively the flashing LED could be used to accurately calibrate commercially obtained video time stamping systems.

This box is no longer available but some may be available from people who have upgraded to VTI timers. Anyone who is interested in creating their own timer boxes is invited to contact Pauline Loader [palbrl@clear.net.nz]

BeeperSync is a software tool developed by Hristo Pavlov in Australia which allows you to link your PC to a Beeper Box and synchronise with a web time server to an accuracy of better than 50 milliseconds. It can be downloaded from http://www.hristopavlov.net/BeeperSync/

4.6 Recording Devices

There are a number of options for recording your data. What device you choose might depend on whether you have a permanently set-up observatory or whether you intend to be mobile. Choices include recording to a camcorder, video-cassette recorder (VCR), digital video recorder (DVR) or laptop computer.

4.6.1 Camcorder

A number of (particularly older) camcorders, especially from Canon (e.g. the MVxx0i models), have an AV input socket that can record video from an external camera. These have the advantage of being battery powered and hence suitable for mobile observers and remote sites. The recorded video then needs to be downloaded to a computer for analysis, so the camcorder must also be capable of providing AV-out. Plus you must have a suitable video capture device to get your data into the computer.

4.6.2 VCR (Video Cassette Recorder)

An old VHS video recorder will do an adequate job of recording occultations. Make sure the heads are clean and that it is not creating significant noise on playback. Avoid using the extended play options as they degrade the quality of the playback. If you are considering doing pre-point observations (see *Appendix 4: How to Pre-point Your Telescope*) then a unit that can be programmed to start and stop at a particular time is useful. Just make sure that you record for a suitable interval before and after the predicted event (see 5.7 *How long do I Observe For?* below.)

Almost all VCRs are mains powered so are generally only useful for mobile work if you have an inverter that will provide mains power from a 12V battery.

4.6.3 DVR (Digital Video Recorder)

A DVR takes a signal from an external camera and converts it to an AVI file which is stored on an internal hard drive. To transfer the file to your computer the DVR can be plugged into the

USB port and is seen by your computer as simply another USB storage device. Some modern DVRs will record from a video camera only so long as the DVR has an RCA (AV) video input.

Note particularly that some models will not record monochrome signals from low-light level cameras such as the Watec 120N+ and GStar-EX as the DVR triggers off the colour signal only.

There exist a range of small battery-powered, 5V or 12V units which are suitable for both home-based observatory and mobile work. These are sometimes described as 'mini' or 'personal' DVRs. Some of these also have a small built in monitor that further simplifies your system.



Figure 4.9: An example of a mini-DVR with a built in monitor.

You may find that the 5V models from China come with a mains power supply that is not good enough to run the unit reliably in some conditions. Many observers now use a 12 V (eg Jump Starter) battery pack with a 12V to 5V power adapter to resolve this issue.

As indicated above the major advantage of a DVR over a VCR is that the DVR creates an AVI file that can be copied straight to your PC. No other means of conversion (e.g. a frame grabber) is required (See 4.6.4 *Laptop computer* below).

Another advantage of a DVR is that it can store a large amount of data in a compressed form. Data storage can often be increased by the addition of an SD card, depending on the model (the model should state the maximum size allowed.) Thirty minutes of compressed video is possible whereas 30 minutes of video stored in uncompressed form on a computer may take up many gigabytes of the hard drive. But this compression can also be problematic in that the signal may be compressed so far that for a very faint event the star's signal becomes lost in the noise despite you being able to see it on the monitor at the time of recording.

Please Note: These units should be used with caution, as it has been found that some units can drop one field per frame to compress the data. This means you are losing data that may be important during analysis of a positive event leading to a greater uncertainty in the time of your result.

4.6.4 Laptop computer

To capture data directly to a laptop computer, without using an intermediate DVR, you will need a video-to-USB adapter or 'framegrabber' device, its associated software, or a video capture program (see below), to digitise the video signal. Suitable units costing under $100 can be obtained from electronic gear suppliers such as Jaycar in New Zealand and Australia (e.g. "USB 2.0 DVD Maker" #XC-4867). You should remember to always create an AVI file when recording this way.

One disadvantage of using a computer as the recorder, particularly with laptops, is that hard drive space can fill up quickly, although this is probably less of a problem today as hard drives progressively become larger in size. Video files can also be transferred to a portable hard drive unit for long term storage once captured rather than be kept on the laptop hard drive to keep the hard drive relatively free.



Figure 4.10: An example of a video-to-USB connector

4.6.5 Video Capture Software

There are two programs, both available for free, that can capture video to a computer.

- *VirtualDub* is a comprehensive program that specialises in pre-and post-processing of video. Among its many features is its ability to capture AVI files for both PAL and NTSC cameras. *VirtualDub* can also split a large video file into smaller segments so that it can be run through *LiMovie* or *Tangra* software for analysis (See 6.1 *Software for Analysis* below).

  Virtualdub can be downloaded from http://virtualdub.org/

  An automatic scheduler and timer for *VirtualDub* can be found at http://www.softpedia.com/downloadTag/VirtualDub+timer

- *Gstar Capture* is a capture program written specifically to enable Gstar-EX video cameras to record directly to a computer/laptop. It captures video in AVI format and should work automatically with your framegrabber of choice.
- *Gstar Capture* Version 4 software can be downloaded as a zip file from http://www.myastroshop.com.au/guides/gstar/index.htm.
  (Scroll down to the lower half of the page)

4.7 Astronomical Digital Video System (ADVS)

The Astronomical Digital Video System (ADVS) is a digital video recording system designed for general astronomical purposes and observing asteroidal occultations in particular. It is being developed jointly by Tony Barry, Dave Gault and Hristo Pavlov in Australia. The ADVS will be supplied as an Astronomical Digital Video Recorder (ADVR) and a Hardware Timing and Camera Control (HTCC) unit, with the user to supply a suitable computer to install and run the software on and to supply their own camera.
For more information and recent developments with the ADVS visit
http://www.kuriwaobservatory.com/ADVS

4.8 Other Equipment Considerations

4.8.1 Power Supplies

If you are using portable power supplies – e.g. at remote or unattended stations – ensure that you have enough batteries and they are fully charged before leaving for the site. Also ensure you have a power inverter if you are running devices that require mains power, and that you have enough powerboards or plugboxes so you can use multiple devices at once.

4.8.2 Cables

Make sure that you have all the cables you need for your set-up. Do not assume that the equipment comes with all the cables needed. It is strongly advised that your equipment be connected in a live configuration well before you attempt your first event.

4.8.3 Focal Reducer

A focal reducer can be used on a Schmidt-Cassegrain telescope to effectively shorten the focal length of the telescope, and so both widen the field of view and extend the limiting magnitude of your system. (See Section 4.3.1.4)

4.8.4 Filters

If you are observing in twilight conditions a Infrared (IR) pass filter may be of assistance to make stars more visible. By only letting IR light through it should make the sky seem a darker blue, increasing contrast between the sky and the star. Don't confuse it with an IR-UV blocking filter that is sometimes used in astro-imaging, however.

As both video and CCD cameras tend to have a better spectral response towards the red end of the spectrum, also check the spectral type of the star beforehand. If the star is brighter in the R-band than it is in the V-band, then the use of a filter which preferentially lets through more red light might improve your signal to noise. But on the other hand, the bandpass of the filter might let less light overall get through to the detector, meaning that you must use longer integration times. The only way to decide whether to use a filter or not with a particular event is to experiment.

4.8.5 Dew Shields and Dew Removers

Dew is the common bane of all observers. Make sure you have at least one method at hand to deal with this menace. Options include:

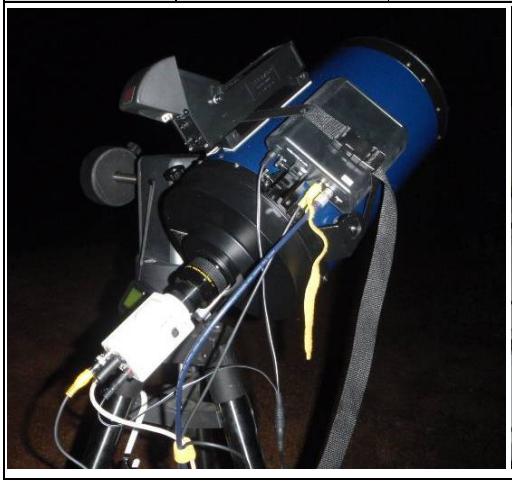
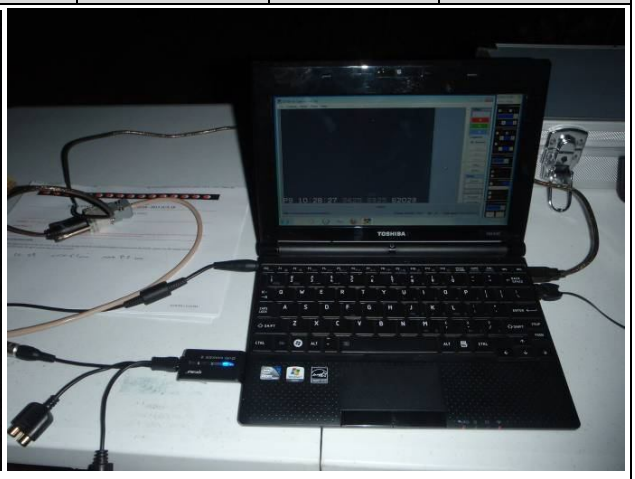
- Dew shields
- Heated strips wrapped around your optics
- 12v hairdryers

4.8.6 Voice Recorders

If you are using a GPS-ABC unit and vocally calling times as you witness events, a digital voice recorder will be an asset. The recorder should have the following features:

- Records for 20-30 minutes without stopping or filtering out pauses
- Records in a common format, such as MP3, which can be opened directly into analysing software such as Audacity
- Has the means to transfer directly from the device onto your computer, e.g. USB cable, appropriate transfer software (if required).

4.9 Some Examples of Equipment Combinations

Observer	Telescope	Mount	VTI unit	Camera	Recorder
B. Loader	8” Meade SCT (classic) + focal reducer	Fork mount with wedge	KIWI-OSD	Watec 120N+	Laptop with USB capture device
					
J. Milner	8” Meade SCT OTA (classic) + focal reducer	iOptron Minitower Pro (Alt-az)	IOTA-VTI	Gstar-EX (Mintron)	Laptop with USB capture device
					

5.0 RECORDING AN ASTEROID OCCULTATION

You've studied the prediction, gathered your equipment and now you're ready to attempt to observe an event.

5.1 Preparation

As the old saying goes - Practise, practise, practise!

- Check your intended observing site within the week of the event and make sure the target star will be above your local horizon at the relevant time.
- Practise finding the target star on a preceding evening. One of the most common reasons for failed observations is the inability of the observer to find the target star in time for the event.
- Make a full practice run a night or two beforehand to make sure you know how your equipment goes together and to ensure that it is working as intended.
- Practise on lunar occultations, which are easier to observe and record. This will help you to gain experience setting the equipment up, pointing the telescope with a video camera, recording an event and then reducing the data for reporting.

5.2 Recording Your Location

Once you have decided where you will observe from – whether from your home or from a remote site – it is essential to accurately record your position. Both the Kiwi-OSD and the IOTA-VTI provide the means to do this. (See Sections 4.5.1.1 *Reading Your Location Information from a KIWI-OSD* and 4.5.2.1 *Reading Your Location from an IOTA-VTI*)

Using both the KIWI-OSD and IOTA-VTA you may find that the height above MSL varies by several meters, even as you watch. This is normal and gives an indication of the accuracy of the measurements. You should average several runs to get the best accuracy. The accuracy of your height needs to be within +/-30m to be useful.

Ideally you should record this sequence at both the start and end of each recording but definitely at least once during the recording.

An alternative source for finding your height is to enter your precise WGS84 coordinates at: http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/intpt.html

5.3 Start Your GPS Unit Well Before the Event

To have the most accurate time available during the recording of the event you need run the GPS of your VTI for at least 15 minutes before the expected time of the event, especially if it has been more than a week since you have used it or you have shifted the unit a considerable distance from where it was last used. This allows the almanac of the GPS unit be updated with the latest status and ephemerides of the GPS satellites so that the position you obtain is as correct as possible. But more importantly it allows the most up to date time in relation to UTC to be obtained and displayed on your screen. **Not updating the almanac may mean your time could be out by a second or more.**

5.3.1 Updating the KIWI-OSD GPS almanac

The KIWI-OSD GPS units take 15-20 minutes to update. To ensure that you have an updated almanac start the GPS unit as soon as possible, then after 15-20 minutes **press the reset button for the first time** to give the KIWI-OSD the chance to do a check, and then **press it again for a second time** to restart and record the coordinates.

- If the almanac was current, the KIWI-OSD will display:- "PREVIOUS TIMES OK"
- If the almanac was NOT current, the KIWI-OSD will display:- "ERROR: USE FIELD COUNT"

5.3.2 Updating the IOTA-VTI GPS almanac

The IOTA-VTI units display a symbol to tell you if the almanac has been updated. If you see an hourglass symbol next to the number of satellites acquired (highlighted in the red box in the example below) that means that the almanac is still updating. Once the almanac is updated the hourglass symbol disappears.



Observations should not be made when the hourglass is displayed, however, if an event is imminent then once the update is complete the observer should note whether the following occurs:
- If the almanac was current the hourglass will disappear, and the times were good.
- If the almanac was NOT current, the IOTA-VTI will display an "Almanac Updated" message on the Position screen and will give a correction to apply to previous timings.

5.3.3 Updating the GPS-ABC GPS almanac

1) At startup GPS-ABC assumes the almanac of the GPS is out of date and will acknowledge this state by two methods;
   a) The A-OK LED (Almanac OK LED) is NOT illuminated
   b) All beeps are sounded as double (other than the 0, 10s and the 55).

This is to clearly indicate visually and audibly that the time displayed cannot be guaranteed.

2) If, during the first minutes of operation the GPS downloads a fresh almanac, GPS-ABC will:

a) Light the A-OK LED
b) Stop double beeping
c) Display an "A" to denote almanac updated
d) Give a correction to apply to previous times.
e) The above will be displayed, as well as the current seconds and the satellite fix status until the Clear Message/Position Sentence Button is pressed.

3) If, after 15 minutes has elapsed since GPS-ABC has been started, and provided a better than five satellite fix has been maintained, GPS-ABC will consider the almanac is current, therefore the time display can be guaranteed, so it will:

a) Light the A-OK LED
b) Stop double beeping

4) If GPS-ABC has been unpowered for less than 12 hours after determining that the almanac is OK (conditions above (2) and/or (3) above), during the first 5 seconds of running after startup:

a) The A-OK LED will not be lit
b) GPS-ABC will double beep.
c) At the conclusion of the five seconds and provided the almanac is valid, GPS-ABC will light the A-OK LED and stop double beeping.

These features are designed to clearly indicate the condition of the GPS's almanac BOTH visually and audibly so the observer can be assured that the time displayed is guaranteed. If however circumstances should arise where the GPS-ABC must be used before the A-OK LED is lit (for example - an event is imminent), then sufficient information is made available in such a manner to aid successful salvage of the observation.
[Source: GPS-ABC Manual Version 8.0, Dave Gault]

5.5.4 Updating the ADVS GPS almanac

The ADVR will monitor the state of the HTCC and hence it's GPS, for the condition of its almanac to determine the reliability of the reported time.

i) If a red '?' is displayed, and the time display is Yellow, then the condition of the GPS's almanac is uncertain, therefore the reported time cannot be relied on.

ii) If the time display is green, then the almanac logic has determined that the reported time is good. The presence of –X indicates that an almanac update has occurred.

The reported condition of the almanac is written to the .adv file for every frame and Tangra3 has logic to account for almanac updates that occur during a recording.

i) If an event is imminent and the condition of the almanac is uncertain, then;

(1) Start the recording anyway

(2) Do not stop the recording at the end of the observation, just keep recording until the condition of the almanac becomes certain. To reduce file size, simply cap the telescope and reduce the frame rate (keystroke U or >) to 1 or 2 spf (seconds per frame).

(3) Or simply take note of the '–X' value (if any) and manually account for any adjustment.

[Source: ADVS Manual, Dave Gault]

5.4 Sky Conditions

When it comes time to report your observation you will be asked to comment on the atmospheric conditions. You don't need to be too detailed.

- Is it clear, foggy or cloudy?
- Is the cloud thick or thin or broken?
- What is the stability of the sky – steady or flickering?
- Is there wind and is it affecting you?
- Is there a nearby interfering light source?
- Lunar occultations require a note of the ambient air temperature at the time of observation

There is a space for extra comments on any of these factors on the reporting form (See Chapter 7: *Results and Reporting*).

5.5 Finding the Starfield

It can be difficult to find the target star in time. Allow plenty of time to do this, particularly if you are new to the game - at least half an hour, and preferably one hour or more. A good rule of thumb is to estimate how long you will need and double or triple it. Notes on obtaining and preparing finder charts to help you are detailed in Section 2.5 *Finder Charts*.

If the asteroid is bright enough to be visible you should be able to see it move slowly over time as it approaches and departs the target star. If this is the case it should be visible separately from up to 15-20 minutes before and after the predicted event time; within that time interval the asteroid will have appeared to merge with the star and you may notice that the target star has become brighter. This will provide a check that you are pointing in the right place.

5.5.1 Pre-pointing at Unattended Stations

Appendix 4 has a description of how to plan the pre-pointing of a telescope. It includes a description of how to pre-point an equatorially mounted telescope (while it is attended) by John Talbot, which includes instructions on how to use *C2A* star chart software with *OccultWatcher* to prepare for an event.

Making a video finderscope is also recommended to make pre-pointing easier. This may involve modifying an existing finderscope to take a video camera or attaching a camera lens to a video camera to give a wider field of view.

5.6 Settings for Integrating Cameras

The following considerations are important if you are using an integrating camera.

5.6.1 Setting the Right Integration Level

If frame integration is applied to your video it should be at the lowest level of integration that allows the target star to be steadily visible at all times. Equally, the integration interval must not be set too high such that the star image is saturated.

You must take note of what level of integration is used for the event. This information is very important when it comes to determining the times of an event.

5.6.2 Turn the Gamma Correction On

If you are able to adjust the gamma setting on your camera you should make sure that it is on and set to 1. Gamma correction is applied to electronic images to balance the contrast of the image to make it seem more like what the human eye would see.

5.6.3 Turn the Automatic Gain Control Off

Automatic gain may lead to over saturation of the star image. However, if you have manual gain control you can use this instead to adjust the visibility of the star.

5.7 How Long Do I Observe For?

As a guide the target star should be monitored for 10 times the length of the 1-sigma uncertainty (e.g. 5 times the 1-sigma uncertainty either side of the expected time of the occultation.) But ideally you should monitor a wider time frame to allow for the possibility of detecting an asteroidal satellite. The time allowed for this should be at least 10 times the maximum expected duration of the occultation either side of the event. This is based on the location of currently known asteroidal satellites, all of which lie within 10 diameters of the parent asteroid. To calculate this take the expected maximum duration of the occultation and times it by 10, then add this time to either side of the expected event time.

5.8 Recording Low Magnitude Drop Events

A low magnitude drop event occurs when the expected drop in brightness of the target star is less than one magnitude. This kind of event can be difficult to detect against the background noise of the sky and your electronic equipment. The table below shows the decreasing change in brightness of the target star the lower the drop in magnitude. A drop in magnitude of 0.2 or less can be difficult to detect against the background noise in the sky.

Drop in magnitude	Change in brightness (%)
1.0	60%
0.7	48%
0.5	36%
0.2	17%
0.1	9%
0.05	4.5%

Table 5.1: The percentage change in brightness of a star for the corresponding expected drop in magnitude for a planetary occultation event. Source: Steve Kerr

Success may depend on:

- The brightness of the star
- The seeing on the night
- The duration of the event (longer is better)
- The sky transparency
- The electronic noise from your equipment.

Strategies to improve your chance of detecting a low magnitude drop event include:

- Minimising electronic noise e.g. Direct capture to a digital file
- Minimising the amount of compression used to store the video file
- Minimising the length of cables used
- Maximising the quality of the cables used
- Using the highest possible integration value that avoids saturation (See Appendix 5)

5.9 After the Event

After each attempt to observe a minor planet occultation you should ALWAYS fill in and return a report form, whether you see an occultation or not. Even observations of "no event" are potentially valuable, because they can help determine where exactly the occultation track did in fact pass. For example, there might be other observers to the south or north of you and if you record a miss but they record an event, it will confirm towards which side of the track the asteroid might have shifted. All observers involved with an event that resulted in a positive observation will be included in the resulting astrometric report and/or publication, whether they saw the event or not. See 7.0 Results and Reporting for further assistance.

5.10 Miscellaneous Considerations

- Personal comfort - stay warm and hydrated if you are outside for a considerable length of time.
- Personal safety – are you far enough off the side of a road, out of view of any passers-by?
- Common mistakes – not finding the target star field in time, not leaving enough time to set up, not having charged batteries/power.
- Dealing with dew – do you have an effective dew removal system? e.g a hair dryer, heating strips?
- Have you checked the weather forecast? – in addition to your local weather service you could use a service such as Skippy Sky Astronomy Weather Forecast , found at http://www.skippysky.com.au/ This site also provides predictions for weather conditions in the New Zealand region.

Section III

Reducing and Reporting Your Data

6.0 Data Reduction

The sky was clear, you located the target star and you recorded the occultation. Now you need to get the occultation times from the video to report them.

6.1 Software for Analysis

Two programs are available to analyse your video and extract the times; *LiMovie* and *Tangra*. Observers using the DriftScan method for CCD cameras should use the *Scanalyzer* software to reduce their results. All three programs are described below.

In general *LiMovie* is preferred for analysing lunar occultations and *Tangra* is preferred for analysing asteroid occultations.

6.1.1 LiMovie

LiMovie (LIght Measurement tool for Occultation observation, using VIdeo rEcorder) is a program written by Kazuhisa Miyashita of Japan to analyse data from a video occultation observation recorded in AVI format. *LiMovie* will measure the brightness of selected stars on each frame of your video record, thus allowing you to pinpoint the frames containing the occultation. Data can be graphed within *LiMovie*, or can be output as a CSV ("Comma Separated Value") file that can be read by a spreadsheet program such as MS Excel. Using *LiMovie*, you can measure the change in brightness of the relevant target and comparison stars over the duration of your captured video file.

LiMovie can be downloaded from:
http://astro-limovie.info/limovie/limovie_en.html

(Note: Do NOT download from http://astro-limovie.info/ This is the "old" version. It will still work but it won't have the most up to date features that you need, especially if you intend to analyse and report on lunar occultations.)

Once you have downloaded it, it is recommended that you check if it needs a Software Update (at the top of main window.)
A quick guide to using *LiMovie* can be found in Appendix 6.

6.1.2 Tangra

Tangra 3 is the latest version of a program written by Hristo Pavlov for reducing astronomical video observations, such as asteroid occultations, to produce a light curve for analysis. It also does astrometric and photometric reductions on video observations of comets and asteroids. Tangra 3 has features that tie in with the ADVS system that is currently being developed. The earlier version, Tangra 1.4, is still available, however.

Tangra 3 can be downloaded from http://www.hristopavlov.net/Tangra3/

Tangra 1.4 can be downloaded from http://www.hristopavlov.net/Tangra/Tangra.html

For a guide to reducing your light curves in *Tangra* go to:
http://www.hristopavlov.net/Tangra/LightCurves.html
and
http://www.hristopavlov.net/Tangra/LightCurveExamples/

6.1.3 Scanalyzer

Scanalyzer is a program written by John Broughton to analyse light curves captured by CCD cameras using the DriftScan method (see 3.3 *DriftScan Observing for CCD Cameras*). For more information and to download this free software go to:
http://www.asteroidoccultation.com/observations/DriftScan/Index.htm

6.2 Video File Format and Conversion to .avi files

Your video file needs to be in .avi format to be read by *LiMovie or Tangra*. However the .avi format is a "wrapper" format, the contents of which can vary from file to file. So if your .avi file is not recognised by your software you can use the program *Avisynth* to translate it into a recognisable .avi format.

If you have the latest version of *LiMovie* it will automatically detect that you have *Avisynth* and use it without you having to make a script.

An alternative is to run the video through the program *VirtualDub* to convert it to a suitable .avi format.

- *AviSynth* can be downloaded from http://avisynth.nl/index.php/Main_Page
- *VirtualDub* can be downloaded from http://www.virtualdub.org/

6.3 Size of .avi Files

Owing to limitations imposed by the Windows operating system the size of your video file may need to be less than 2 Gigabytes to be read by either *LiMovie* or *Tangra,* although the latest versions of these programs do not seem to have this problem. If this happens for you then these programs will read the first 2 GB but then cannot read beyond that point. To cut the video files down you can use a video editor such as *VirtualDub* to cut the file into smaller-sized portions. Here's how:

1. Open the video in VirtualDub and locate the section of the video you would like to cut out for analysis.
2. Select a frame for the start of the crop and chose "Set selection start" under the Edit menu (Figure 6.1).
3. Select a frame at the end and chose "Set selection end" under the Edit menu.
4. Go back to the Edit menu and chose "Crop to selection".
5. Save the cropped file under a new name to avoid losing your original data and check that it is now under 2 GB in size. Reselect start/end as necessary.

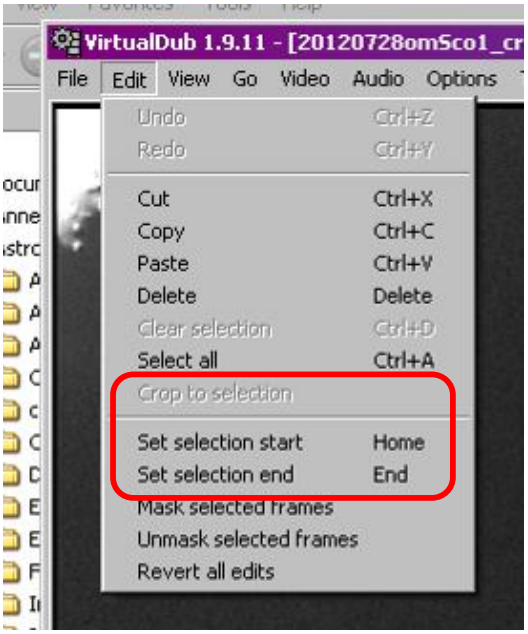


Figure 6.1: The Edit menu in *VirtualDub* which allows you to crop a large video file into a file less than 2 GB so that it can analysed by *LiMovie* or *Tangra*.

6.4 File Compression

.avi files use lossy compression techniques so you need to be aware that information about the occultation may be lost in the resulting noise. Similarly too much compression can lead to the production of undesirable artefacts in the video. For example, the star may only just be visible above the background noise at the time of recording. But when you play the recording back the star may not be visible on the screen. If you are unable to adjust the degree of video compression being applied then, other than increasing the integration setting on your video camera to 'brighten' the star (and thereby losing time resolution), there may not be much that can be done to make sure the event is captured.

6.5 Dropped Frames

A dropped frame occurs when a frame in your video is skipped during the recording process because the hardware (e.g. frame-grabber, laptop) cannot keep up with the data rate coming from the camera. Single frames may be duplicated, as described in the process below, or sometimes several frames may be missed in the recording process. As each frame is important in detecting the most accurate time of reappearance or disappearance it is important to know if any frames were affected or dropped around these crucial times in the recording.

The input signal from your camera to a DVR or a framegrabber is a continuously varying analogue voltage which must be converted to a digital frame before it can be recorded. The conversion process uses a high speed Analogue to Digital (A to D) converter which is designed to handle the expected speed of the video stream. The PC or DVR processor receiving the video stream must then pass the digitised data to a Hard Disk Drive (HDD) which may have unpredictable overheads and delays depending on the compression algorithm (or CODEC) used and the speed and bandwidth of the HDD and its interface. If the processor cannot keep up with the input stream it has no option but to drop a frame. In some cases it inserts a duplicate of the

previous frame into the buffer (so that the image may seem to 'freeze' momentarily) and in some cases it just leaves out the frame altogether (so that the image appears to jump). Dropped frames can be detected in several ways.

a) The field counter or millisecond time inserted by the VTI will be identical on adjacent frames.

b) Two or more sequential frames contain identical star measurements.

c) The field counter shows a larger than expected gap e.g. an increase in the counter larger than two for each frame if multiple frames are missing.

See the *Fields and Frames* box on page 51 for more information on the difference between fields and frames and how to read the field counter.

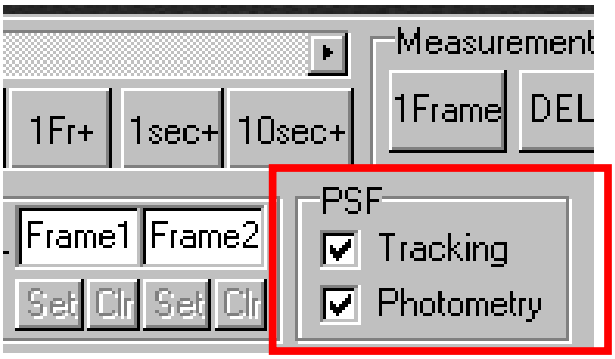
In most cases these dropped frames will not be a problem unless they happen to be at the critical time of a disappearance or reappearance in which case you will lose one or more frames. This should be reflected in the accuracy estimate in your report.

6.6 Aperture Photometry versus Point Spread Function

When a light curve is created, the software measures the relative brightness of the star (i.e. performs photometry) for each frame to create the light curve. For occultations there are two main methods of photometry: Aperture photometry and Point Spread Function (PSF). Aperture photometry is where the pixel counts (of a star image) within a circle centred on the object is measured and then has the average count of the background sky subtracted from it. PSF is where the relative intensity of the pixels across a star image are fit to a Gaussian curve distribution and the background noise level is subtracted. Saturated pixels are discarded from measurement. See Appendix 5: *Concerning Image Saturation, Photometry and Stellar Diameter* by David Herald for further information. Both *LiMovie* and *Tangra 3* allow you to choose which method to use, but you must have the latest version of *LiMovie* to do so (See *6.1.1 LiMovie* above).

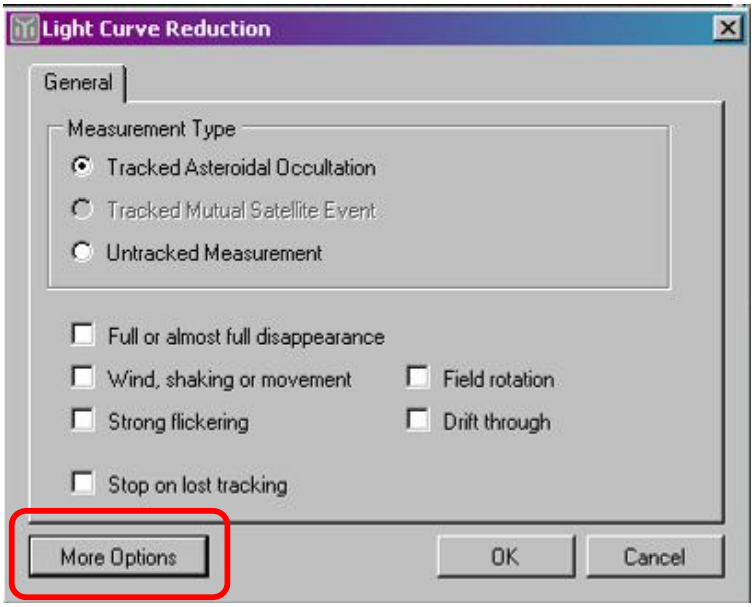
6.6.1 Photometry Methods in LiMovie

If you have the latest version of LiMovie you should see a PSF box in the main menu.

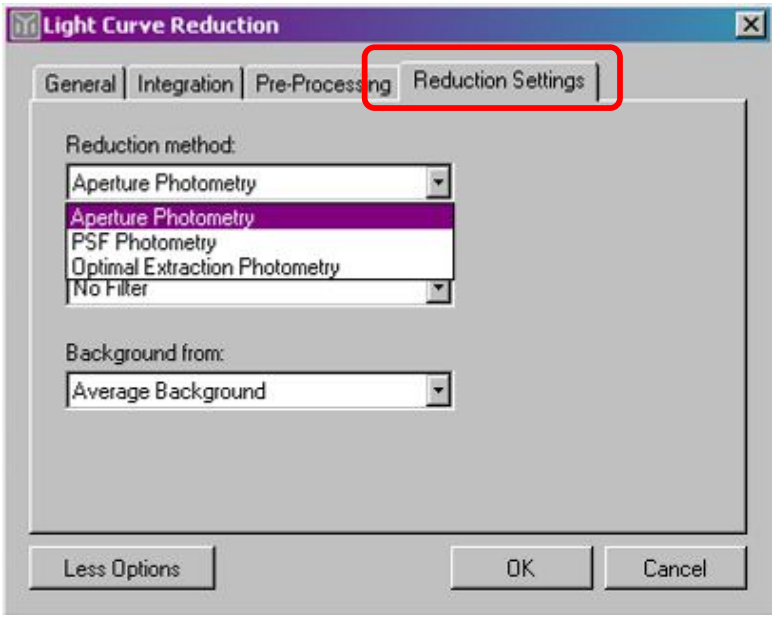


6.6.2 Photometry Methods in Tangra

When you use *Tangra* you will be able to choose which method is to be used to create the light curve. When the Light Curve Reduction dialogue box appears at the beginning, click on the **More Options** box to make more tabs appear.



When the extra tabs appear at the top choose **Reduction Settings** and then open the drop down box to choose your method of photometry.



6.7 Reading the Light Curve

Both *LiMovie* and *Tangra* have graphing options which allow you to see your results in graphical form and so can assist in determining event times. Both programs can create a CSV file which can be loaded into MS *Excel* or other spreadsheet programs, and in which you may perform other operations to enhance the signal to noise ratio (SNR) of the results. *Tangra* will also save files in the new .lc graphic format, which can then be easily shared with others using the same software.

6.7.1 The Effects of Fresnel Diffraction

If a point source (e.g. a star with no apparent angular size) is occulted by a straight edge (e.g. the asteroid's limb moving perpendicularly towards the star) in general the star's light will be seen to drop abruptly as the star is occulted. In such cases the point of occultation is taken as the point at which the change in light reaches the 25% level. This will be the case for most events you record. Sometimes it is easy to pinpoint the 25% point, and sometimes it may be more difficult to determine this point without very close examination of the light curve.

What actually happens is that when a star is occulted diffraction takes place at the limb of the asteroid, and the star's light appears to oscillate for a time before the geometric occultation takes place, as seen in Figure 6.2 below for a reappearance event. This phenomenon is known as *Fresnel diffraction*.

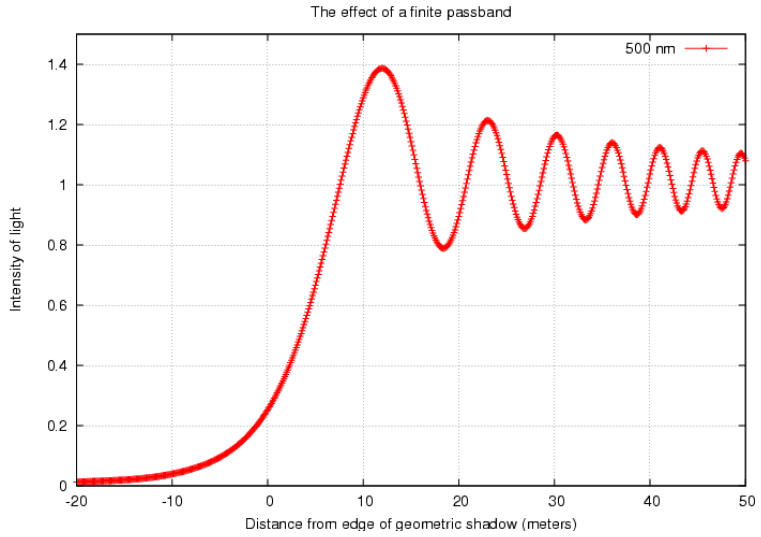


Figure 6.2: A graphical representation of Fresnel diffraction as expected at a reappearance event.
Source: http://spiff.rit.edu/richmond/occult/bessel/bessel.html

The visibility of the diffraction pattern is governed by several factors.

1) Signal to noise:
The less noise in the signal, the greater the chance of seeing one or more diffraction fringes.

2) The colour of the starlight reaching the detector:
Light of different wavelengths produces diffraction fringes with slightly different

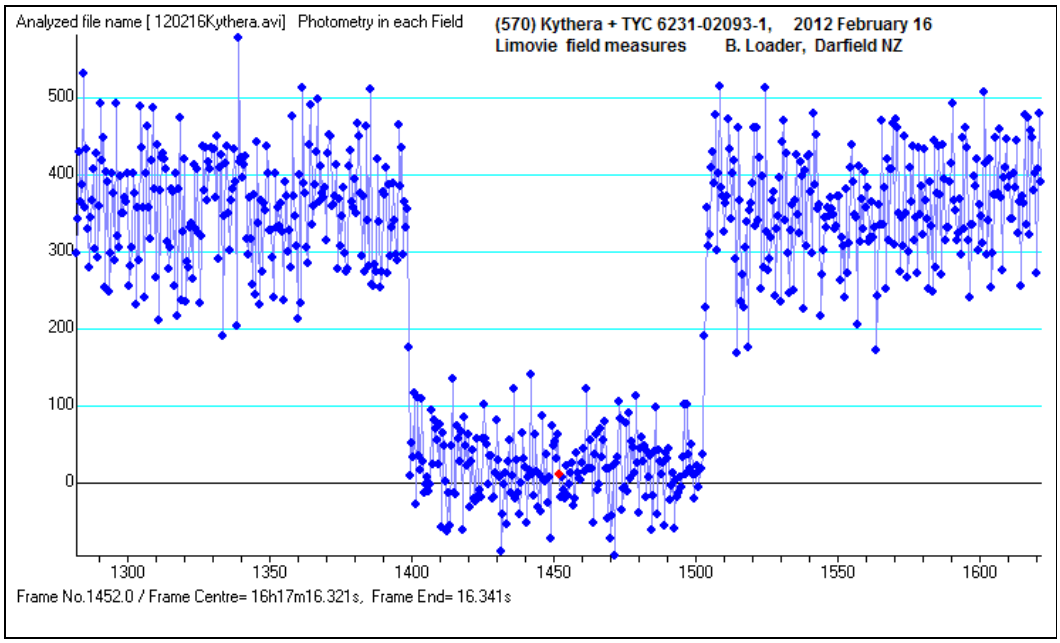
frequencies, so that in white light - which is a combination of all the colours - the fringes from all the colours tend to blur each other out. You can restrict the wavelengths of light reaching your detector by using a filter, but the more narrow the bandpass of the filter the less light overall will reach your detector and the lower your signal to noise ratio will be.

3) Time Resolution:
The frequency of diffraction fringes is typically of order a few milliseconds. If you observe an event where exposures are being integrated - thus lessening the time resolution - this will lessen the chances of seeing a diffraction pattern. However in cases where the timescale of the event itself is lengthened - e.g. where the star may just skim the edge of the asteroid - the diffraction pattern may be spread out to many times its normal width, making fringes more visible.

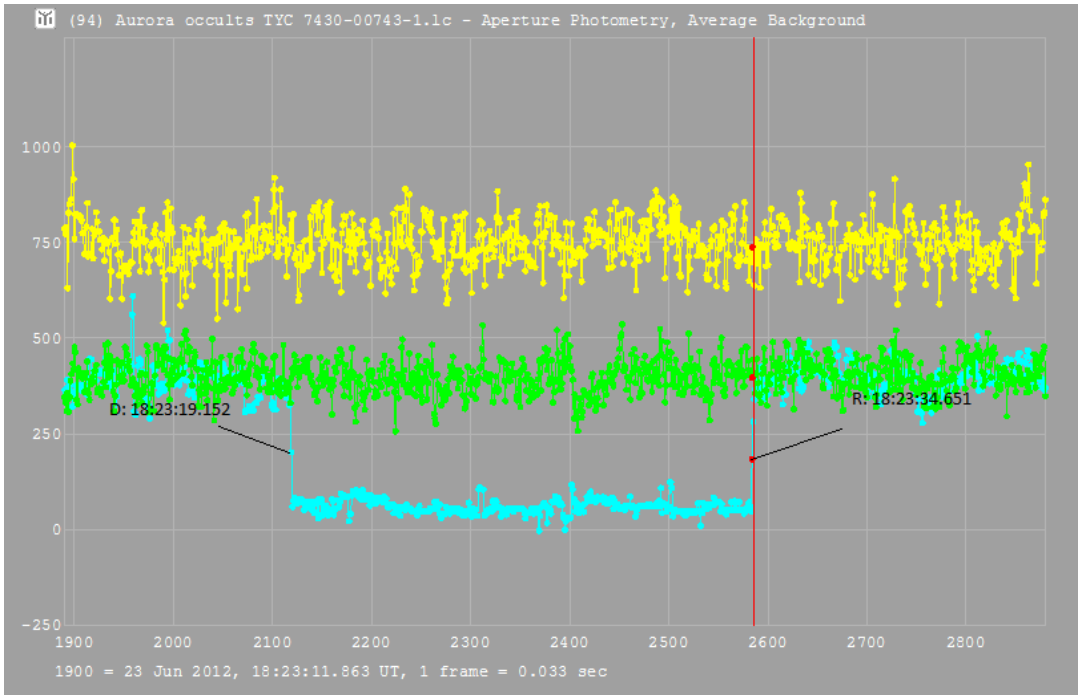
4) Stellar Angular Diameter:
Most stars have very small angular diameters - of order two milliarcseconds or less - and for all intents and purposes they can be regarded as point sources. However in the case of stars with large angular diameters - e.g. Aldebaran (20 mas), Antares (40 mas) - the angular diameter of the star will affect the shape of the diffraction pattern. In fact, the shape of the diffraction pattern can be used to estimate the angular diameter of the star. In cases of very large stellar angular diameter where the star might take a significant time to be occulted, then then no diffraction pattern will be visible and the point of geometric occultation can be taken as the level at which the star's light has changed by 50%.

Subject to the above provisos, in most cases where diffraction is visible the point of geometric occultation can be taken as the point where the light intensity drops to 25% of its pre-occulted value.

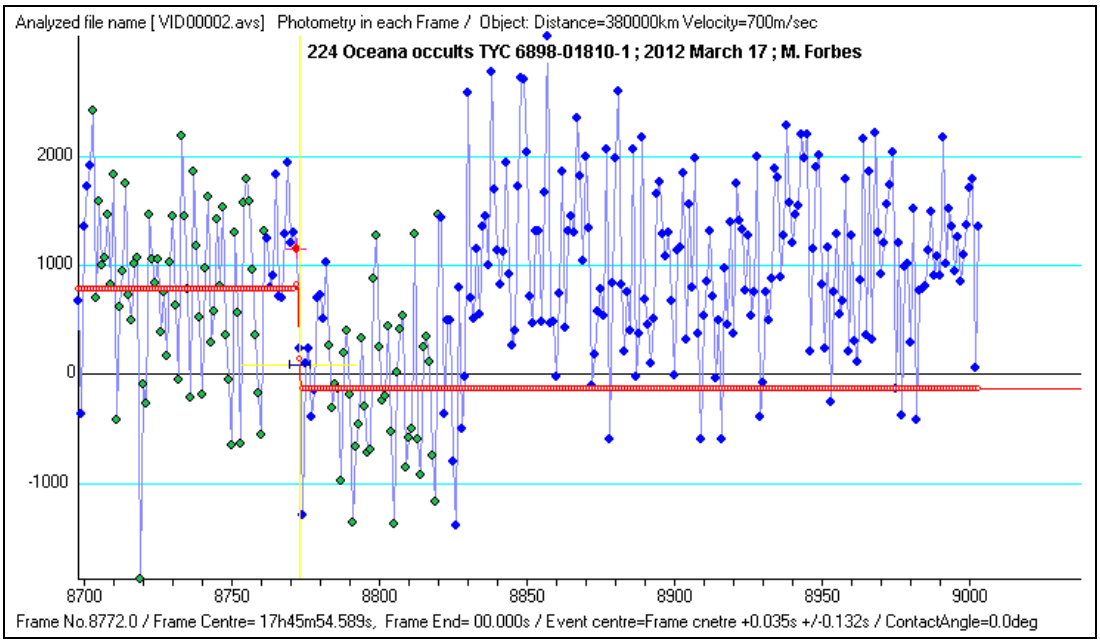
Below are some examples of light curves to give you an idea of what various events and effects will look like and, in some cases, how they were read to provide the correct event times.



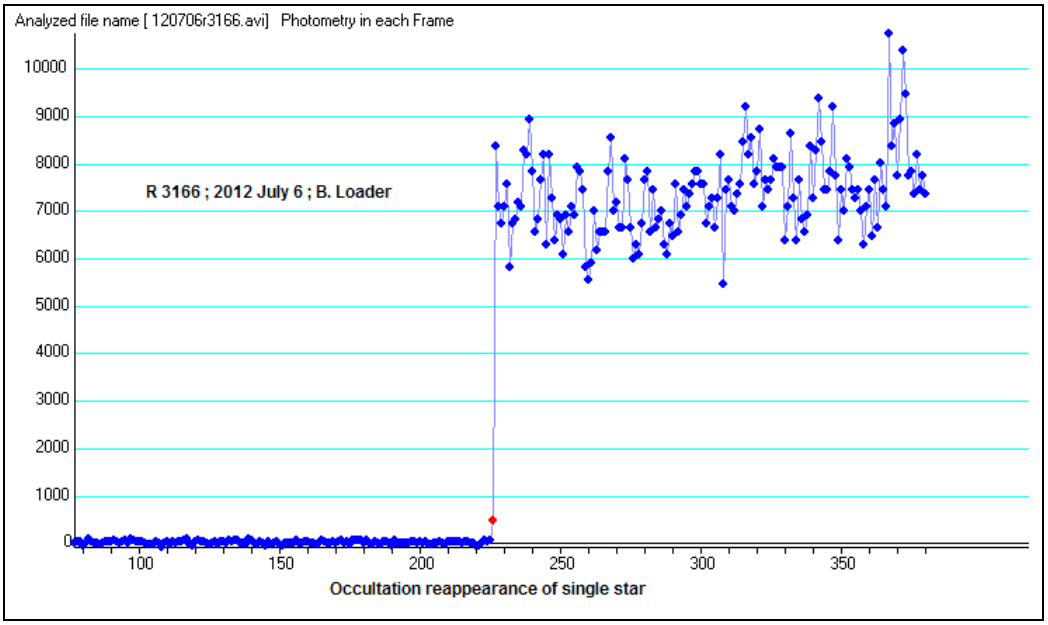
Example1: A typical asteroidal occultation analysed with *LiMovie*. The star disappears and reappears in one or two frames. (Source: B. Loader)



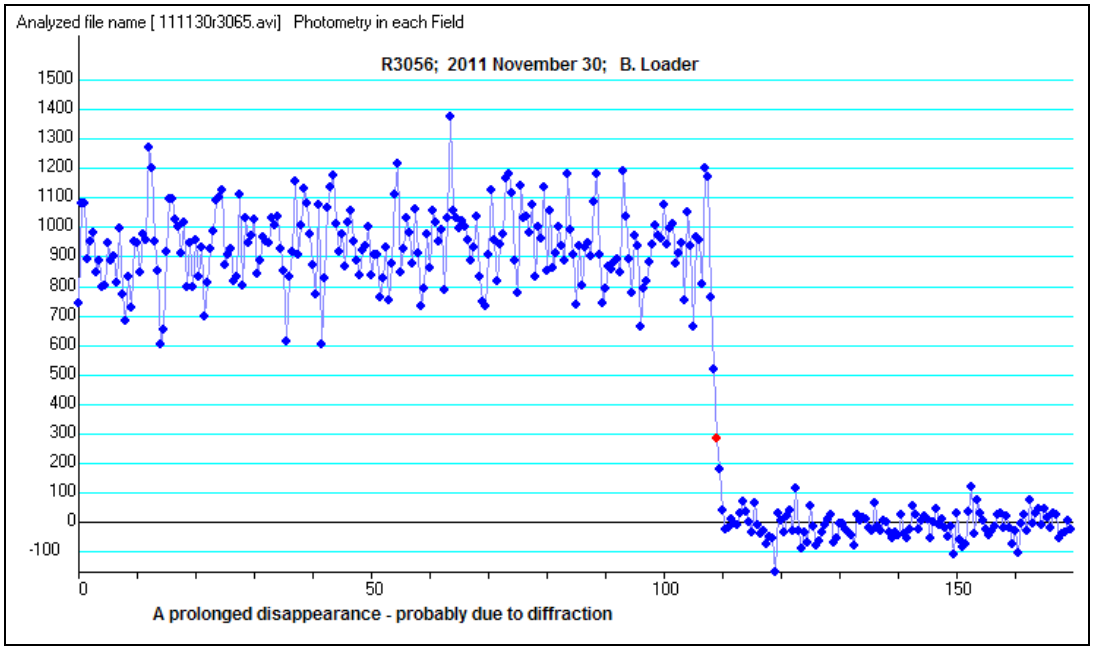
Example 2: The frames where disappearance and reappearance were measured for this occultation of (94) Aurora are indicated in this example from *Tangra* (Source: C. Chad)



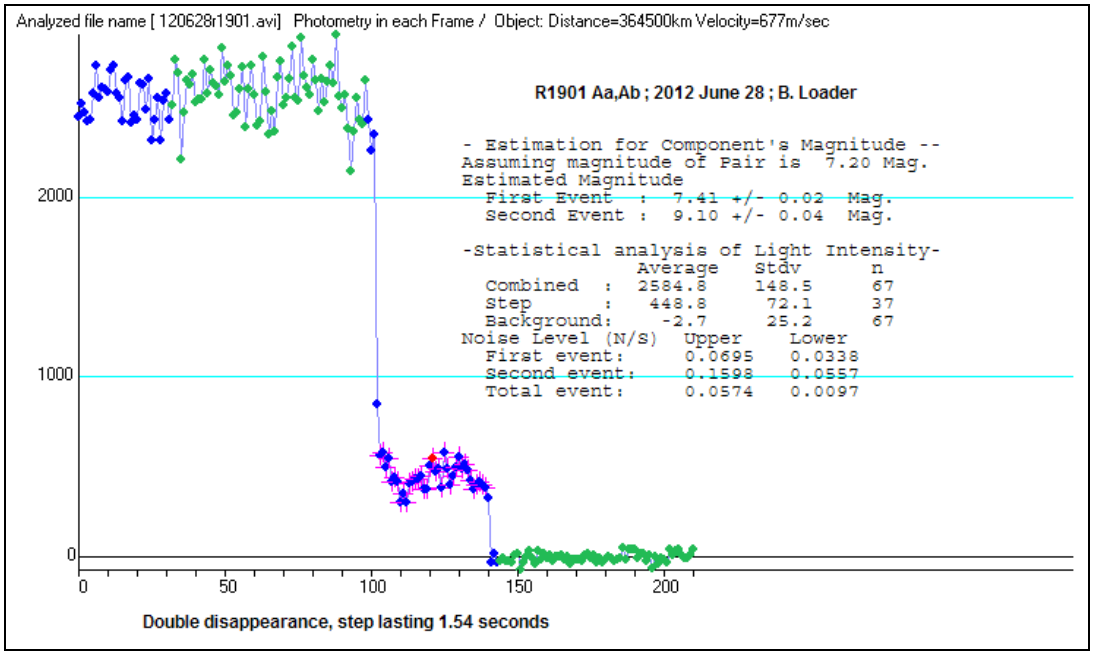
Example 3: A typical asteroid occultation with a noisy signal analysed in *LiMovie*. (Source: M. Forbes)



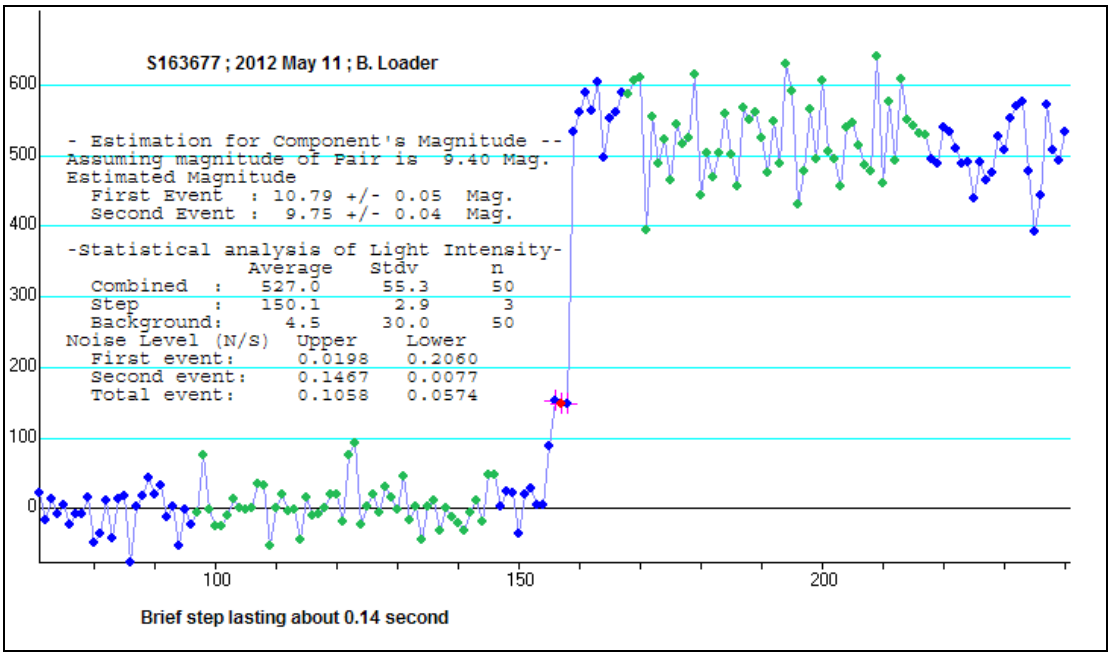
Example 4: Reappearance of a single star from a total lunar occultation (Source: B. Loader)



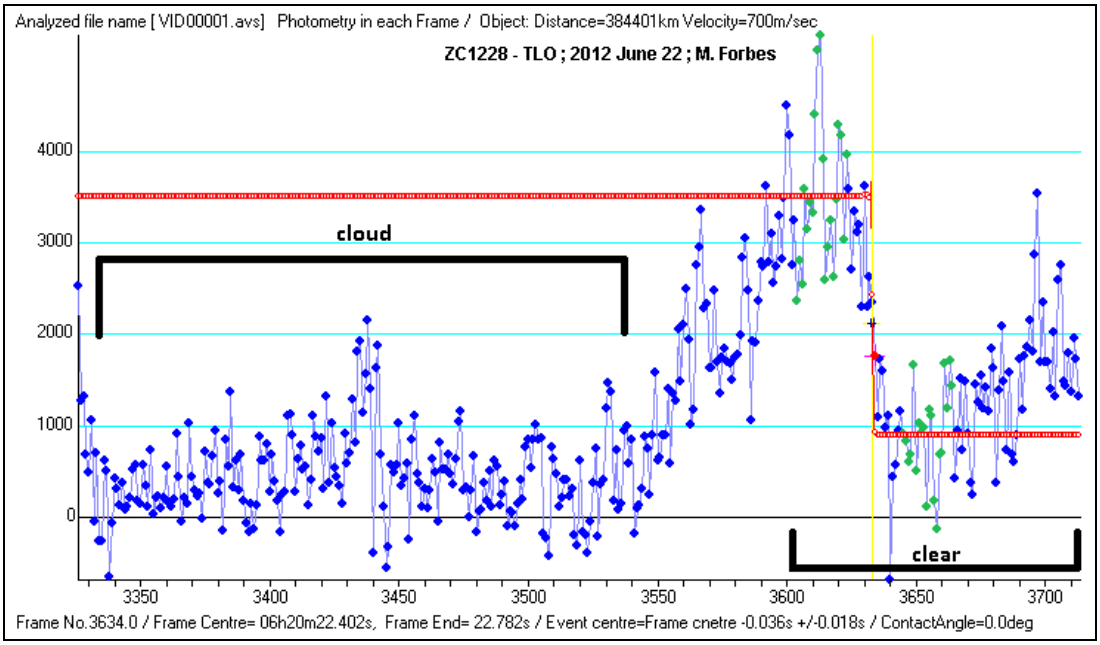
Example 5: Disappearance of a large star during a total lunar occultation. Because of the angular diameter of the star it takes several frames to be completely occulted, in which case the time should be read at the 50% level. (Source: B. Loader)



Example 6: Disappearance of a double star during a total lunar occultation. Note the "step" in the light curve where only the fainter secondary star in the pair is visible, the primary star already having been occulted by the Moon. (Source: B. Loader)



Example 7: Reappearance of a double star with a small separation between components. (Source: B. Loader)



Example 8: The effect that cloud can have on your signal strength during an occultation. (Source: M. Forbes)

6.7.2 Low magnitude difference results

When the star is of similar brightness to or fainter than the occulting object the dip in magnitude in the light curve may not be obvious. There are two software programs that may be of assistance.

The Asteroidal Occultation Time Analyser (*AOTA*) is part of *OCCULT* and can be accessed via the Asteroid Observations page in *OCCULT*. To use this program a light curve must first be generated by either *LiMovie* or *Tangra* and then exported as a CSV file. That file can then be imported into *AOTA* for further analysis.

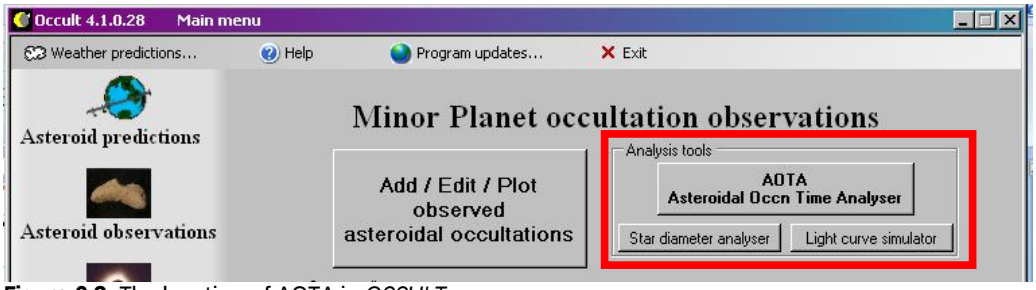


Figure 6.3: The location of AOTA in *OCCULT*

There is also the software tool *Occular*, which is intended to help find a statistically probable event. However, it is recommended that you seek the advice and assistance of experienced observers before you use this program. *Occular* can be downloaded from http://www.asteroidoccultation.com/observations/

6.8 Determining the Time from the Video Frame

Once you have determined the frame on which the star disappears/reappears, read the time from the time stamp on that frame, and then if required apply a correction depending on the camera and the integration setting that was used. Time corrections for integrating video cameras are covered in the following section, *6.9 Time Corrections for Integrating Cameras*.

Note that a correction needs to be applied to the times derived from the output of a Watec camera, even if no integration is used.

6.8.1 Reading the time from a KIWI-OSD frame

Referencing the example below, the components of the time stamp from a KIWI-OSD are thus:

The time in UTC in hh.mm.ss format.

The time in milliseconds of the end of the second field of the previous frame overlaid with the time in miliseconds of the end of the second field of the current frame. The numbers are blurred because of this overlay.

The end time of the first field in the frame is always clear.

The sequential field count since the unit was turned on.



So in this example the time should be read as **13:29:01.596** i.e. 13 hours, 29 minutes, 1 second and 596 milliseconds.

When viewing frames (i.e. the two fields making up the frame are overlaid) each exposure has a duration of 33.3 ms (1/30th sec) in an EIA (NTSC) system and 40 ms (1/25th sec) in a CCIR (PAL) system. So if an event occurs we can only give the time of the event as the 'middle' of the exposure +/- 17 ms (rounded to the nearest ms) in an NTSC system and +/- 20 ms in a PAL system.

6.8.2 Reading the time from an IOTA-VTI frame

Referencing the example below, the components of the time stamp are:

The number of satellites visible at the time

The time in UTC in hh.mm.ss format

The time in decimal milliseconds of the end of each of the two fields that make up the frame of the video

The field count since the unit was turned on.



With an IOTA-VTI you should always use the lowest figure of the two field time stamps, regardless of what order they appear in, as the unit will occasionally swap their order around on start up as seen below in Figure 6.4. This is not of concern and does not affect the final result. The lower number will be the mid-time of the frame. In the example above the time would be read as **10:28:46.1717**, i.e. 10 hours, 28 minutes, 46 seconds and 171 milliseconds +/- 17ms in NTSC or 20ms in PAL.



Figure 6.4: An example of the millisecond display being reversed on start up. The lowest number is the mid-time of the frame, regardless of its order on the display. In this example the time would read **11:44:16.0279**

6.9 Time Corrections for Integrating Cameras

The margin of error when using an integrating video camera will be half the length of time of the stacked frames. For example, if integrating 16 frames together then the error will be 16 x 0.020 = +/-0.0320/2 = +/- 0.16 seconds for a PAL camera, or 16 x 0.017 = +/- 0.272/2 = +/- 0.14 seconds for an NTSC camera.

In addition, if you are using the integrating function on your camera to make the star visible for the event you will need to apply a time correction to your result.

If you are using the RASNZ Excel-based report form (available from http://www.occultations.org.nz) then in the reporting process the form should automatically indicate the necessary time correction to be applied to most of the cameras in common use. There is also a box on the form to indicate whether you have applied this correction to your reported times or not.

Note that a correction needs to be applied to the times inserted on the output from a Watec camera, even if no integration is used.

Users of Gstar-Ex/Mintron cameras should be aware that certain levels of integration are not considered to be reliable for consistent timings. These levels are also indicated in the report form when you choose the integration you used in the Mode box with a triple asterisk.

If you have any doubt about applying time corrections to your results please communicate this clearly to the regional coordinator when you make your report, ensuring that you report what settings you used on your integrating camera regardless.

To read more on what time corrections to apply depending on which camera you have, the following web page by Gerhard Dangl is considered to be the definitive work on this subject:

http://www.dangl.at/ausruest/vid_tim/vid_tim1.htm

Note that there are separate tables for CCIR (PAL) and EIA (NTSC) cameras, and there is a difference between the Watec 120N and the Watec 120N+ models.

6.10 Analysing Audio Timings of Visual Observations

To analyse audio timings you can use a program like *Audacity*. This free sound editor can be downloaded from http://audacity.sourceforge.net/

A detailed description of how to used *Audacity* is given in Appendix 7: *Analysis of Occultations using Audio Techniques*, written by Dave Gault.

7.0 RESULTS AND REPORTING

Please note that the following information is intended only for observers in Australia, New Zealand and the Pacific Islands. If you are observing in other regions of the world you should contact your local reporting co-ordinator for the correct forms to use.

Standardised reporting forms should always be used to report your results. The forms differ between lunar and minor planet occultations. The options are described below.

7.1 Total and Grazing Lunar Occultations

Timings of total and grazing lunar occultations used to be collected by the *International Lunar Occultation Centre* (ILOC) in Japan, but in 2008 the *International Occultation Timing Association* (IOTA) took over this responsibility. Observations made worldwide are now collected by local co-ordinators and passed on to IOTA's global co-ordinator.

Under current arrangements observers in Australasia should send their timings via your local RASNZ Occultation Section country co-ordinator. This enables a preliminary reduction of your timings to be made, and allows the co-ordinator to quickly advise you of any problems. It also helps the Occultation Section keep track of how many occultation observations are being made in Australia and New Zealand annually. After a preliminary reduction your data will be batched with others and ultimately archived at the seven Astronomical Data Centres of VizieR.

The email addresses of the current Australian and New Zealand co-ordinators can be found on the RASNZ Occultation Section website at http://www.occultations.org.nz/ (Go to the "Occultation Reporting Process and Tools" link on the left of the home page).

You can report your lunar occultation timings in one of four ways:

1. ***OCCULT*:** Use the report form provided in *OCCULT* (See Section 2.1.2.1). This can be found in the Lunar Observations section by clicking the "Add/Edit/Plot observed Lunar Occultations" button at the top (See Figure 7.1 below). A quick guide to using this form is given in *Appendix 8: How to fill out a Monthly Lunar Occultation Report Form*, and it is recommended that you also read the Help file in *OCCULT*.

   Note: The ability to email observations from *OCCULT* assumes you have an email account using an 'SMTP' server. If you use a browser-based email service (such as Hotmail) you may have to manually create the report using the options below.

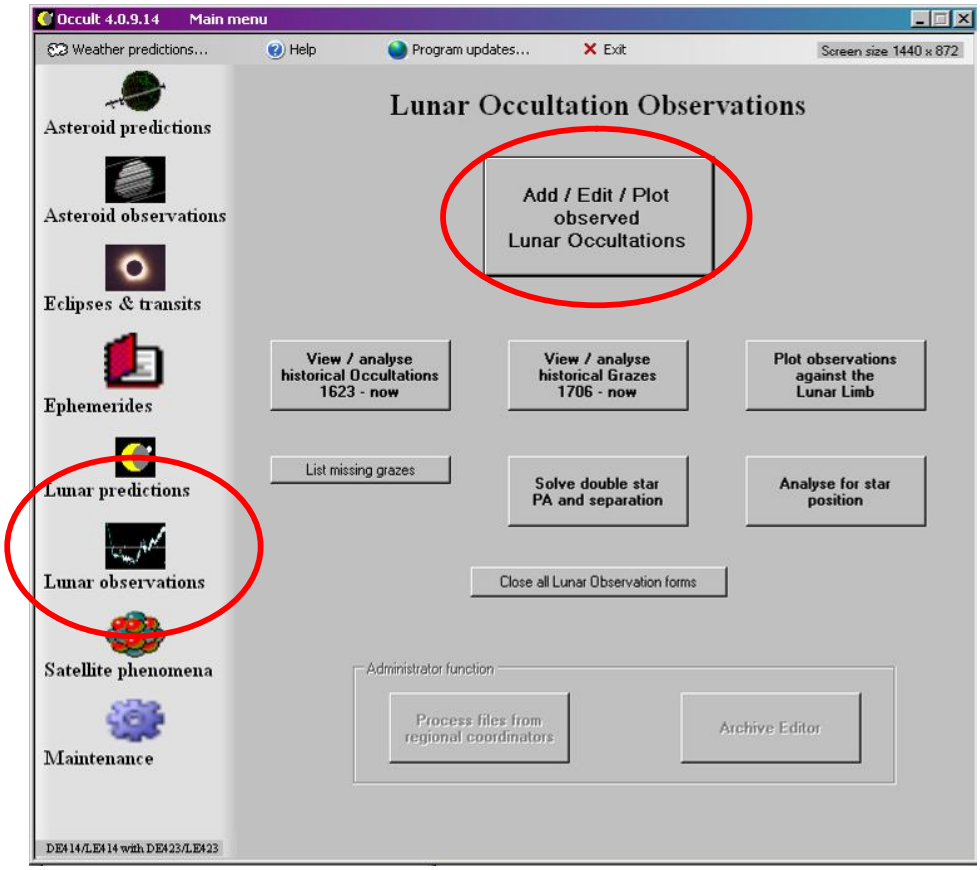


Figure7.1: The lunar occultation reporting form in *OCCULT* is found on the Lunar Observations page. Click on "Add/Edit/Plot observed Lunar Occultations" to open the form.

2. **Lunar Occultations Report Form:** Available from the RASNZ Occultation Section website at http://www.occultations.org.nz/report.htm It requires that you have either *Excel* or *OpenOffice* installed first. *OpenOffice* can be found at https://www.openoffice.org/ Instructions and help for filling out the form are contained within the file. Once completed you should send this form to your appropriate regional coordinator.

3. **Standalone Lunar Reporting Software:** Available from the RASNZ Occultation Section website at http://www.occultations.org.nz/report.htm. Best used by observers who do not have *Excel* or *OpenOffice*, it is in the same format as that provided by *OCCULT*. A Help file is included.

4. **LOW, the Lunar Occultation Workbench** by Eric Limburg. This is in common use in many parts of the world, particularly Europe. It uses the same output formats as *OCCULT* for reporting and archiving. LOW also has prediction facilities and other nice features (but like *OCCULT*, is also large - about 90MB)

In all cases it is essential that observations are <u>not</u> reported twice.

Observations should be sent as a single batch report at the end of the month to your regional coordinator.

After receiving your report, the regional co-ordinator will check it and carry out preliminary reductions, which will be sent back to you. If problems are found they will likely check with you for any necessary corrections. Once they are resolved, observations will be converted to an Archive format and added to an Archive file held by the coordinator. These will be sent at regular intervals to the IOTA global co-ordinator. Ultimately the observations will be archived at the seven Astronomical Data Centres of VizieR where they are available for research.

Which catalogue does the star belong to?

When filling in your lunar occultation report form you will need to say which star was occulted. The following three formats are commonly used:

- R nnnn - A ZC star (the R comes from the full catalogue name of the *Robertson Zodiacal Star Catalog*).
- If the number lies between 57982 and 210563 it is an SAO star. When reporting occultations the catalogue is identified with an "S."
- X nnnnnn – a star from the XZ catalogue.

7.1.2 Reporting Lunar Occultations of Double Stars

If a lunar occultation of a double star is observed there is an additional report form that should be filled out and sent to Brian Loader in New Zealand. This requires a light curve graphic with associated information as generated by *LiMovie* to be included. See *Appendix 8: How to fill out Monthly Lunar Occultation Report* Form for a detailed description of how to generate the required information and fill out the report form in *OCCULT*.

The situations this report form covers are:

- Two components of a known or suspected double or multiple star
- A suspected double star that was flagged for further observation but shows no result
- Possible new discovery of a double star

Double star reports can be sent individually at any time e.g. as you complete them, so that the coordinator can compare the results with any other observations of the same star as soon as possible.

7.2 Planetary Occultations

Unlike lunar occultations, when you monitor a possible asteroidal occultation **it is important to make a report whether you see an occultation or not**. This is because even if you did not see the event, your observation might still be crucial in determining the diameter of the asteroid. For example, if you were just outside the area in which an occultation was observed, your observation may help define the southern or northern limit of the occultation band, thereby providing a constraint on the deduced size of the asteroid. There are many occasions where such negative observations have been crucial.

You can report your observations in the following ways:

- **RASNZ Occultation Section's *Asteroid Occultation Report Form*,** available at http://www.occultation.org.nz/report.htm. Instructions for completing the form are included in the file (see tabs at bottom of screen). An example of a blank form is shown in Figure 7.2 below. Some of the spaces in the form have pre-populated drop-down pick boxes to aid you in filling out the form, as seen in Figure 7.3. It is a good idea to fully familiarise yourself with this form before recording an occultation.

- **Occult Watcher pre-populated report form**, available as an Add-in to the program. This takes the basic information of the minor planet, the star to be occulted and your location information and pre-populates a RASNZ Occultation Section's Asteroid Occultation Report Form (as described above) in *Excel*. You will still need to fill out the details such as the times you observed and the equipment you used. Once installed, it can be accessed by right-clicking the event and going to "Report an Observation".

  Note 1 -The comments section may be used to include extra information on settings or conditions. These comments are included with the published results; for examples of what to include in this section browse through past reports of events as presented in the Recent Minor Planet Successes page, accessed from the Occultation Section's website.

  Note 2 – It is becoming common to attach an image of the resulting light curve for a positive observation. Although it is not essential, it does allow other observers to assess your results independently for possible errors in analysis.

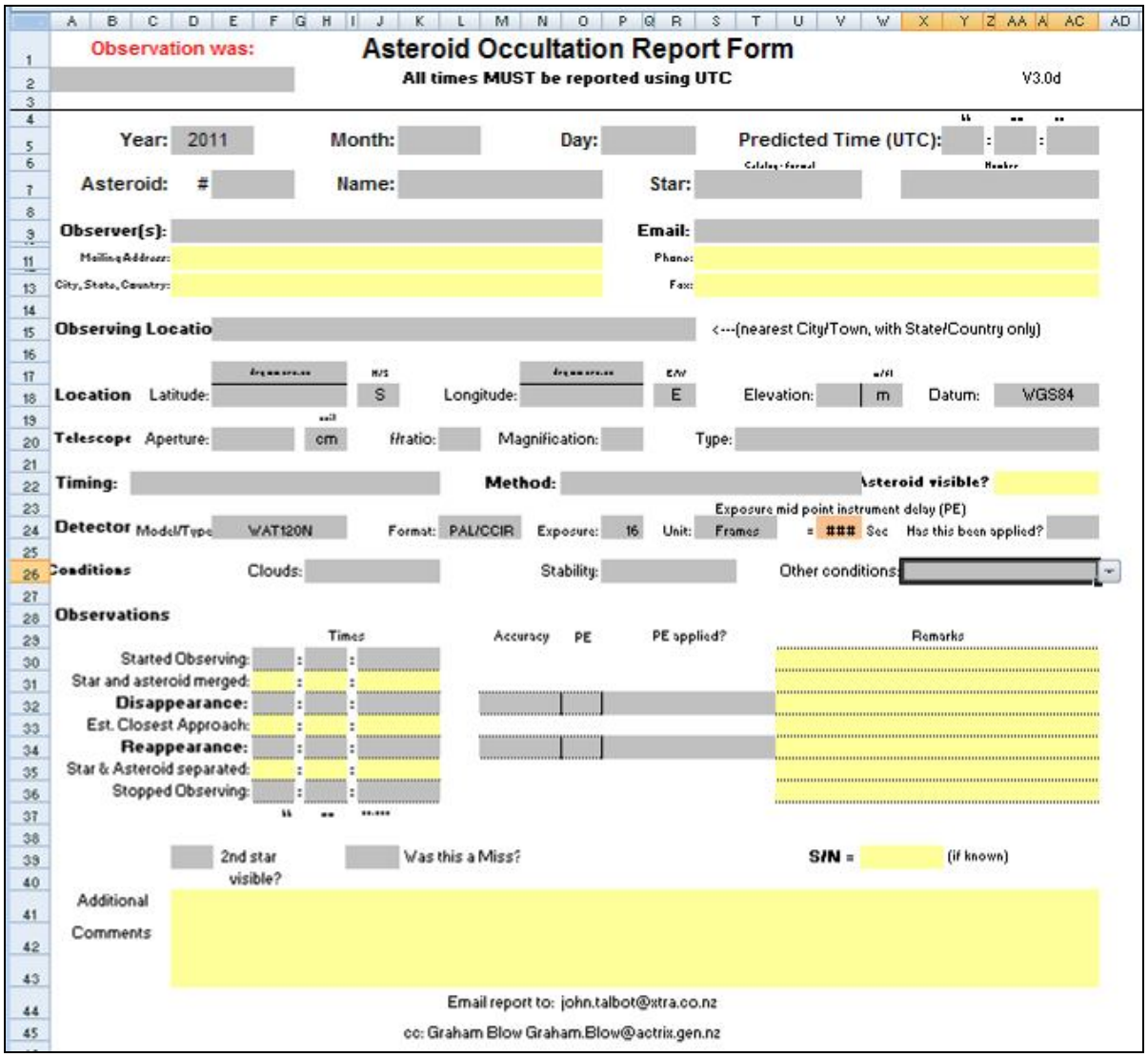


Figure 7.2: A blank example of the RASNZ Occultation Section's *Asteroid Occultation Report Form*, available at http://www.occultations.org.nz/report.htm.

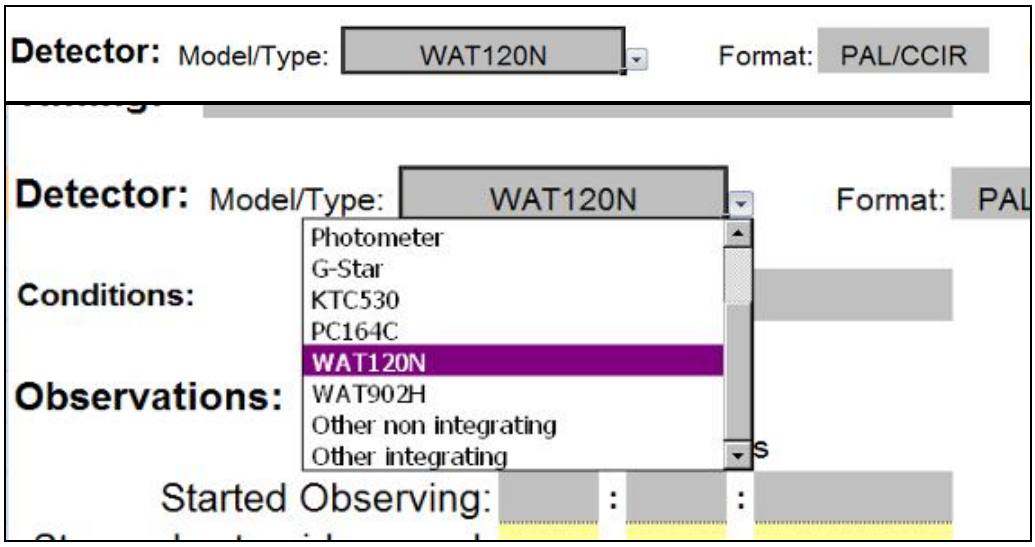


Figure 7.3: Several boxes in the report form have drop down pick-boxes to help you fill in the form. Select the box on the form and an arrow will appear on the right hand side to indicate that there is a drop down box with pre-populated information to choose from.

7.2.1 Naming Conventions

Reports submitted to the RASNZ Occultation Section should conform to a standardised naming convention. This helps the co-ordinators to efficiently deal with your reports and to combine them with reports from others.

All files associated with an event should be reported using the following naming standard (including the underscores "_" where indicated):

<YYYYMMDD>_<AstNbr>_<AstName>_<StarCat>_<StarNbr><+/-><ObserverName>_<St1/St2>_<Ev1/Ev2>_<Comment>.<FileExtension>

where:

2. <YYYYMMDD> = the year using all four digits, month and day
3. <+/-> = a positive (+) or negative (-) event (Note: **Not** <+/_>)
4. <St1/St2> = Observing site 1 or 2 for one observer using multiple sites; may be omitted if not applicable.
5. <Ev1/Ev2> = Event number, for use with double stars, binary asteroids, etc - may be omitted if not applicable.
6. <Comment> = Anything about the observation that needs to be especially flagged
7. <FileExtension> = .xls, .lc, .csv, .jpg, .gif, .png etc

So some example valid report names might be:

- 20130412_705_Erminia_UCAC2_15977111_Loader.xls
- 20130412_705_Erminia_UCAC2_15977111_Loader_St1.xls (Observation made at Site 1 of 2)
- 20130412_705_Erminia_UCAC2_15977111_Loader_Ev2.xls (Event 2 of multiple events)

- 20130412_705_Erminia_UCAC2_15977111_Loader_St2_Ev2.xls
- 20130412_705_Erminia_UCAC2_15977111_Loader_St1.lc (Site 1 lightcurve file)
- 20130412_705_Erminia_UCAC2_15977111_Loader_TangraLC.png (Graphic of the Tangra lightcurve)
- 20130412_705_Erminia_UCAC2_15977111_Loader_Limovie.csv (CSV output of Limovie)

7.2.2 When to Report your Observations

If you observe a positive occultation you should send a report immediately (or as soon as it is practical for you to do so). All events with a negative result should be reported by the end of the calendar month in which they were observed in.

In either case please do not delete any raw data such as video recordings before the co-ordinator has had a chance to check and reduce results as some issues may need you to revisit the raw data.

If you are uncertain about any of the information in the report you should alert your regional co-ordinator when you submit the report. They will be able to review the report and assist you in editing the data as required.

Please note that the RASNZ Occultation Section's *Minor Planet Occultation Report Form* is intended only for observers in Australia, New Zealand and the Pacific Islands. If you are observing in other regions of the world you should contact your local reporting co-ordinator for the correct forms to use.

Trans Tasman Symposia on Occultations

To learn more about current techniques and advances in the field you are strongly encouraged to attend a Trans Tasman Symposium on Occultations (TTSO). The meetings are held each year, alternating between Australia and New Zealand. During even years the Symposium is held in conjunction with the National Australian Convention of Amateur Astronomers (NACAA) in Australia and in odd years it is held in conjunction with the Annual Conference of the Royal Astronomical Society of New Zealand (RASNZ).

General NACAA and RASNZ Conference information can be found at:
NACAA: http://www.nacaa.org.au/
RASNZ: http://www.rasnz.org.nz/

Details of TTSO meetings are flagged on the RASNZ Occultation Section's Website at:
http://www.occultations.org.nz/

Schedule of Symposia:

TTSO1: RASNZ Annual Conference 2007, Auckland, New Zealand

TTSO2: NACAA XXIII, 24 March 2008, Penrith, NSW, Australia,

TTSO3: RASNZ Annual Conference 2009, Wellington, New Zealand

TTSO4: NACAA XXIV, 5 April 2010, Canberra, ACT, Australia

TTSO5: RASNZ Annual Conference, 26-27 May 2011, Napier, New Zealand

TTSO6: NACAA XXV, 9 April 2012, Brisbane, Qld, Australia

TTSO7: RASNZ Annual Conference 2013, 27-28 May, Invercargill, New Zealand

TTSO8: NACAA XXVI, 21 April 2014, Melbourne, VIC, Australia



Participants at TTSO6, April 2012, Brisbane, Australia.

Appendices:

Appendix 1: Web links

Appendix 2: CCTV Adaptors

Appendix 3: Introducing GPS-ABC, A GPS based precision clock and occultation timer

Appendix 4: How to Pre-Point Your Telescope

Appendix 5: Pre-pointing an Equatorially Mounted Telescope

Appendix 6: Concerning Image Saturation, Photometry and Stellar Diameter

Appendix 7: Basic Analysis of Occultation Events Using LiMovie

Appendix 8: Analysis of Occultation Events Using Audio Techniques

Glossary

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Appendix 1: Web Links

Astronomical Digital Video System (ADVS)
http://www.kuriwaobservatory.com/ADVS

Audacity
http://audacity.sourceforge.net/

Avisynth
http://avisynth.nl/index.php/Main_Page

Beeper Sync
http://www.hristopavlov.net/BeeperSync/

C2A (chart software)
http://www.astrosurf.com/c2a/english/

Cartes du Ceil (chart software)
http://www.ap-i.net/skychart/start

Datum conversion – Australia
http://www.ga.gov.au/geodesy/datums/redfearn_grid_to_geo.jsp

Datum conversion – New Zealand
http://www.linz.govt.nz/geodetic/software-downloads/nzmapconv

DriftScan method for CCD cameras
http://www.asteroidoccultation.com/observations/DriftScan/Index.htm

Grazing occultation information
http://www.occultations.org.nz/graze/grazoccs.htm

Gstar Capture software
http://www.myastroshop.com.au/guides/gstar/index.htm

IOTA
http://www.occultations.org/

IOTAoccultations Yahoo Group
https://groups.yahoo.com/neo/groups/IOTAoccultations/info

IOTA-ES website
http://www.euraster.net/

IOTA-VTI ordering and information
http://videotimers.com/home.html

KIWI-OSD operating information
http://sites.google.com/site/kiwiosd/
and
https://sites.google.com/site/kiwiosd/example

Limiting magnitude calculator
http://www.cruxis.com/scope/limitingmagnitude.htm

LiMovie
http://astro-limovie.info/limovie/limovie_en.html

LiMovie manual
http://www.asteroidoccultation.com/observations/

Lunar Occultation Workbench
http://www.doa-site.nl/

"Mighty Minis" by Scott Degenhardt
http://scottysmightymini.com/

Occular
http://www.asteroidoccultation.com/observations/

OCCULT software
http://www.lunar-occultations.com/iota/occult4.htm

OccultWatcher
http://www.occultwatcher.net/

OpenOffice
http://www.openoffice.org/

Predictions for Pluto and other TNOs
http://www.lesia.obspm.fr/perso/bruno-sicardy/

Pre-pointing using Guide 8
http://scottysmightymini.com/tools/How_to_make_Guide8_prepoints.htm

RASNZ Occultation Section
http://www.occultations.org.nz/

RASNZOccultations Yahoo Group
http://groups.yahoo.com/group/RASNZoccultations/

Scanalyzer (for analysing DriftScan observations)
http://www.asteroidoccultation.com/observations/DriftScan/Index.htm

SkippySky weather forecaster
http://www.skippysky.com.au/

Stellarium (chart software)
http://www.stellarium.org/

Steve Preston's Asteroid Occultation Predictions
http://www.asteroidoccultation.com/

Tangra 1.4
http://www.hristopavlov.net/Tangra/Tangra.html

Tangra 3
http://www.hristopavlov.net/Tangra3/

Time corrections for Watec video cameras
http://www.dangl.at/ausruest/vid_tim/vid_tim1.htm

Timing accuracy
http://www.lunar-occultations.com/iota/timingaccuracy.htm

VirtualDub
http://virtualdub.org/

VirtualDub automatic timer
http://www.softpedia.com/downloadTag/VirtualDub+timer

Appendix 2: CCTV Adaptors

Connecting a CCTV Camera to a telescope, including focal reducers where needed.

By Jonathan Bradshaw

Thankfully for International standards, all CCTV cameras with interchangeable lenses come with a thread called a 'C-Mount'. In its simplest configuration, we use a C to 1.25" adaptor sometimes called the nosepiece. This nosepiece screws into the camera and allows it to be mounted to a telescope in exactly the same way as a regular 1.25" eyepiece. If the telescope has a 2" focuser, then a standard eyepiece 1.25" to 2" adaptor will be required too.



Watec camera mated to a high quality C-1.25" nosepiece

Using a high quality nosepiece ensures a solid connection and will enhance the telescopes ability to achieve and maintain a good focus. Poorly machined parts or ill-fitting adaptors will only serve to exasperate issues where multiple adaptors might need to be stacked as seen below.

Getting your camera into focus can be a significant issue. Schmidt Cassegrain Telescopes, and other similar designs are fortunate in having a very wide focus range and can usually accommodate a camera and any accessories without focus issue. Newtonian telescopes on the other hand, especially those designed prior to the DSLR revolution, may not have sufficient inward travel for the camera to come to focus. Without making modifications to the telescope itself, the situation can sometimes be rescued with ultra low profile adaptors machined for the purpose



Machined 2" adaptor used to get focus in a low profile focuser on a 20" Dobsonian designed for visual work

Refracting telescopes can also present their own challenges. Older style refractors have long draw tunes and can easily accommodate the necessary in-travel required to achieve focus. Modern

refractors are often designed only to achieve visual focus with a diagonal mirror in place. This ensures that the draw tube is kept short which is a good thing for the overall rigidity of the telescope but means that when the diagonal is removed, an extra adaptor will need to be introduced to give the required length



A highly rigid refractor setup with (L to R) 2" to T2 Adaptor with extension, T2 to C Adaptor with extension, Camera

Sadly, most astronomers are not fortunate enough to have a telescope which is a perfect focal length for the CCD chip (the sweet spot for standard definition CCTV is somewhere between 700mm and 1100mm). So you will be looking to add a focal reducer of some variety to overcome that issue. Focal reducers though, come in many shapes and sizes which need to be adapted accordingly:

- **Prostar .5 nosepiece.** This focal reducer is specifically designed for astronomical use of CCTV cameras and acts a nosepiece too, giving a solid mount in all telescope types.



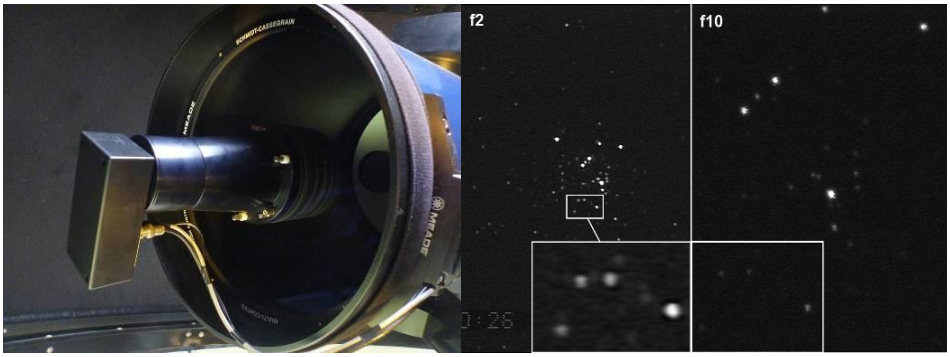
Prostar FR on a Gstar-EX Colour camera

- **Meade .6 and .3 reducers.** Designed for optimal use on high f ratio Schmidt Cassegrain Telescopes, but may be of use on Newtonians too (Subject to field distortion)



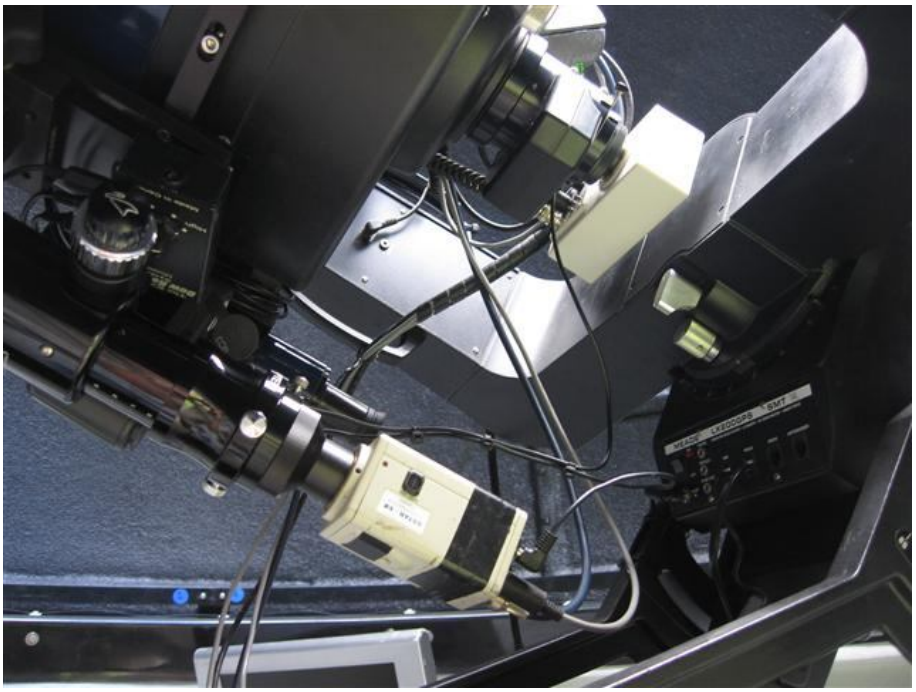
The Meade f3.3 Focal reducer is connected to a modified GStar-EX camera using a low profile C-T2 adaptor

- **Hyperstar**. This system replaces the secondary mirror of a compatible Schmidt Cassegrain Telescopes and converts the instrument to f2, making the camera much more capable of seeing fainter stars with less integration, and giving a wide field of view.



Modified Gstar-EX on 14" Meade Hyperstar with field comparison with identical camera settings

The overall aim is to have a solid mounting between telescope and camera with the fewest components possible. This rigidity will ensure that the camera's tiny field of view, which is unlikely to ever be more than half a degree and often much less, is not compromised by flexure in the system of adaptors and focal reducers.



Appendix 3: Introducing GPS-ABC, A GPS based precision clock and occultation timer

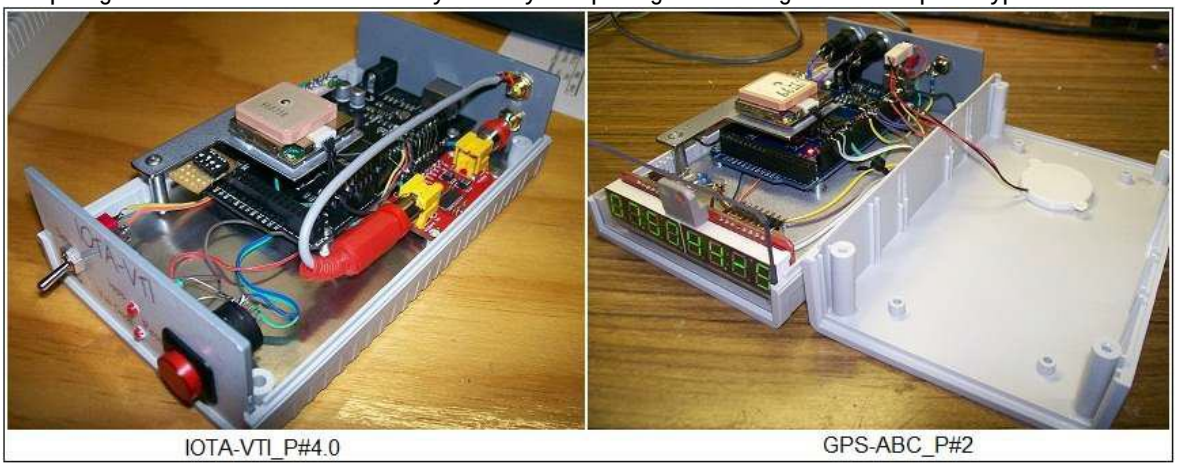
By Tony Barry and Dave Gault
20 April 2012

Encouraged by the success of the IOTA-VTI[1], the developers have added another device to the pedigree of precision timing equipment designed to support the occultation observer - specifically in the case of GPS-ABC – for the visual observer or for use as a backup for the video observer.

Historically, thousands of occultation observations have been performed worldwide using shortwave radio transmissions as the time base. However, gradually the radio based services are closing down their transmitters and as of the date of writing, only stations WWV and WWVH can be received in Australia and New Zealand. The observing technique is simple: the observer arranges for a tape recorder to record both the sound of the short-wave time transmissions and the sound of his/her voice as called from the telescope, calling "gone" when the star disappears and "back" when the star reappears. Afterwards the audio recording is analysed to retrieve the timings - however, if the radio reception is poor (more noise than signal) this may prove to be difficult. A device with a clear and accurate time signal would improve the reliability of retrieving the time of the observation.

Recently video observations, particularly those that are Video Time Inserted (VTI) have become the norm, and it might be assumed that visual observations have become "old hat." But this is not so, as seen by the 2011 July 19th 90 Antiope asteroid occultation[2] where three visual observers made valid observations out of the total of 58 observations, the balance being video or photoelectric in nature. Sure, video seems to have taken over the scene, but with the proliferation of huge Dobsonian telescopes, a keen visual observer can still make a valuable contribution if suitably equipped with a device that gives a clear and accurate audio time signal.

The pedigree of GPS-ABC can be readily seen by comparing these images of some prototypes:-



IOTA-VTI_P#4.0 GPS-ABC_P#2

Note: The red video titler PCB of the IOTA-VTI is replaced with two 7-Segment LED arrays, that display time, satellite fix details and (eventually) geolocation information. Of course the circuit wiring of each device is different in many respects, but the same type of processor board and GPS

module are used in both devices. Also the GPS-ABC has a piezo buzzer programmed to give a clear and coded audio time signal so that recordings of occultation observations can be easily analysed.

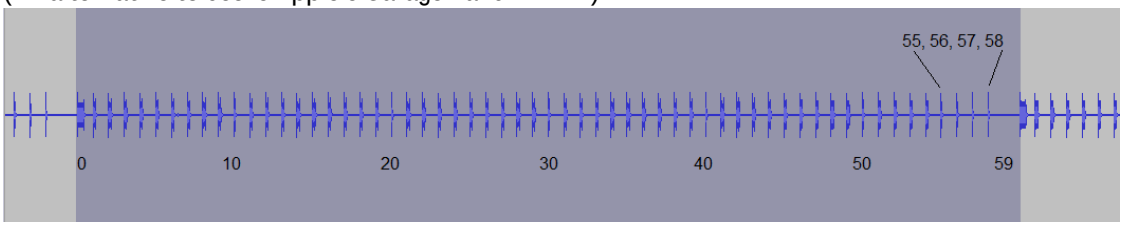


A detailed look at the front of the second prototype of GPS-ABC (P#2) shows the time and the number of satellites in the GPS fix.

Note: the red 1pps LED is on, indicating the 7-Segment array is changing the seconds, from 05:21:39 UT to 05:21:40 UT.

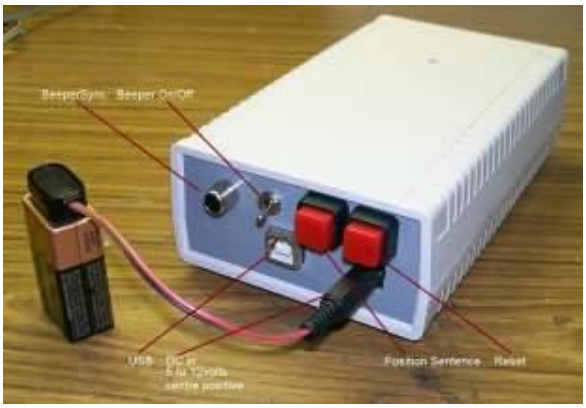
If the piezo buzzer is turned on, a coded audio beep is sounded at the instant of the second. The coded beep format is:
- every second (except those listed below) = normal beep
- beginning of the minute = long beep
- 10th, 20th, 30th, 40th and 50th seconds = short beep
- 55th, 56th. 57th and 58th second = brief beep
- 59th second = silent (no beep)

This is how Audacity[3] displays the sound of GPS-ABC coded beep.
(An alternative to use is Apple's Garage Band[4 soaftware])



Note1 :- the silent 59th second, the long zero second and (a bit harder to see) the short 10th second beeps.

Note2 :- for a complete description of how to make an audio analysis of an occultation observation recording, see Appendix 7: Analysis of Occultation Events Using Audio Techniques[5].



A detailed look at the rear of the GPS-ABC_P#2 reveals the following details, clockwise from top-right:
- the Reset push button
- the 8 to 12 volt DC (centre positive) socket
- the USB socket, used for uploading the GPS-ABC code and to power the device from a laptop
- Beeper Box synchronisation socket
- Beeper on/off switch
- the Position Sentence push button (not implemented yet)
- A good quality 9v alkaline battery will power the device for at least 2 hours.

How to acquire a GPS-ABC? At the time of writing, the device is offered open source, meaning you contact the authors and we will send you a Document Kit. This contains the Manual and other documents that describe where to purchase the individual components and how much they cost, as well as a document that describes how to modify a plastic case the authors have used in the construction of the prototypes.

Then, using simple hand tools and a soldering iron, you make your own GPS-ABC.

Also contained in the kit is the source code you will upload into the device, once the construction is complete.

This is an open-source project and subject to a Berkeley 3-clause licence, the details of which are spelled out at the end of the GPS-ABC Manual. This may change in the future if there is considerable interest in the device, sufficient to develop a Motherboard to aid assembly and reduce costs and the device may be offered as a ready to go product. Time will tell (excuse the pun).

There is a Youtube video made by Dave Gault that explains and demonstrates the device[6].

At this point in time the authors consider this a useful device to be used as the time-base for occultation observations, and so we are pleased to offer it to the occultation community. For more details, please contact the authors[7].

Tony Barry and Dave Gault

Notes

1) IOTA-VTI website - http://videotimers.com/home.html
2) 90 Antiope occultation - http://tiny.cc/k0w1cw
3) Audacity by soundforge - http://audacity.sourceforge.net/
4) Garage Band (Apple Platform) http://www.apple.com/au/ilife/garageband/
5) Analysis of Occultation Events Using Audio Techniques – *See Appendix 7 in this manual.*
6) YouTube video - http://www.youtube.com/watch?v=adeX3HTqWCk
7) Dave Gault – davegault@bigpond.com

Appendix 4: How to Pre-Point Your Telescope

Section 1: Non-tracking telescopes

Unattended telescopes can be pre-pointed to the correct area in the sky to catch the occultation. The following method is recommended for non-tracking mounts, or at least mounts that are not tracking during the recording of the event. The method involves allowing the target star to drift into the centre of the field of view of your telescope at the predicted time of the event. To do so you need to point your telescope at another area of sky at a specific time such that, when the telescope is not driven, the target star will be in the centre of your field of view at the predicted time of the event. *OCCULT, Guide* and *C2A* software will all generate a list of pre-point stars you can use.

Advantages

- No star hopping to faint targets
- You can use a bright star as a target
- You can use a less sophisticated telescope, such as a Dobsonian
- You don't have to be in attendance while the observation is made
- You can set up multiple units to record multiple chords for an event

Disadvantages

- It takes a little more work to plan an event
- The method is subject to disturbances beyond your control – people wandering by, curious animals or a change in the weather
- You can't see the asteroid approach the star

Scotty Degenhardt gives a description of how to use *Guide8* software to prepare a pre-pointing chart at http://scottysmightymini.com/tools/How_to_make_Guide8_prepoints.htm

A brief description of how to use C2A to generate a pre-pointing chart and how to generate a list of pre-point stars is given below.

Making a video finderscope is also recommended to make pre-pointing easier. This may involve modifying an existing finderscope to take a video camera or attaching a camera lens to a video camera to give a wider field of view of the sky.

The use of a focal reducer may also increase the field of view available and so increase the time the star has to drift through, increasing your chance of capturing the event.

Steps to Pre-pointing your Telescope

At home:

1. Find the details of the predicted event you wish to observe.
2. Set up a planetarium program of your choice (*C2A* or *Guide*) and generate a line that represents the line of drift that the telescope will view that leads up to the target star.
3. Find a suitably bright star to pre-point your telescope at and note the time that it must be in your telescope's field of view.
4. An alternative option that may be complimentary to steps 2 and 3 above is to bring up the event in *OCCULT* and generate a list of possible pre-point stars. Choose a star that has only a few minutes of arc offset from the centreline of the drift path.

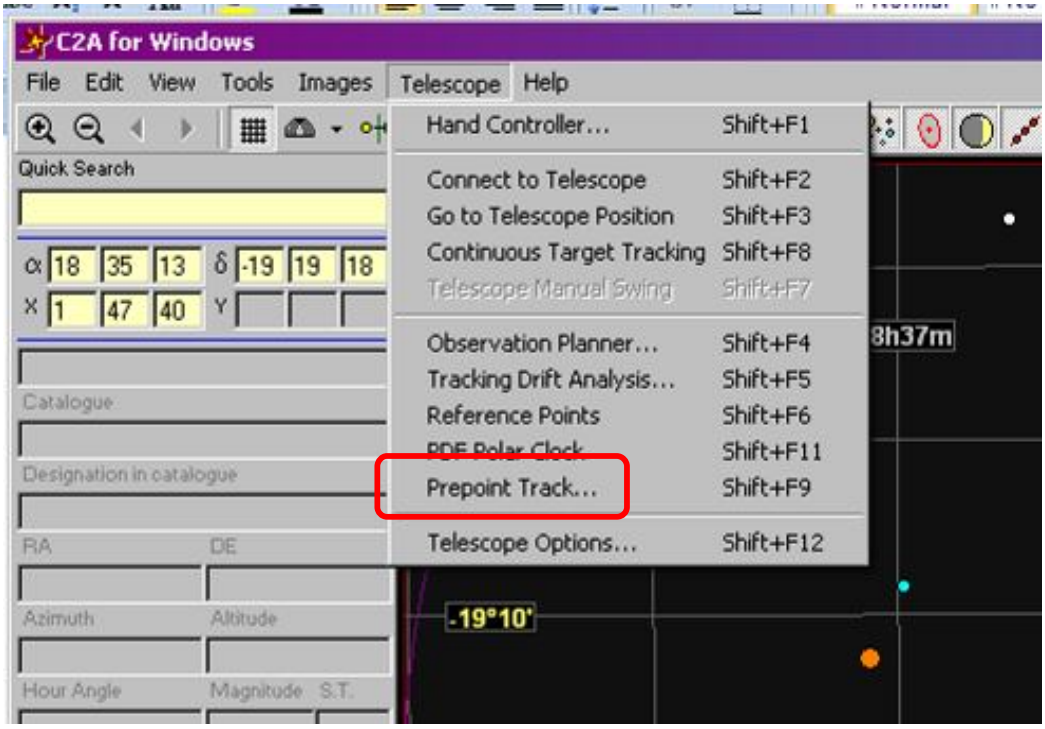
In the field:

5. Set up your telescope well before time.
6. Locate your pre-point star and keep it in view at all times.
7. At the appointed time switch off the motor drive or stop hand-pushing the Dobsonian so the telescope stands still.
8. Wait for the star to be occulted to drift through the field of view at the appointed time!

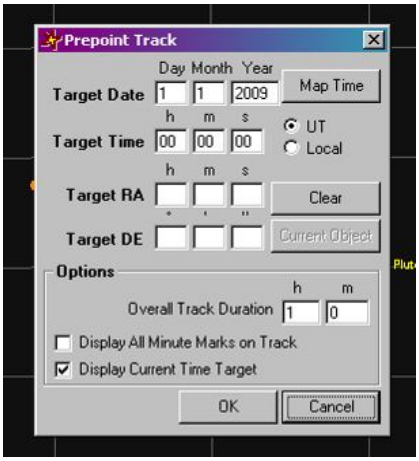
Using C2A to Generate a Pre-Pointing Chart

Open C2A and adjust the chart view so that it shows the target star to be occulted.

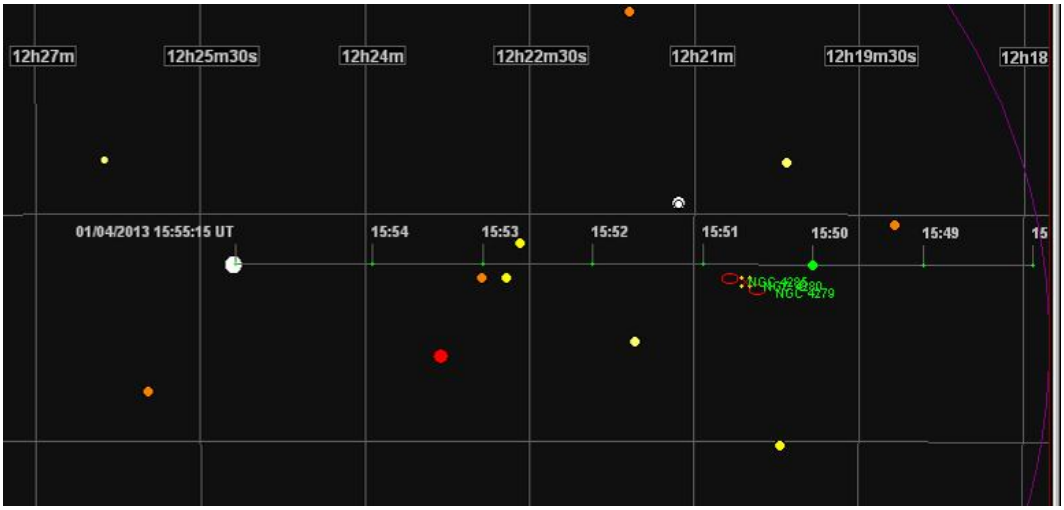
Go to the Telescope menu and chose "Prepoint Track…"



When the Prepoint Track dialogue box appears fill in the information required, decide how long you want the prepoint track to be and if you want the minute ticks to be displayed. Press OK when done.

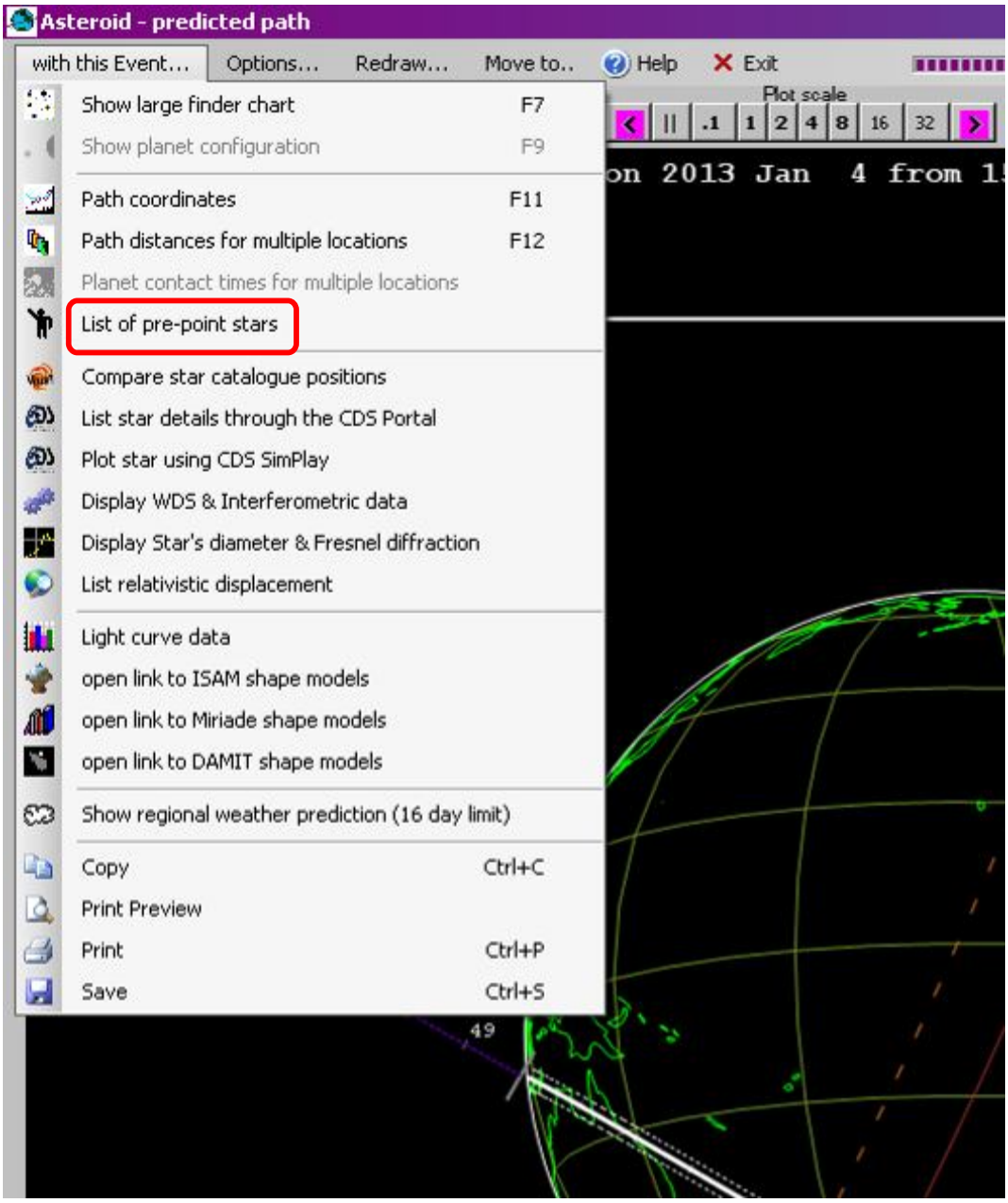


The prepoint track should now appear on your chart. Examine it for suitably bright stars or star asterisms to point your telescope at and note the time that the telescope must be pointed there.



Using Occult to Generate a list of Pre-Point Stars

- Display the track map of the predicted path for the chosen event .
- Click on “With the Event…” at the top left of the window and chose “List of pre-point stars”.
- Examine the generated list and chose a star that is both of a suitable brightness and as close to the line of drift as possible, preferrably within 1 arc minute of offest.



Section 2: Pre-pointing an Equatorially Mounted Telescope

By John Talbot

Pre-pointing is suitable for any telescope regardless of the type of mount used but the description below assumes an equatorial mount.

You will need to know:

- The RA and Dec of the star to be occulted
- The time the event is predicted to occur

It's also useful to know:

- Your Location – Latitude and Longitude
- The predicted duration of the event and the expected time error
- How long it takes for a star to drift across your field of view

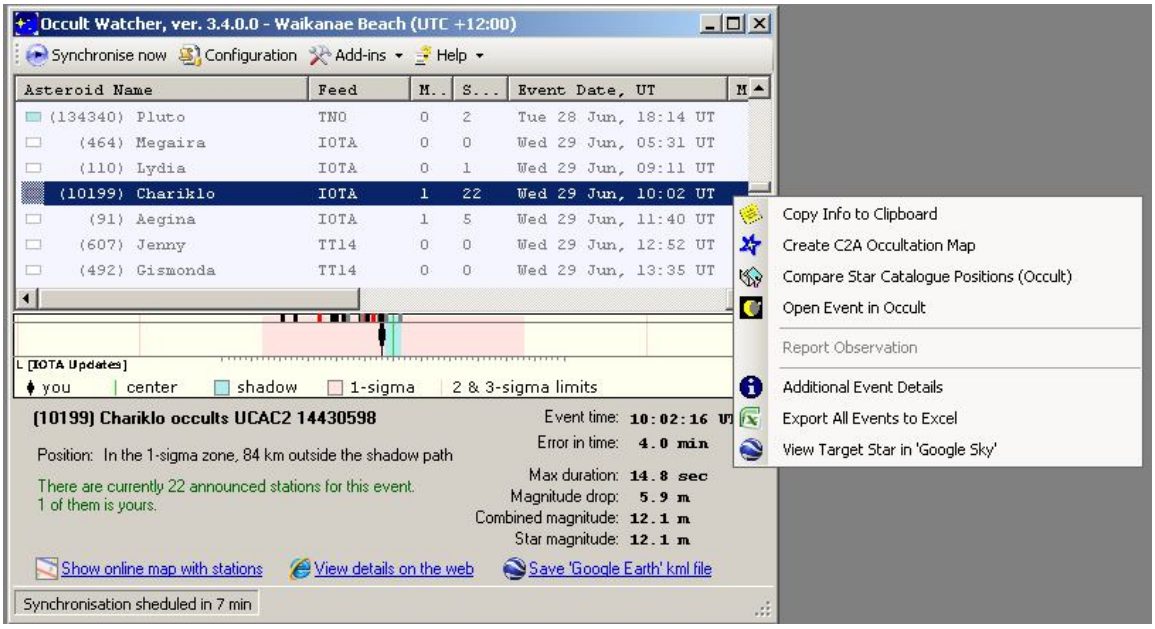
Generating a list of pre-point stars using OCCULT

OCCULT has an option to generate a table of suitable stars to pre-point your telescope at, and the time to do so. When you have an occultation prediction prepared, right-click on the world map for that prediction to bring up a selection of options. The aim is to find a bright star with as small an offset as possible. Below is an example of a pre-point star list for the occultation of 2UCAC 14430598 by 10199 Chariklo on 2011 Jun 29.

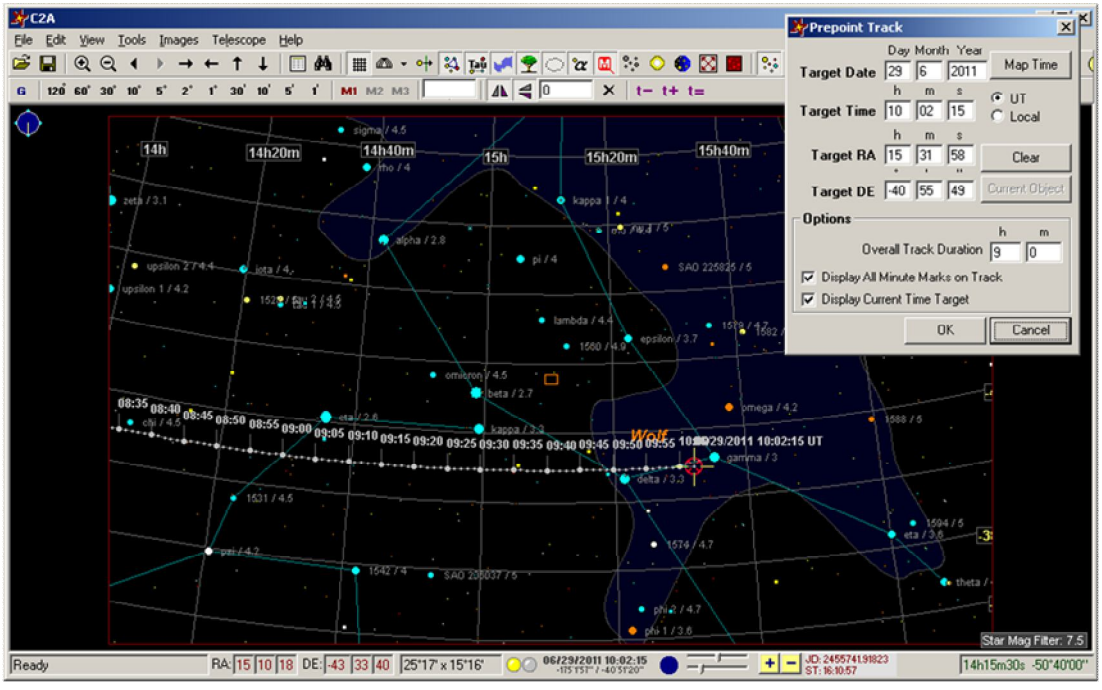
Time offset	**Star**	**RA**	**Dec**	**Offset**
h m s	**mag**	**h m**	**o '**	**ArcMin**
10 2 0	12.1	15 32.0	-40 56	star
9 51 25	3.2	15 21.4	-40 39	-16.8
9 50 49	7.8	15 20.8	-40 54	-1.8
9 48 59	5.6	15 18.9	-40 47	-8.4
9 46 7	5.2	15 16.1	-41 29	33.9
9 38 16	5.8	15 8.2	-40 35	-20.5
9 35 24	5.1	15 5.3	-41 4	8.6
9 34 47	6.3	15 4.7	-40 52	-3.8
9 22 4	7.9	14 52.0	-40 48	-7.0
9 18 16	7.7	14 48.2	-41 1	5.8
9 13 29	8.0	14 43.4	-41 1	6.2
9 10 25	6.7	14 40.3	-40 51	-4.7

Using OccultWatcher and C2A

Provided you have down loaded and installed the C2A Add-in to OccultWatcher you can use C2A to display the predicted track. Right click the event in *OccultWatcher* and select the *Create C2A Occultation Map* option.



You will get a star chart centred on the target star and with the pre-point track drawn with time ticks. You can adjust the track length in C2A by selecting *Telescope > Prepoint Track* from the menu bar at the top.



Now locate a bright star near the track that is easy to point the telescope to.

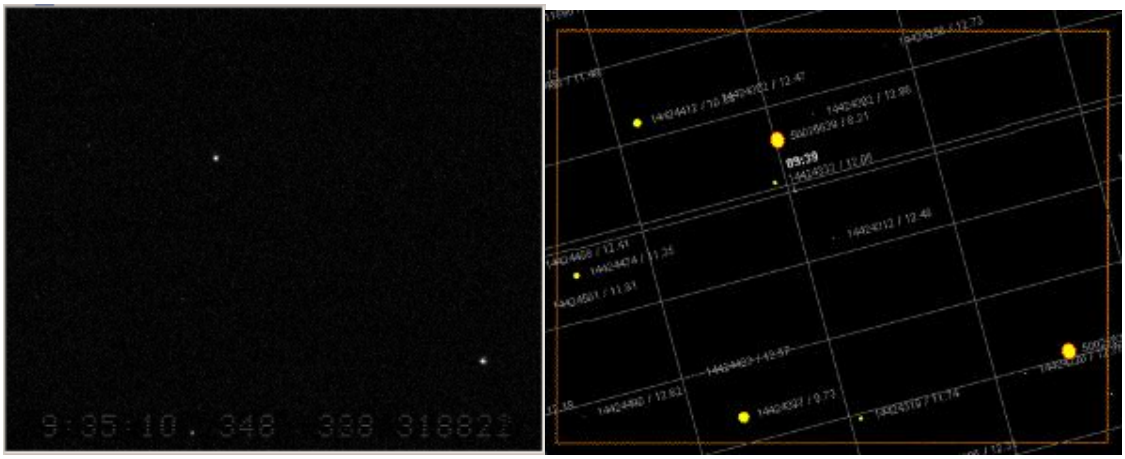
Make sure you have it in the camera field of view well before the due time as shown on the chart and start the drive again.

Adjust the Declination until the predicted track is in the centre of the field of view. This should be easy if you have well calibrated Dec setting circle or display. Otherwise you can star hop until you are on the track.

Keep tracking until (x) minutes before the due time for the field you have in view, where (x) is the approximate predicted time error times 2 or 3. If the event duration is predicted to be much shorter than your drift time then let x=0.

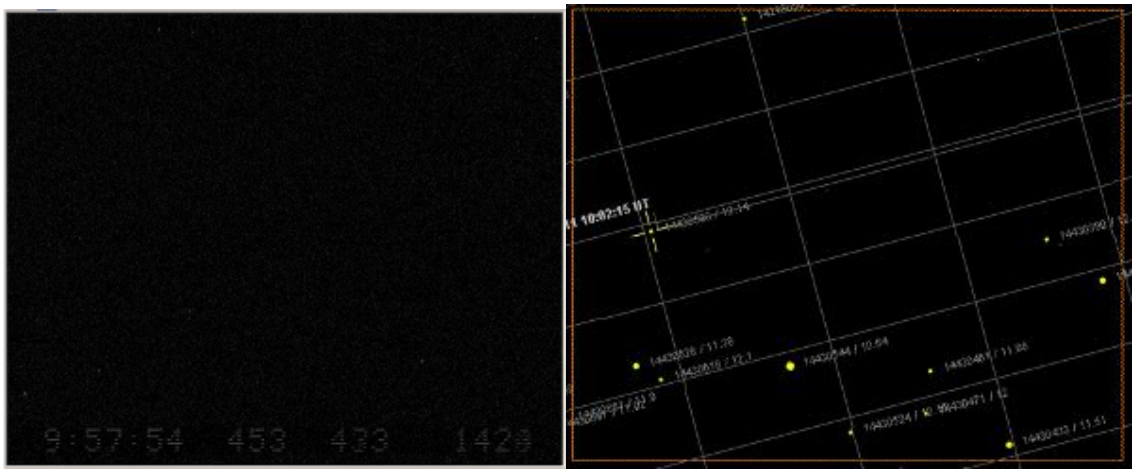
When the correct time (now –x) is reached then stop tracking. I just stop my RA drive. (This maybe a problem with a GOTO scope.)

Check that the fields really matches the predicted view as they drift past.



If the camera is not lined up East-West you may have to rotate the field in C2A.
I like to begin tracking early (~4mins in this example)

When target field comes into view you can start your recording. You may want to start your recorder earlier and record your VTI reset sequence before the target arrives.



When the star is just coming into view make sure the recording is started and allow the star to drift through.

If a longer recording time is required (i.e. longer than it would take the star to drift thought the field of view), turn on the RA drive again as it reaches the centre of the field of view and keep the target star in view while recording as long as you need.

Record another KIWI-OSD reset sequence.

Turn off recording.

Appendix 5: Concerning Image Saturation, Photometry and Stellar Diameter

(Previously published as "Learning from Two Recent Asteroidal Occultations" in the *Journal of Occultation Astronomy*, 2012-03)

By David Herald

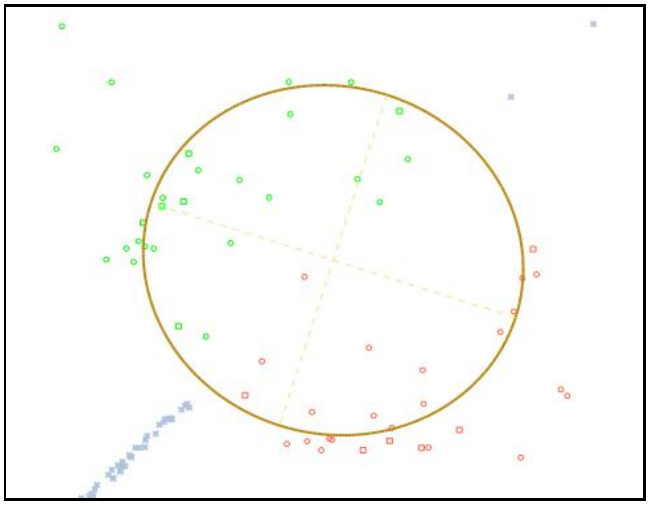
During 2010 and 2011 there were two extremely well-observed occultations. The first was an occultation of a 3rd mag star by 472 Roma on 2010 July 8, widely observed across Europe with 231 reported stations. The second was the 2011 July 19 occultation by the binary asteroid 90 Antiope, well observed in the US from 57 stations with 46 recording an occultation.

Such well-observed events present a great opportunity for learning. The results from the Roma event turned out to be very disappointing, with the asteroid profile being very poorly defined. The Antiope event resulted in an excellent profile of both components of this binary asteroid – but when the data was looked at in detail to investigate the diameter of the star, a number of issues surfaced.

This paper discusses some issues about image saturation, looks at deriving the diameter of the star from the light curves, and explores how our processes can be improved.

Image saturation

The Roma occultation was anticipated with great expectations. The star was bright, so it would be an easy event to observe. And the star had a relatively large diameter, such that interesting light curves would be expected. In practice these two factors resulted in a set of reported observations that lacked consistency, such that the results can best be described as extremely disappointing – as shown in the following plot of the reported occultation times derived from video recordings.



Clearly the fact that the occultation events were gradual adds a complication to the measurement of the video recording. We can reasonably assume that all video observers reported times corresponding to the 50% light level (which is the appropriate level when stellar diameter effects are significant). However the extent of the scatter is such that it cannot be explained by assuming some observers reported times corresponding to the 25% level (appropriate to Fresnel diffraction) or corresponding to a zero light level.

At the time of the observation, most people used LiMovie to measure the light curve of an asteroidal occultation. Importantly, the measurement methodology used in LiMovie at that time was something called aperture photometry. While aperture photometry is a standard methodology, it has limitations if there is any image saturation present. And because the Roma occultation involved a very bright star, image saturation was almost certainly present in many if not most video recordings.

To explore the effects of image saturation on photometric measurements, you need to understand how images are measured. In broad terms, there are two basic methods:

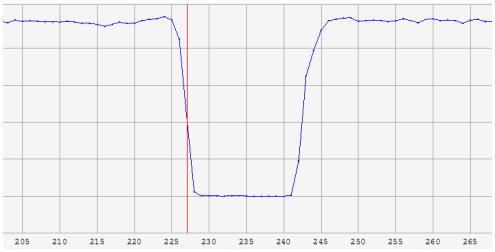
1. **Aperture photometry.**
   In this method:
   a. the value of each of the pixels in a measurement region are added together;
   b. the values of each of the pixels in a surrounding region representative of the background are added together;
   c. the value from (b) is proportioned by the ratio of the area of the pixels in (a) to the area of pixels in (b); and finally
   d. (c) is subtracted from (a) – to give a measurement of the light from the star.

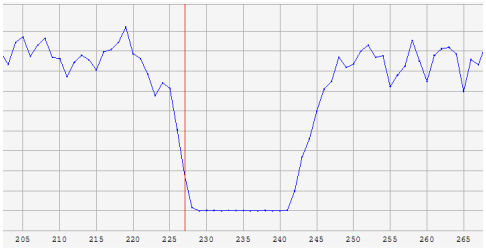
   Saturation has the effect of limiting the value that a pixel can have when measured in step (a). Consequently if saturation is present, aperture photometry will under-report the true value of the light signal. With an 'instantaneous' occultation, this is of little consequence. However with a 'gradual' occultation, the light level at maximum light will be under-valued, while the light level at low light levels will be correctly measured (as there will be no saturation) – with the result being a measured light curve that does not properly represent the true variation in the light level.

2. **Point Spread Function (PSF) photometry:**
   For a well-defined star image, the light distribution of a star on the detector has the form of a Gaussian distribution. PSF photometry fits a 2-dimensional Gaussian curve to the values of the pixels. In this process, pixels that are at or near to the saturation level are disregarded – as they do not represent a valid measurement. The light measurement value that is returned represents the height of the peak of the Gaussian light curve, rather than the sum of the pixel values. Pixels that are affected by saturation are excluded from the determination of the height of the Gaussian light curve – and as a result the measurement is unaffected by image saturation. A separate measurement of the background level is also made – for subtraction from the light measurement value.

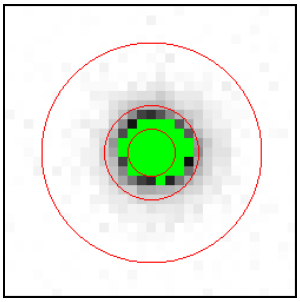
Interestingly, when image saturation is present, the maximum light level measured with aperture photometry will exhibit a lower level of noise than that measured with PSF photometry. The reason is that in aperture photometry many of the pixels will be saturated and have a fixed invariant value, giving a false reduced noise level, whereas the PSF measurement ignores those saturated pixels and estimates the maximum light level from the unsaturated noise-affected pixels.

The difference between aperture photometry and PSF photometry are illustrated in the following two plots obtained from a video recording of the Roma event. The measurement was made using Tangra, with post-measurement reprocessing using aperture photometry (left light curve) and PSF photometry (right light curve).





The following plot of the stellar image from the video at full light shows the region of saturation in green. As can be seen, the stellar image is heavily saturated, with over 40 pixels being saturated.



Comparative observations to be made about these light curves are:

- The difference in the noise level at maximum light level – the noise in the aperture photometry light curve is undervalued because of extensive image saturation
- The light curve from the aperture photometry exhibits steeper sides than that measured with PSF photometry
- The red line is positioned at the point of 50% light level on the aperture photometry light curve. That same line is located on the PSF light curve at around the 25% light level. That is, the time reported from the light curve measured using aperture photometry is in error, having been adversely affected by the image saturation.

It may additionally be noted that the PSF measurement, by its nature, is a more accurate representation of the actual light curve recorded on this image-saturated video.

There are several important points associated with an understanding of the two basic measurement techniques. They are:

1. Image saturation is not an issue if the video is measured using PSF photometry – *but only if the image is properly focussed*. PSF measurement assumes the image of the star is point-like, such

that a Gaussian curve can be fitted to the star image. De-focussing an image to avoid saturation means that the star image is no longer point-like – such that a Gaussian curve cannot be validly fitted. Similarly, images that are highly distorted (eg large coma arising from the camera being poorly aligned with the optic axis) are not well suited to PSF photometry.

2. PSF photometry is not suitable if the object being measured is faint, as there will be insufficient data in the pixels to reliably fit a Gaussian curve;
3. Aperture photometry is well suited to faint objects;
4. Aperture photometry becomes inaccurate whenever image saturation occurs. In particular, the measurement of the light level becomes invalid if many pixels are saturated. However a small amount of saturation (e.g. just 2 or three pixels in the centre of a stellar image) will have minimal effect.

If an occultation event is substantially instantaneous, image saturation is not an issue – you will have full light in one frame, and zero light in the next. However when the event is 'gradual', image saturation will result in the measured light curve differing from the real light curve – and this can result in misreporting the time corresponding to the 50% light level. Also the presence of image saturation will render the light curve unsuitable for determination of the star's diameter.

With occultations of relatively bright objects, it is frequently asserted that observers must avoid image saturation at all costs. The usual advice is that if image saturation is likely - defocus the image so that the star image is distributed over a larger area, thereby avoiding saturation. This is generally bad advice. The correct advice is:

A. If you are measuring a video with bright objects, make sure you use PSF photometry for the measurement. *Do not use Aperture photometry. Do not defocus the image.*
B. If you are measuring a faint object, use Aperture photometry (and do not defocus!)
C. If you are measuring an intermediate brightness object, you can use either PSF or aperture photometry – remembering that the end objective of the measurement process is to obtain the highest possible signal-to-noise ratio in the measurement.
D. If you feel you must defocus the image, it is absolutely essential that you defocus enough to ensure image saturation is not possible. If you fail to do this, the ability to reliably measure the brightness of the star during the event will be compromised.

Note that both Tangra, and recent versions of Limovie (0.9.97.3g and later), provide options to measure images using either PSF photometry or Aperture photometry. This choice should not be seen as an obscure issue that can be ignored. Rather users should get into the habit of:

- Bright object – use PSF photometry
- Faint object – use Aperture photometry
- Intermediate object – use whichever gives the cleanest light curve in the particular instance.

Star diameter analysis

The Antiope event involved 57 stations, of which 46 observed an occultation. [For 5 of the stations that observed a Miss event, the star passed between the two components of Antiope!] The great majority of observations were made using video – with all the light curves displaying a gradual event, characteristic of the effects of a significant stellar diameter. This resulted in over 60 light curves that could be analysed to measure the star's diameter.

The star occulted by Antiope was the 6th mag star HIP 112420. This star is quite red, with B-V = 1.664, and V-I = 2.100. While there have been no direct measurements of the diameter of this star,

the diameter can be estimated as 2.3 mas using the magnitude and colour of the star. In comparison, the apparent diameter of each of the components of Antiope was about 68mas.

If you assume:

- Fresnel diffraction makes no significant contribution to the observed light curve; and
- The occulting limb can be approximated as a straight edge; and
- The brightness of the stellar disk is uniform – that is, there is no significant limb darkening on the star

you can easily generate a theoretical occultation light curve based on an assumed apparent diameter of the star, using the rate of motion of the occulting limb in a direction normal to that limb.

Of these factors, for this event:

- Fresnel diffraction was expected to contribute about 0.2mas for a light drop of 2 mag, and 0.5mas for a light drop of 5 mag – much smaller than the expected effects of the diameter of the star;
- The fact that the apparent diameter of the star is expected to be around 4% of that of the asteroid means that a straight-line approximation to the limb of the asteroid is reasonable. [In comparison, if the star was 50% of the diameter of the asteroid, the curvature of the limb of the asteroid cannot be ignored. Similarly for the Roma event the star's diameter was too large compared to the asteroid's diameter to treat the limb of the asteroid as a straight line];
- Limb darkening can be ignored in the first instance, noting that its primary effect would result in a diameter that is smaller than the actual diameter;
- The orientation of the limb of the asteroid for each observed chord can be measured from the usual reduction plot of all observed occultation chords; and
- The rate of motion of the star relative to the asteroid is well known – being an essential quantity in the analysis of the occultation chords. For the Antiope event, the rate of motion was about 2.49mas/sec – with the exact value depending upon the observer's location (which changes the contribution of the Earth's rotation to the apparent motion of the asteroid).

Accordingly within the program *OCCULT* I built functionality to:

- Measure the rate of motion of the star in the direction normal to the limb, for each occultation point – with the user setting the orientation of the limb on the basis of estimating the best alignment to adjacent observers;
- Generate a 'theoretical' light curve that is based on that relative rate of motion, and an assumed diameter of the star;
- Compare that light curve with the observed light curve, using values imported from the csv file generated by either Limovie or Tangra, with tools to assist in fitting the theoretical light curve to the observations; and
- Derive a final measurement of the stellar diameter as a mean of the results from each of the individual light curves – with a system of weighting to reflect uncertainties in the estimated limb slope, and the quality of the observed light curve.

This functionality is present in *OCCULT* 4.1.0.0.

The fit of the theoretical light curve to the observed data involves:

- Time displacement of the theoretical light curve relative to the observed data, to obtain the best match in event time;
- Variation of the theoretical light curve by changing the nominal star diameter;

- Computation of the standard deviation of the differences between the theoretical light curve and the observations, and display of the distribution;
- Recognising that the noise level in a video signal is strongly dependent on signal level – computation of the χ^2 statistics of the differences between the theoretical light curve and the observations, and display of the distribution; and
- Adjusting the time displacement and the star diameter to obtain minimums in both the χ^2 statistics and the standard deviations.

One of the issues with this process is that the event time reported by the observer is dependent upon how the light curve has been interpreted. Any 'errors' in the interpretation of the light curve will result in a consequential displacement of the end of their observed chord relative to the adjacent observers, and thereby affect the measurement of the local limb slope from the usual plot of events. Accordingly the process of analysing the light curves to determine the stellar diameter needs to be iterative. That is, involve the steps of:

1. An initial determination of event times;
2. Determination of limb slopes for each event, by comparison with adjacent chords;
3. Analysis of all the light curves to derive a best fit of a theoretical light curve to the observations;
4. Re-determination of the mid-event time from each light curve; and
5. Repeat steps 2 to 4.

More details of how the functionality in *OCCULT* works is described in the Help topic associated with the **Star Diameter Analyser** tool in *OCCULT*.

The diameter of HIP 112420 from my analysis of 61 light curves from the Antiope observation is 2.14 ± 0.03 mas. This value is quite close to the estimated diameter of 2.3 mas.

However the uncertainty value needs to be treated with caution. The uncertainty is derived from the variance in the diameter determined from each of the light curves. It assumes that the uncertainties in the various factors used to generate a diameter from a specific light curve will result in a scatter that is normal about the derived diameter. However this is generally not the case – and a more realistic determination of the diameter is 2.1 ± 0.1 mas.

Availability of data to re-analyse

Historically occultation results have generally involved a fairly brief transition from full light to minimum light – lasting no more than a small number of video frames. In that context the derivation of event times is straight forward, and the reporting process can sensibly be limited to the user-determined event times – as has been the case for the last 40 years.

However when the event involves transitions that last a significant number of frames, the proper interpretation of the light curves can be more complex. Furthermore when stellar diameter effects are significant, the correct interpretation of the light curve may depend upon the results from adjacent observers. Additionally the precise shape of the light curve may contain information that is relevant to the correct interpretation.

For the Roma event, very few of the original video recordings are available for independent analysis. Similarly very few .csv files obtained from LiMovie, or .lc files from Tangra, are available. This means that there is almost no capability to re-process the measurements of the videos to ensure saturation has been properly dealt with, and to measure the diameter of the star. This is unfortunate.

The Antiope event offered much greater promise for more detailed data analysis. However the practical difficulties I came across when analysing the data were:

a. .csv files containing the measurements of the videos were available for 42 sites. No .csv file was available for four video sites that recorded an occultation.
b. To validate the event times, and confirm the correctness of the derived limb slopes, one must be able to associate a frame in the .csv file with a time. Some of the .csv files included OCR measurement of the video-inserted time stamp – such that a linkage to time was available. I was separately provided with a linkage between frame numbers and time for several other .csv files. However I was only able to link the .csv data to UT times for 25 of the 42 .csv files. The good news is that for the majority of sites, the reported times and the times derived from my fitting of the light curves were in close agreement. The bad news is that for 17 of the video sites I have been unable to independently verify that the reported time is consistent with my analysis of the individual light curves. [As a matter of principle, this is not a good situation – observational results should be open to re-assessment. More specifically, my analysis to determine the stellar diameter from all the individual light curves has been compromised.]

When following up a number of queries associated with the observations, the following issues surfaced.

a. For one site, the reported time for the reappearance was in error by about 1 second when compared to the video recording – and has since been duly corrected. [This is a clear example of the value of having the observational data readily available for re-assessment – simple reporting errors can be readily identified and corrected.];
b. For several sites of one multi-deployment array, the reported times had been adjusted by exactly 1 second. This adjustment occurred because the times derived from the video appeared to be 'out' by about 1 second when compared with other observations, and an assumption was made that this was caused by a 1-second time error in the KIWI-OSD used to calibrate the camcorder internal clock before and after the event. Unfortunately detailed consideration demonstrated that the basis for this correction was unsustainable. The most likely explanation for the apparent time base errors is non-linear drift of the camcorder clocks over the several hours between the calibration points, resulting in an unrectifiable uncertainty in the time base.

As a result of the situation in (b), the following guidelines have been established for establishing the time base for a multi-station deployment reliant on camcorder internal clocks:

A. The observer should ensure they are using an idiot-proof time stamping device that allows hot-connection of video cameras without losing the time-base, and has clear indication of validity of the almanac – such as the IOTA-VTI.

   Note: Many IOTA observers have KIWI-OSD time inserters acquired before the IOTA-VTI was developed. These devices have known timing issues if the almanac is not updated and/or if cables or power have been disconnected during the timing, and so continued use of these time inserters is not recommended. If the observer continues to use the KIWI-OSD, allow 15-20 minutes lead time to ensure the almanac has been updated, and then press the reset button to ensure the time is valid.

B. The observer must perform time stamping of the camcorder *at each deployment site* – both at set-up, and collection – so that
    a. the reliance on the camcorder clock is kept to the shortest duration possible, and
    b. minimises changes in environmental conditions during the interval between time stamps.

    Batch time stamping all camcorders before starting the deployment, and after all have been retrieved, is not acceptable - as it creates too high a dependency upon assumed linearity of the internal camcorder clock to ensure a reliable time base;
C. In the deployment process, observers need to ensure (as much as possible) that the camera and camcorder are at ambient temperature prior to deployment – so that they are not undergoing significant temperature adjustments in the first 10 mins or so after deployment.

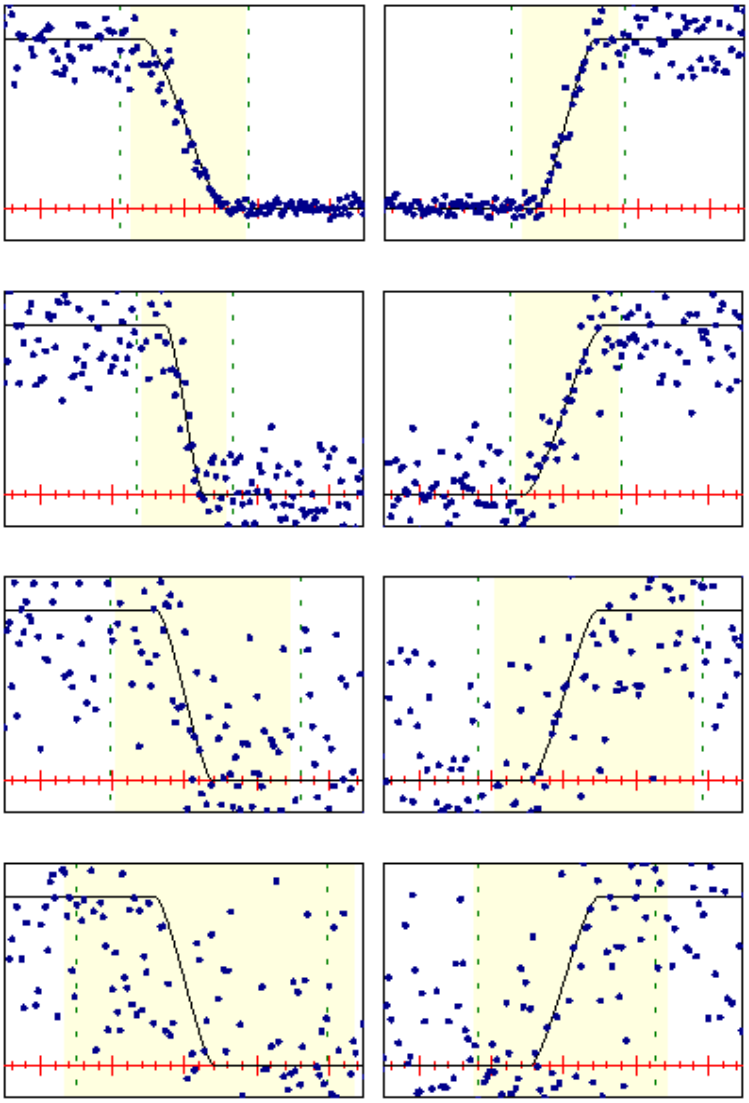
We should be striving to be in a position where we can (when necessary) re-analyse the data – both to demonstrate the validity of any conclusions reached from the data, and to perform a more detailed analysis than simply derive the occultation D and R event times. In the context of video recordings, this requires (at a minimum):

- Availability of a csv file containing the measurements of the video used to report the event times [this can be created by both LiMovie and Tangra], or a Tangra .lc file.
- Availability of the linkage between the video and UTC. This can be achieved by any of the following:
    - With LiMovie, including the OCR interpretation of the video-inserted time stamp in the measurement
    - With Tangra, specifying the start/end times at the end of the measurement, for inclusion in the .lc file
    - Separately writing down the video-inserted time stamp on specified frame numbers – preferably a frame near both the D and R times (so that the presence of any dropped frames between the events can be detected)
    - For multi-station deployments – (i) the relationship between the video-inserted time stamp and the internal clock at the pre and post event times, and (ii) the internal clock value at a frame near both the D and R times.

One of the problems in sharing videos is the inevitably large file size – usually far too large for an email attachment. However one of the very nice features of Tangra is that it can create a 'light curve' file (.lc) that contains the relevant portion of each video frame surrounding each of the measured objects, together with a record of where the measurement aperture was located. The .lc file size is almost always small enough that it can be reliably sent as an email attachment, enabling the video to be easily disseminated to those that need it. [Furthermore, if you have the .lc file, you can remeasure the event with different settings – such as changing between aperture and PSF photometry.].

Data quality

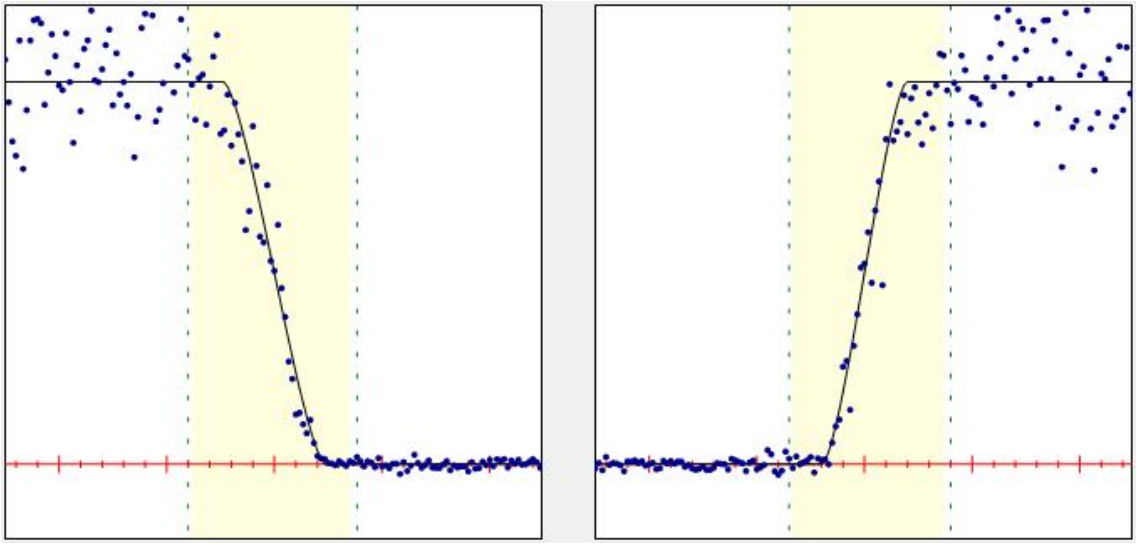
One of the 'interesting' results from reviewing the Antiope data was the widely variable quality of the video recordings. The following are four examples of light curves from the Antiope event showing a best-fit light curve used to derive the stellar diameter. I would loosely refer to the examples as good, average, poor and useless:



The primary point to note here is that if the transition from full light to minimum light occurs over only a few frames, the event time can be determined quite reliably under a wide range of noise levels. However when the light transition extends over many frames the uncertainty in the event times becomes rather large, and the ability to extract any information about the stellar diameter is reduced or lost. In short, you should aim at having a light curve that clearly shows the event, and avoid light curves like the last two of the above examples.

Effects of gamma

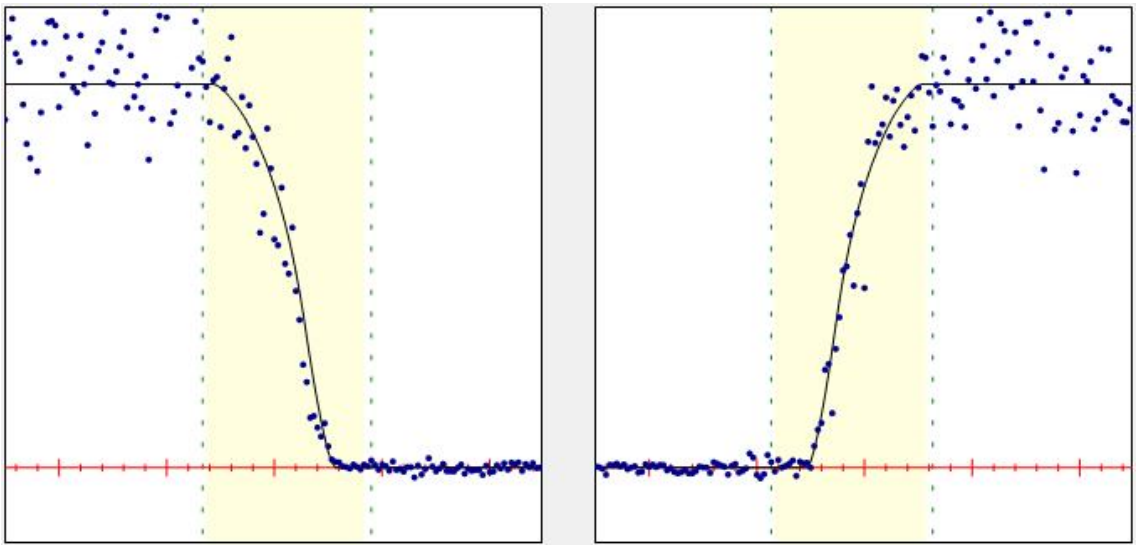
For a small number of observers of the Antiope event, the fit of the theoretical light curve to the observed data indicated a stellar diameter that was significantly smaller than that derived from the majority of light curves. A particular example is:



The fit superficially looks good, with diameter solutions of 1.72 and 1.36mas (compared to an overall solution of 2.1mas). However on closer inspection there are problems with the fit of this light curve. If properly fitted, the data points should be distributed roughly equally on each side of the fitted curve. However on both light curves (but particularly evident on the R light curve, the data points near the top of the light curve are almost all located below the theoretical light curve for a period of the expected full light level. This gives rise to the question – are these light curves affected by gamma?

The difficulty with making corrections for gamma is that it can only be done at the measurement stage, by correcting the reported values of each individual pixel for the gamma correction. However when gamma is less than 1 the effect is similar to the effect of saturation. That is, the value of highly-illuminated pixels is reduced compared to other pixels. As a result, the effects of gamma less than 1 can be crudely approximated as being equivalent to the effects of saturation.

Within the Star Diameter Analyser of *OCCULT*, I have included a capability to adjust a theoretical light curve as measured using aperture photometry, for the effects of saturation. The following plot of the above event shows the theoretical light curve on an assumption that the star image is heavily saturated (equivalent to a small value of gamma).



As is apparent, the theoretical light curve has a much better distribution of observed points on either side of the light curve at the top part of the light curve. The diameter solutions for these two light curves are 2.05 and 1.85mas – values which are consistent with the overall solution of 2.1mas. Note that the event times as defined by the 50% light level in the light curve are also slightly different from the previous plot.

Unfortunately I have no knowledge about whether or not the particular observer was recording this event with a non-unity value of gamma, and so the attribution of gamma to this light curve is speculative.

However the essential learning from this is that for events that are expected to involve stellar diameter issues, observers need to make sure they know the level of gamma they are applying when making the recording. In this, they need to be aware of both the inherent gamma of the camera they are using, any gamma applied by the camera controls (e.g. the Watec 120N camera control) and any gamma (or contrast) setting available and used in the recording software (e.g. the controls available in VirtualDub with respect to the Video Source).

It is worth noting here that there may be good reasons for setting gamma to something other than 1. For example, using a gamma less than 1 will enhance the signal change at occultation of faint objects against a dark background. Conversely the use of a gamma greater than 1 will enhance the signal change at occultation of objects faintly visible above a bright background.. In both instances, the small light change that will be recorded will be essentially linear. Gamma only becomes a problem if:

i. You are trying to translate a change in light level to a change in stellar magnitude; or
ii. In interpreting the shape of a light curve when a large light change has been recorded (e.g. bright object disappearing from visibility) such that the change of light from full to minimum is non-linear because of the non-linear nature of gamma when applied to large light changes.

In short – there can be good reasons to record an event with a gamma that is not 1. But if you do this, you should make sure you 'reverse' the gamma when you measure the video recording so that the measurement properly reflects the 'true' change in the light signal.

Summary

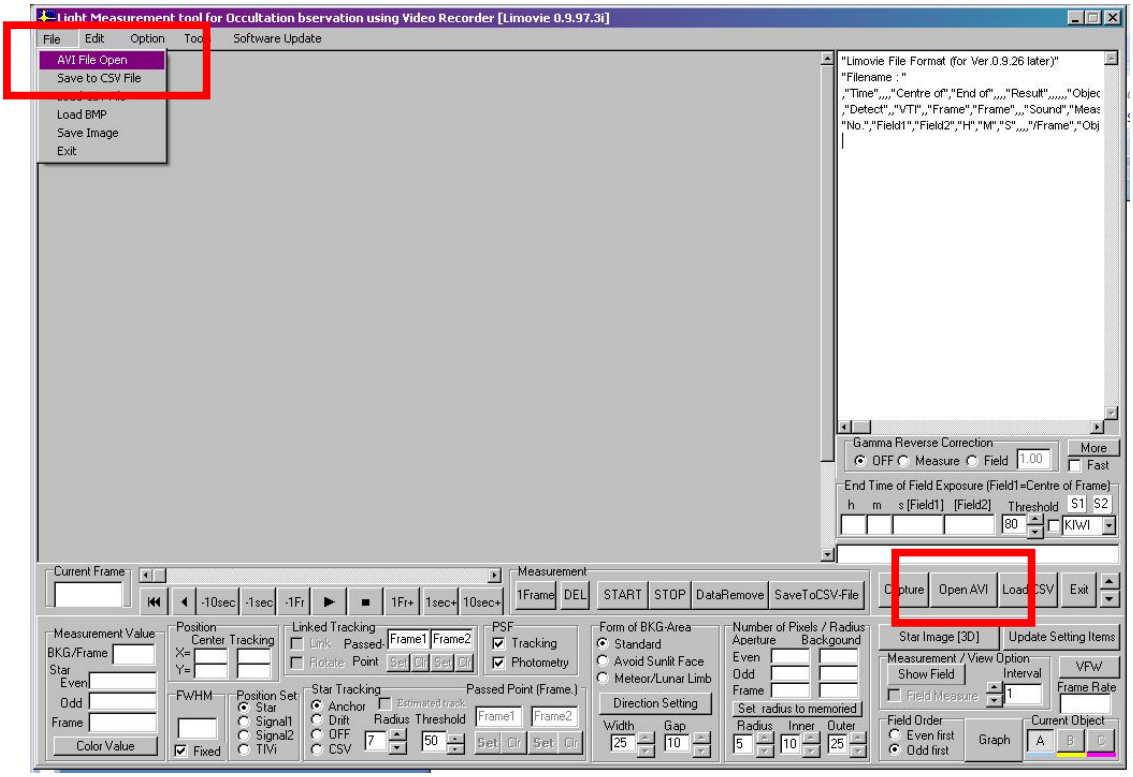
Some key learning from these asteroidal occultations is:

- Never defocus your images to deal with saturation. Rather make sure you measure the video using PSF photometry;
- Ensure you save your measurements of the video in a csv file (Limovie/Tangra) or the Tangra .lc file so that it is readily available for re-analysis. Also ensure a linkage from the frame number to UT is provided.
- Ensure your raw video is available if needed. The Tangra .lc file is well suited to email distribution of the raw video.
- Strive for the cleanest possible video recording.
- Understand the gamma setting that has been used when recording the video. When measuring the video with Limovie or Tangra, 'reverse' the gamma – so that the measurement is based on a gamma of 1.

Appendix 6: Basic Analysis of Occultation Events Using LiMovie

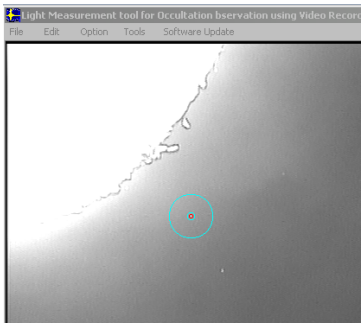
(This appendix includes a guide for how to prepare a light curve for a double star report.)

Open LiMovie and then open an .avi file. You can do this by either using the drop-down File menu or the "Open AVI" button at lower right.

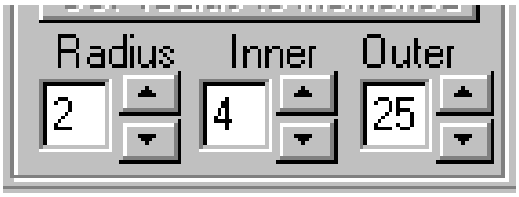


Older versions of LiMovie only opened video files smaller than 2 Gb. (See *6.3 Size of .avi Files* if you need to crop a file to size.) The latest version does not seem to have a file limit.

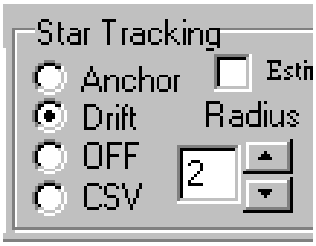
Click on the target star to be measured. The coloured "bullseye" circles should move to centre itself on the star.



You can widen the radius of the inner bullseye slightly to help with tracking if the star image is particularly jumpy. The outer bullseye defines the region where the background measurement will be made. The two circles should be made so that there is a reasonable area available for the background brightness to be measured.



Choose either "Anchor" or "Drift" on Star Tracking. "Anchor" can be used if the recording is very steady, but if the star moves about and tracking is lost during the analysis it may be better to choose "Drift."

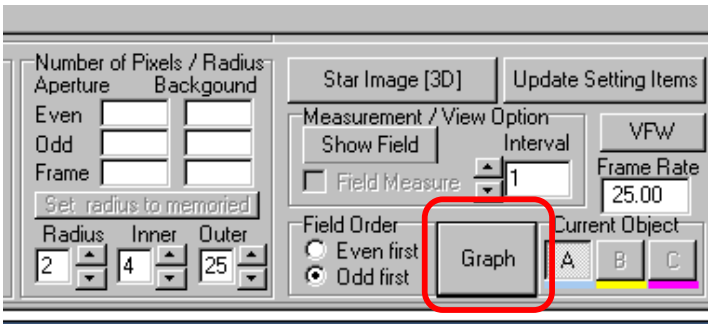


Move the progress slider along to an appropriate start position in the video if you don't need to analyse the whole length of the recording.

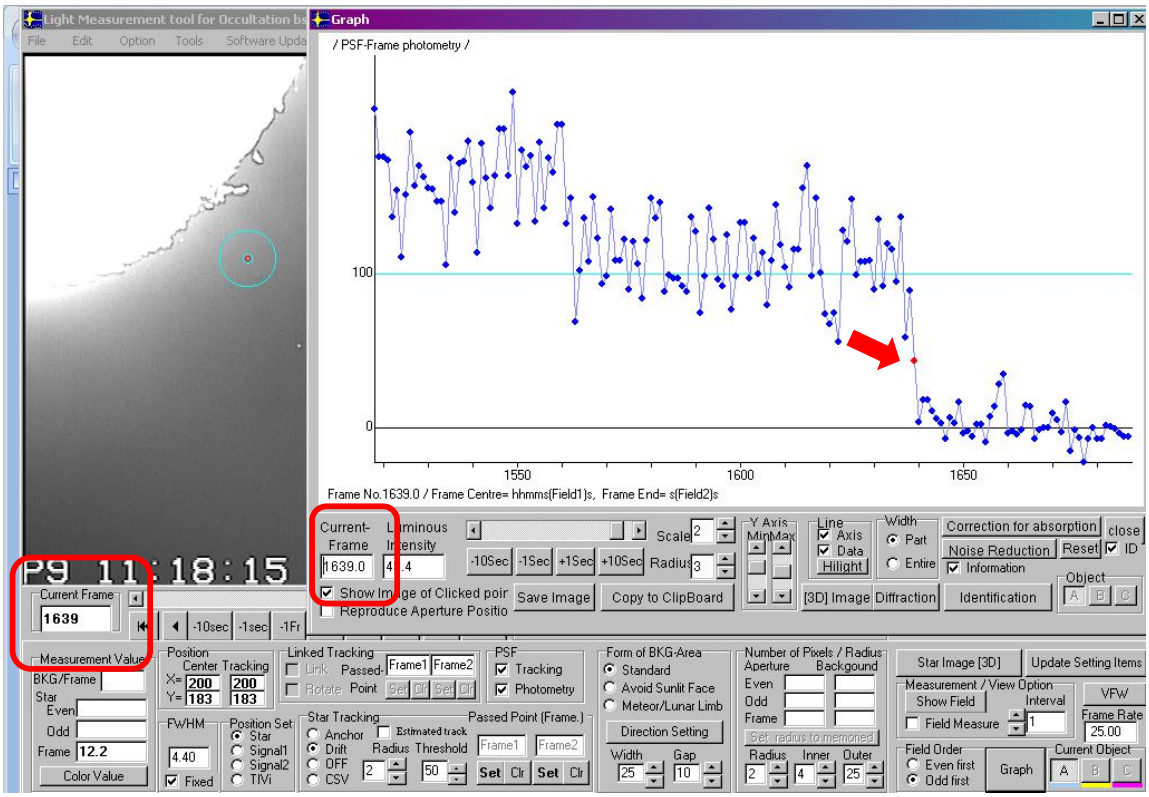


To start and stop the measurement press START or STOP (above). If you want to clear the data to try a new run press Data Remove.

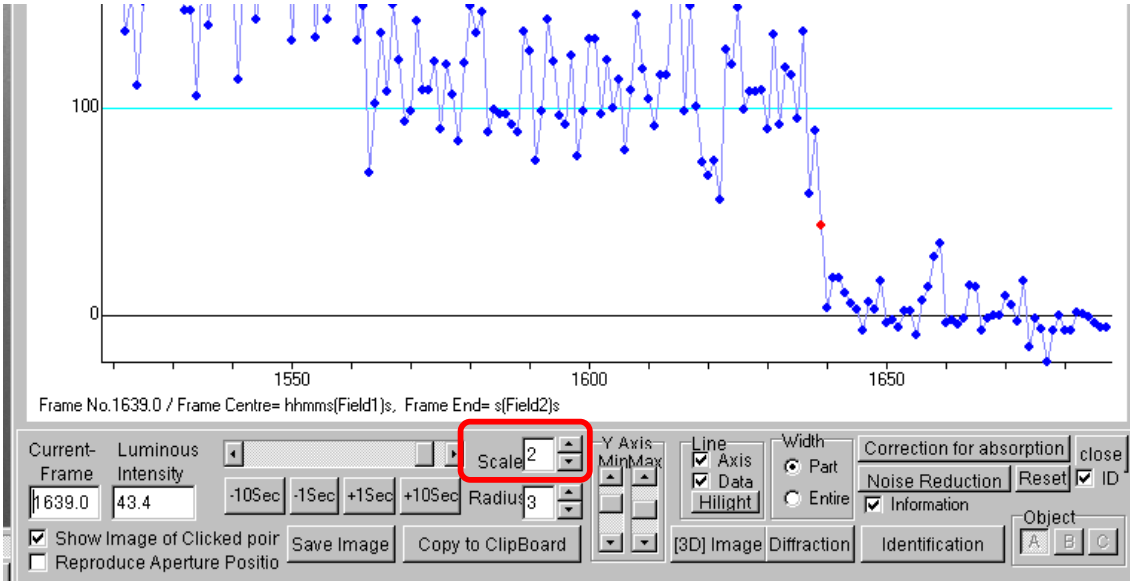
Once you are happy with the run, press “Graph”. A new window should open with a graphical representation of the light curve.



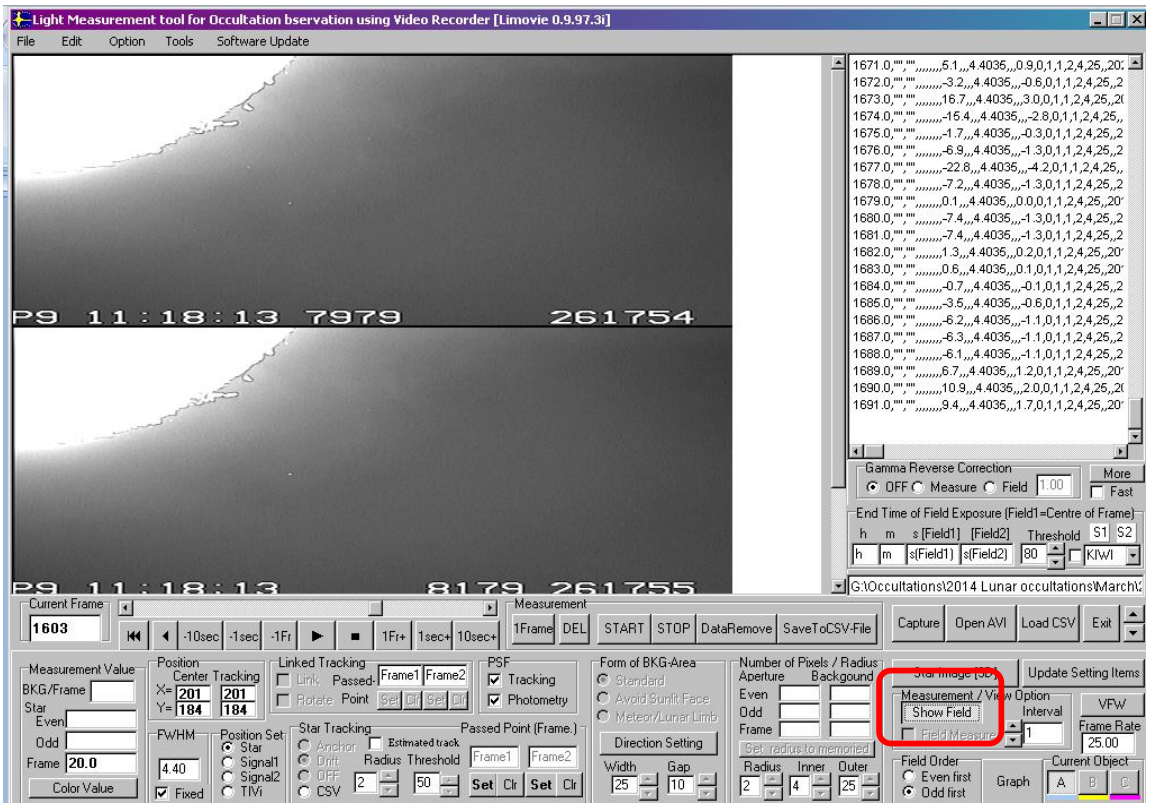
When you click on a dot on the light curve - it will be highlighted in red - LiMovie will tell you which frame it is, both on the light curve window and the open .avi file window. You can then read off the time showing at the bottom of that frame.



You can stretch out the light curve by adjusting the scale

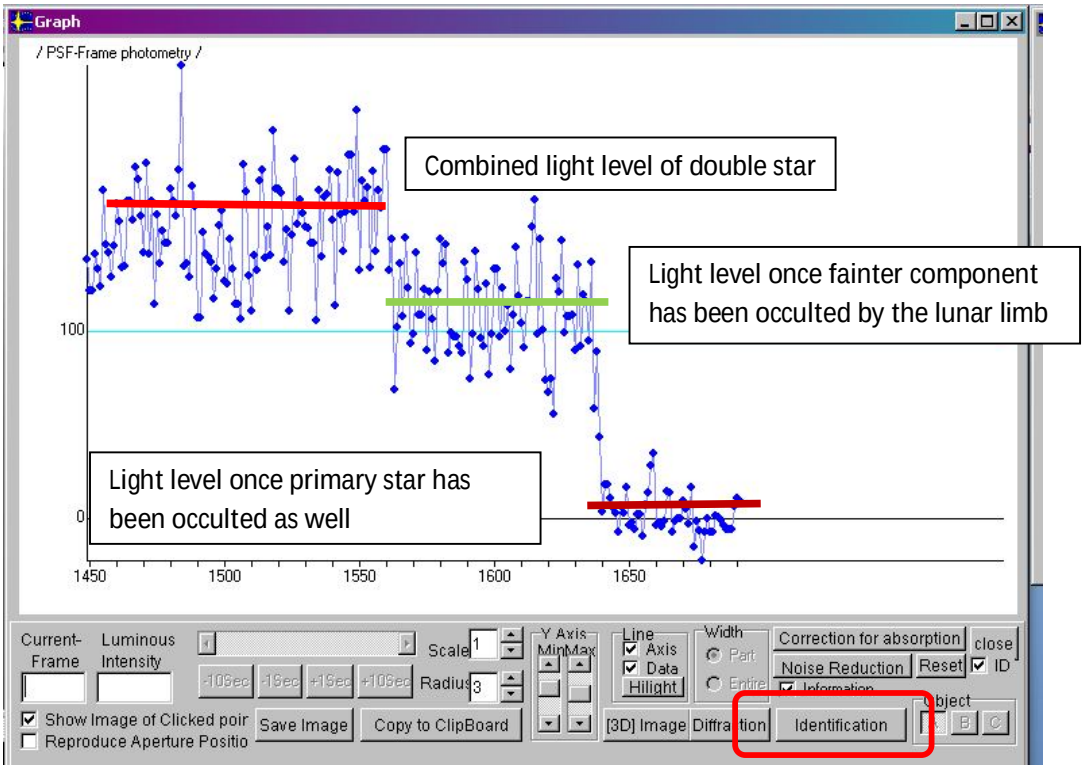


If you have blurred numbers you can separate the frame into its individual fields by choosing the "Show Field " option.

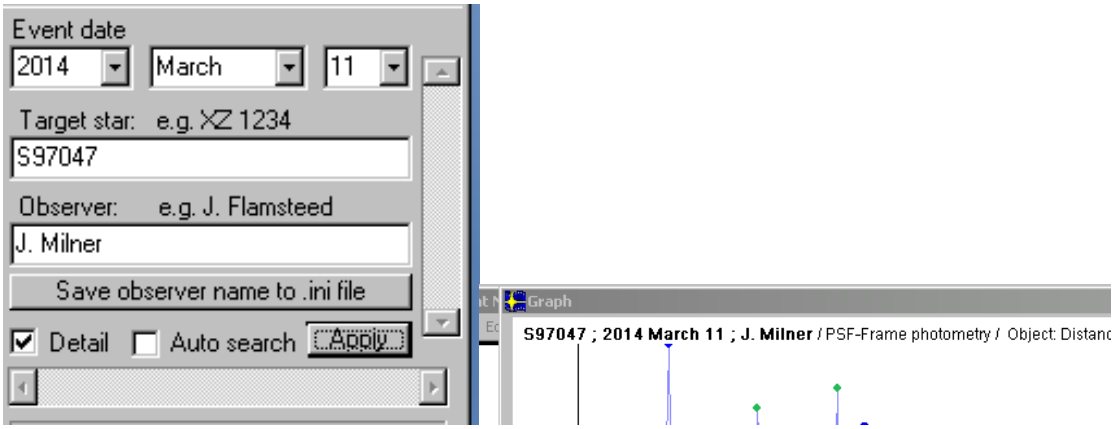


To Prepare a Light Curve for a Double Star Report:

Produce a graphed light curve showing the step event. In this example there is a small step for the fainter star before the brighter primary star was occulted, resulting in the more obvious second step.

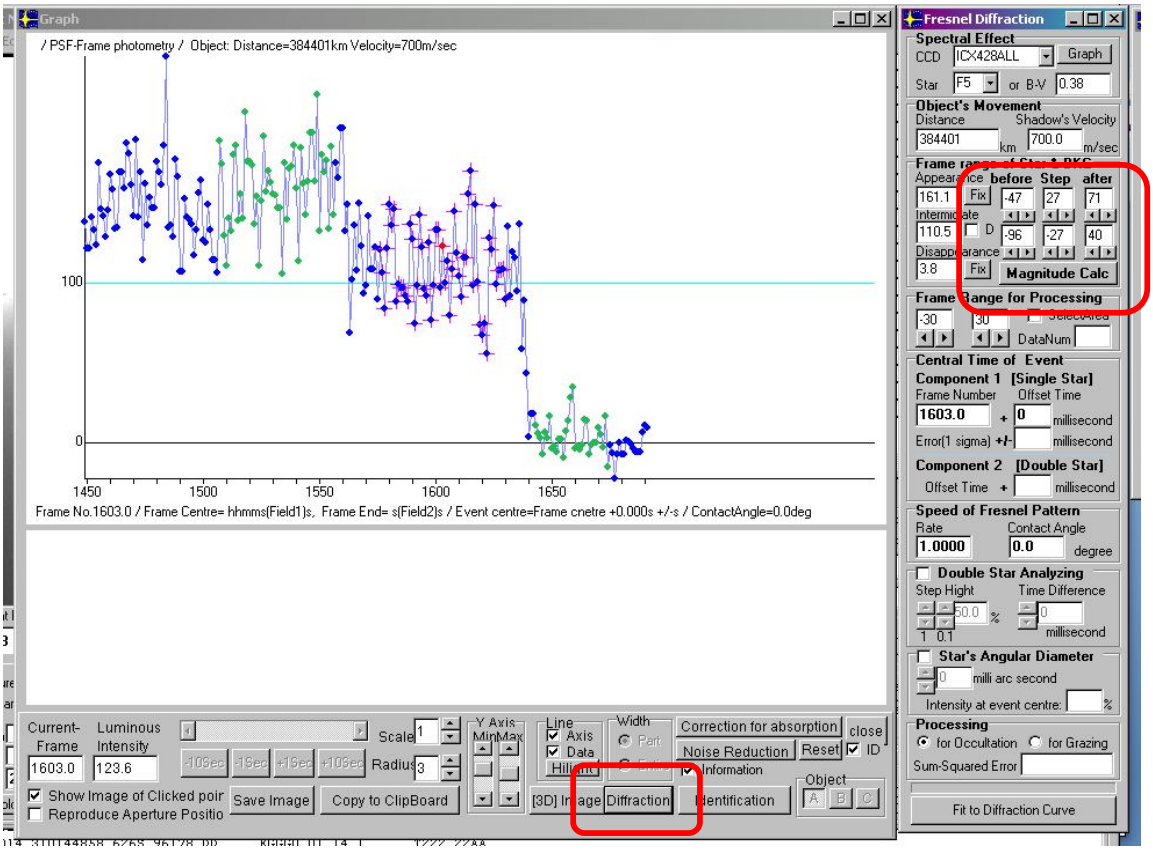


To add identifying details to the plot press the Identification button. This brings up a dialogue box. Fill in your name, the catalogue number of the star and check the date! Press Apply – this should add it to the top of the graph.

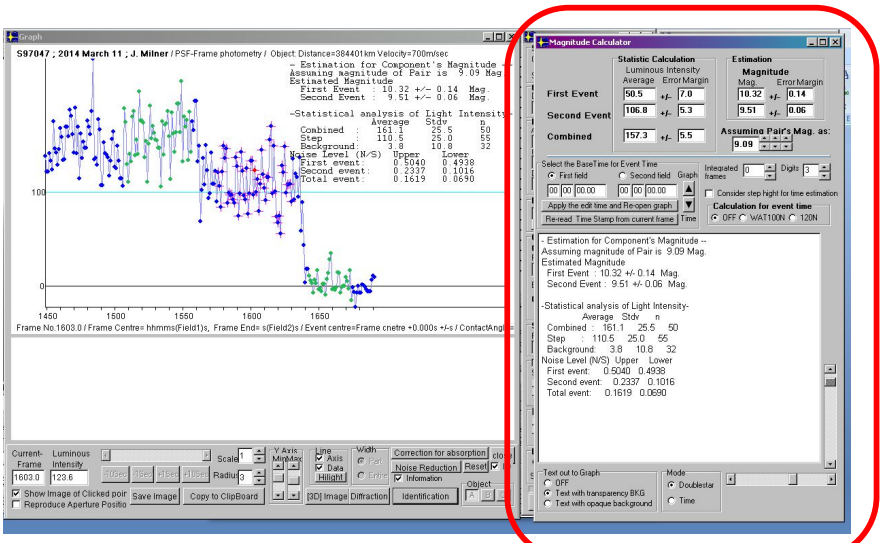


Choose a frame in the middle of the step (as marked by a solid red dot). Then choose the "Diffraction" button at the bottom of the graph. You should see some green dots appear either side of the red one. Move and expand these green dots out either side using the "before" and "after" ranges so it looks similar to the example below. The red crosses are made by adjusting the "Step" in the middle.

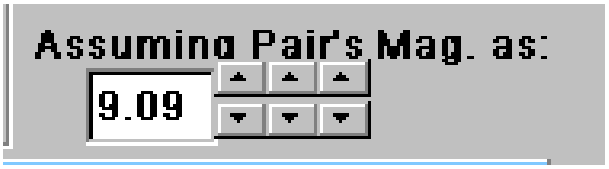
Once you have done this you can press the “Magnitude Calc” button.



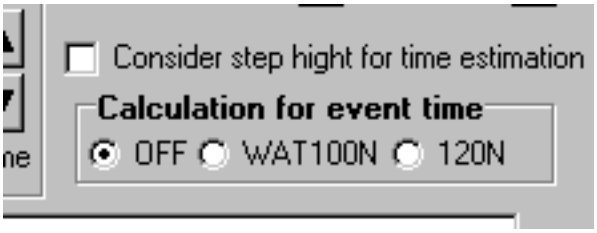
A new dialogue box, the Magnitude Calculator, should appear to the side of the graph.



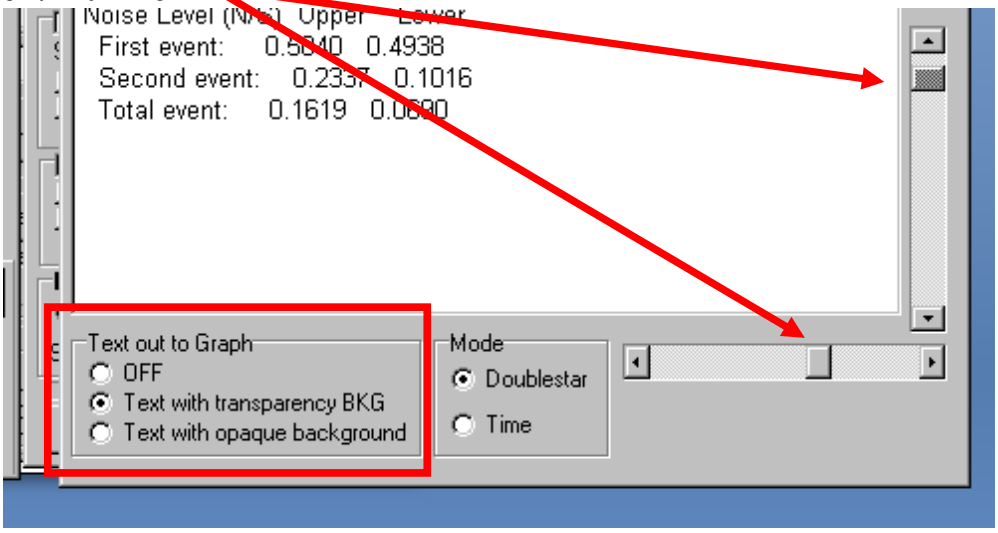
Set the assumed magnitude. You should be able to find this value in *OCCULT*.



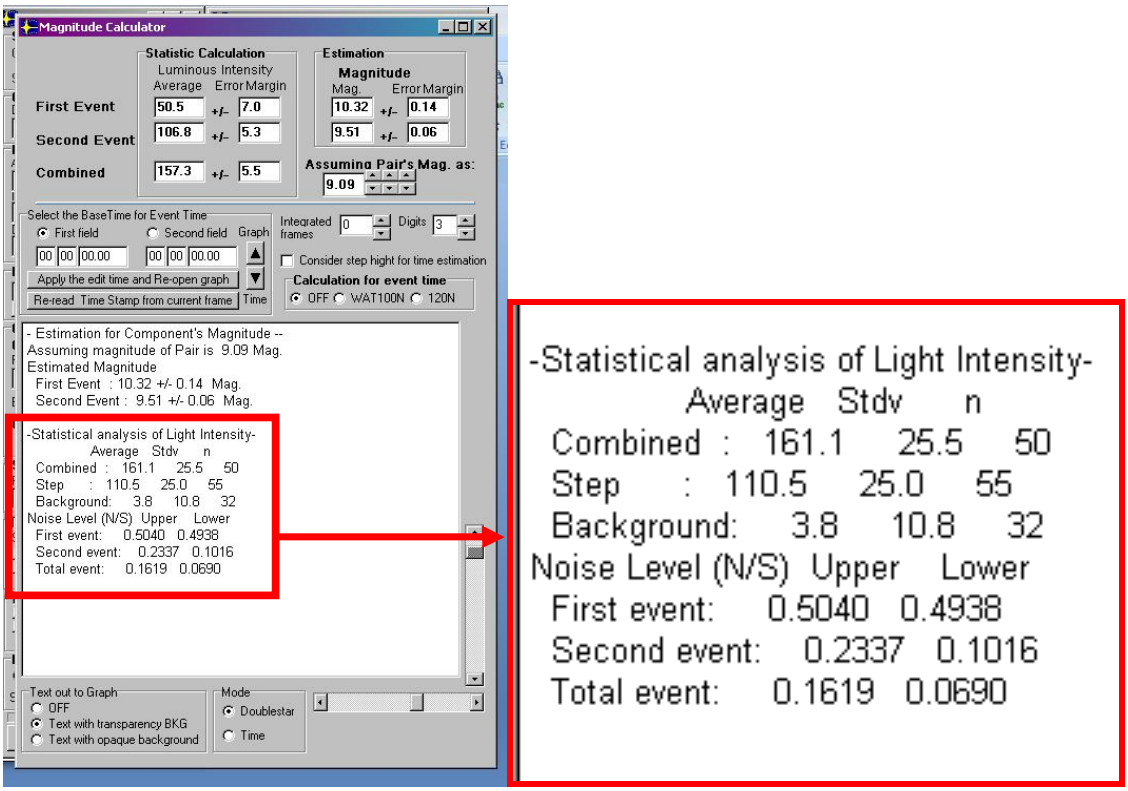
If you are not using a Watec camera you may want to turn “Calculation for event time” off.



Apply the magnitude calculation and standard deviation data by choosing either opaque or transparent in the “Text out to Graph” box and then adjust the position of the block of data on the graph by using the slider bars.



While you are here, make a note of the information under "Statistical analysis of Light Intensity." This will help you work out your S/N ratio for your monthly lunar occultation report.



As we want the S/N ratio, not the N/S ratio, you can take the N/S for the total event and divide it into 1

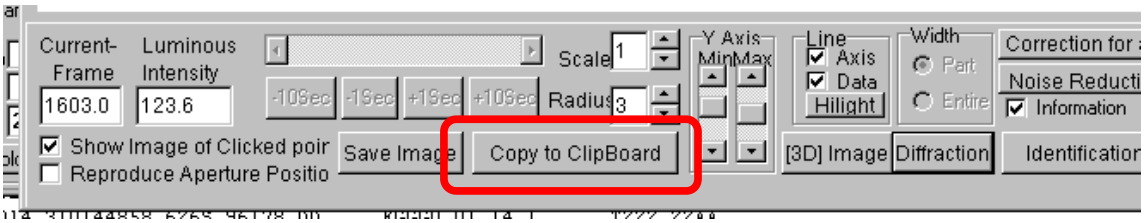
S/N = 1/(N/S for total event) = 1/0.1619 = 6.17

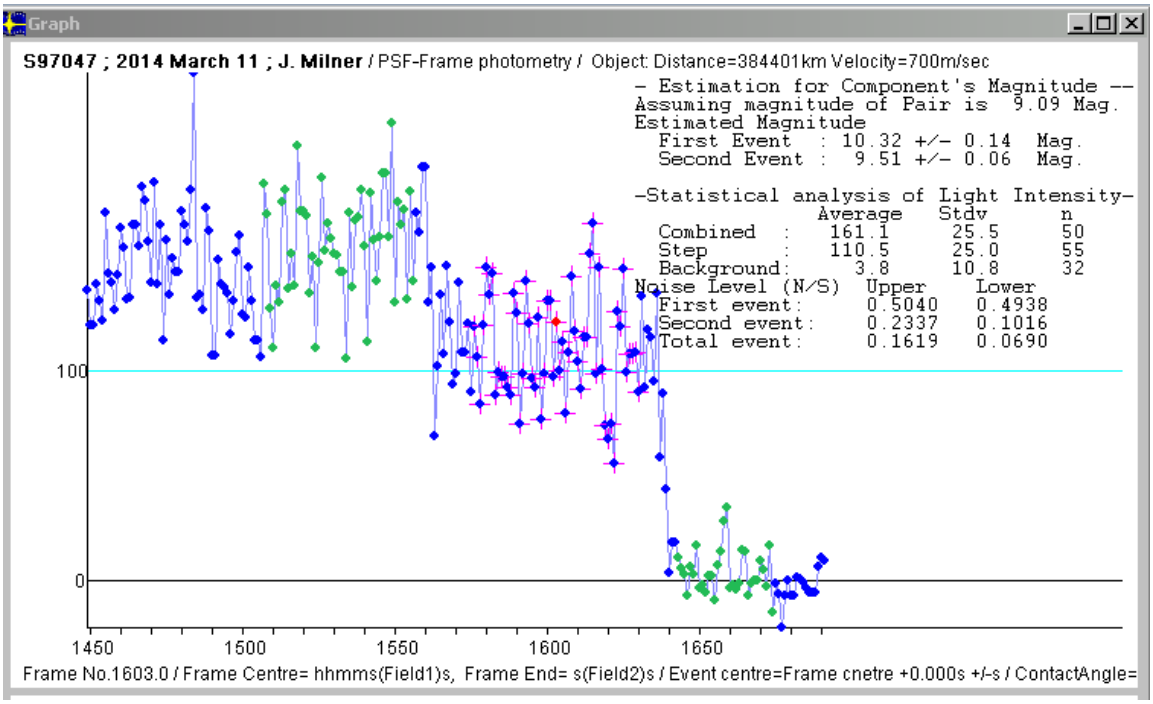
or

S/N = (Combined Average – Background Average)/Combined Standard Deviation

= (161.1 – 3.8)/25.5 = 6.17

Once you are happy with the presentation press “Copy to Clipboard” and go straight to your monthly lunar occultation report file for that month, where you will need to have already entered the times for this particular event.





Appendix 7: Analysis of Occultation Events Using Audio Techniques

By Dave Gault

The use of an audio time-base for the successful observation of occultation events has a long history. From the early 1960s, David Dunham, Bob Sandy and others used reel-to-reel tape recorders and later cassette tape recorders, to record the sound of the short-wave time signal broadcasts of station WWV (Fort Collins, Colorado) or WWVH (Hawaii) as well as the sound of their voice calls from the telescope as the events occurred. There were a lot of other shortwave broadcast stations available in the past but sadly most have ceased transmissions. Our time signal station here in Australia was radio VNG which closed in 2002. Today, there are alternative methods to obtain an audio time-base, the best of which use GPS as a basis for operations.

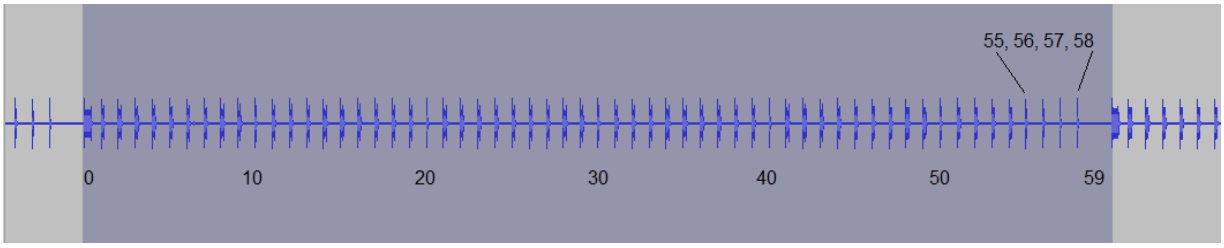
The recording of the observer's voice has a number of advantages over a stopwatch or some other device operated by the observer's hands:

- The voice is not as much affected by cold temperatures as an observer's fingers and so the observer's Personal Equation (PE, also known as Reaction Time) might be more consistent.
- The microphone can be clipped to the observer's collar or lapel or even a microphone headset could be worn, that would free the observer's hands for other duties including controlling the telescope.
- The observer can give a commentary on the proceedings, noting indirect observing conditions like the presence of cloud, or eyepiece fogging, telescope re-pointing activities or passing traffic.
- The observer can instantly add comments that effect the observation directly, like the detection of a step-like event which might occur due to a double star, or a slow event which may indicate a large stellar diameter.
- Comment can be added immediately after the event to explain how the observer felt about the event call and whether a larger than normal PE should be applied.

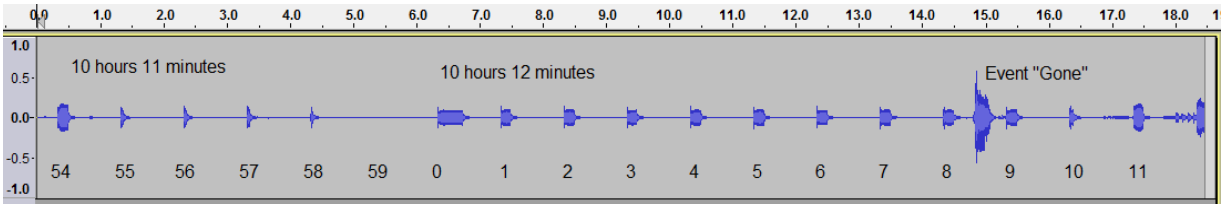
The best arrangement is to have a stereo recorder set up so that one channel records the sound of the timing device, and the other channel is devoted to the sound of the observer's voice. However a simple mobile phone recorder can be used as a make-do recording device.

The analysis of audio recordings is best performed using free software that is available over the internet. The author uses "Audacity" by Sourceforge on the PC, and an alternative for Macintosh computers is "Garage Band". Stephen Russell first demonstrated this technique to me at the first Trans-Tasman Symposium on Occultations – in Auckland in 2007.

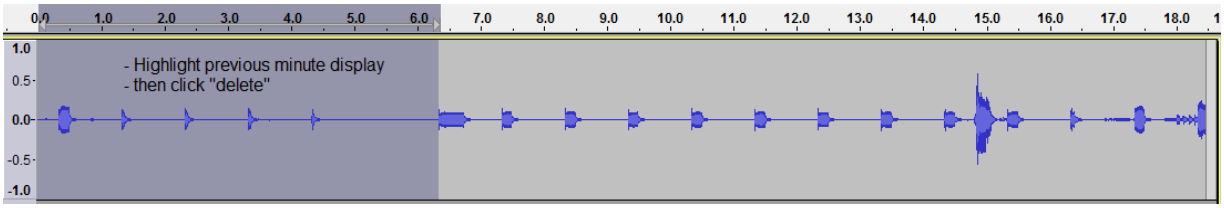
Here is what a minute recording of the audio beeps of GPS-ABC look like using Audacity.



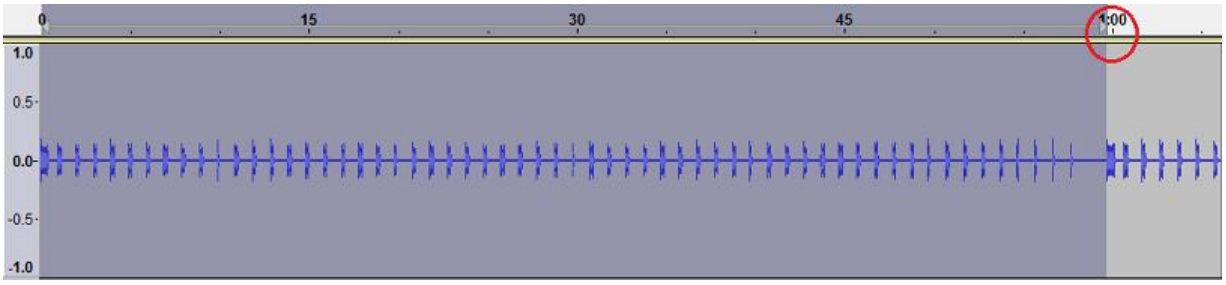
The long beep at the beginning of the minute, as well as the silent 59th second can be easily determined as well as the shorter 10th seconds beeps.
The steps to determine the time of an event are, (assuming the sound recording has been saved to computer, usually as a .wav file);
1) Open the file using Audacity or similar and note the silent 59th second



2) Highlight and delete the recording preceding the minute beep

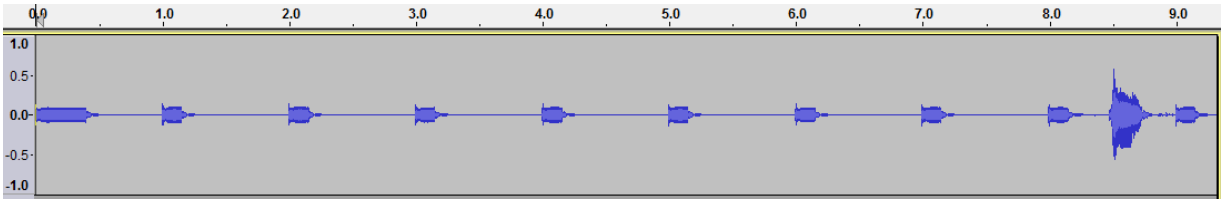


3) Note that the scale at the top (in seconds) is now zeroed,

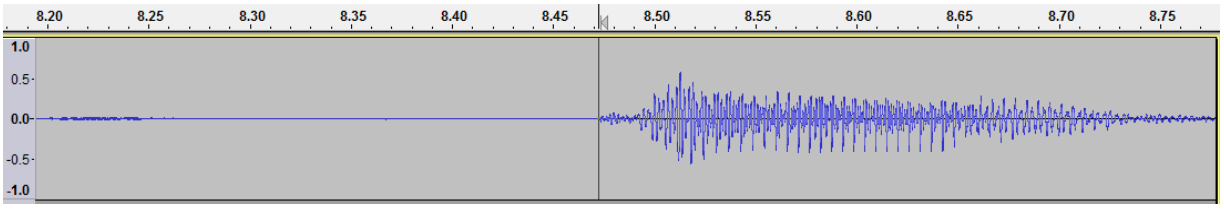


Then check the scale at the beginning of the next minute. Any variations in record and playback speeds can be adjusted using the Audacity effect “Change Speed”

4) Read off the approximate time of the event. In our example this occurs at about = 8 ½ seconds



5) Zoom into the "gone" event to closely examine the plot for the sound of the word.

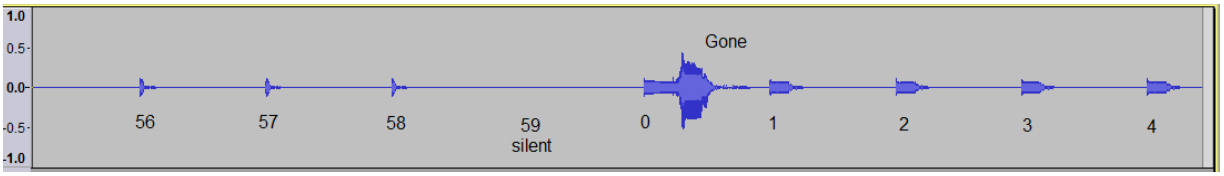


The beginning of the sound of the word "gone" is probably due to the sound of the movement of muscles in my throat required to make the "g" sound and so is the first instance of my reaction to the event. The raw event time is 10:12:08.472 UT

Of course the next step is to determine my Personal Equation (PE) value. This does not have to be performed for every observation, as PE is a subjective estimate based on measured values, adjusted by the feelings of the experienced observer.

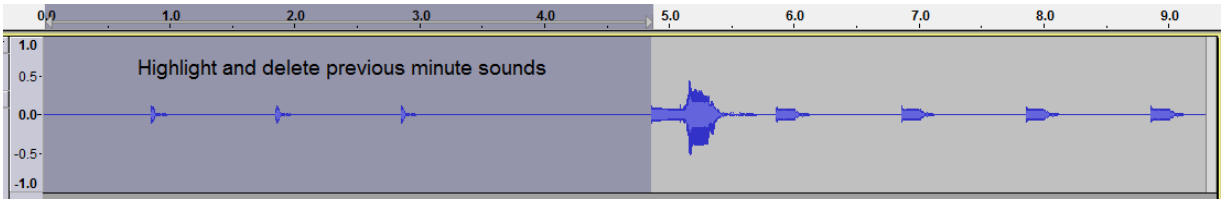
The steps to determine the PE value are very similar to the above method, only this time the observer watches for the flash of the 1pps LED on the GPS_ABC and tries to "time" that. In the GPS-ABC device and the program BeeperSync the minute is preceded by a silent 59th second. So the observer closes both eyes and opens them during the 59th second, and says "gone" immediately on seeing the LED flash.

The Audacity recording of this plot looks like this:

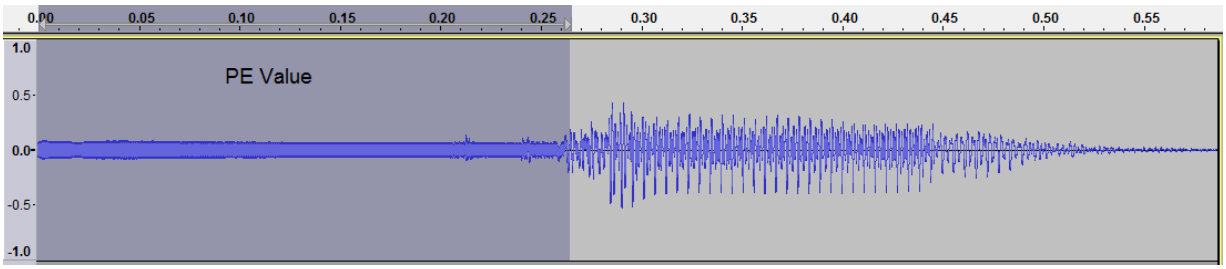


Note the word "gone" is louder than the time beep and can easily be distinguished.
The steps to determine the PE value are:

Highlight and delete the recording of the preceding the minute



Zoom in to examine the sound of the word “gone”



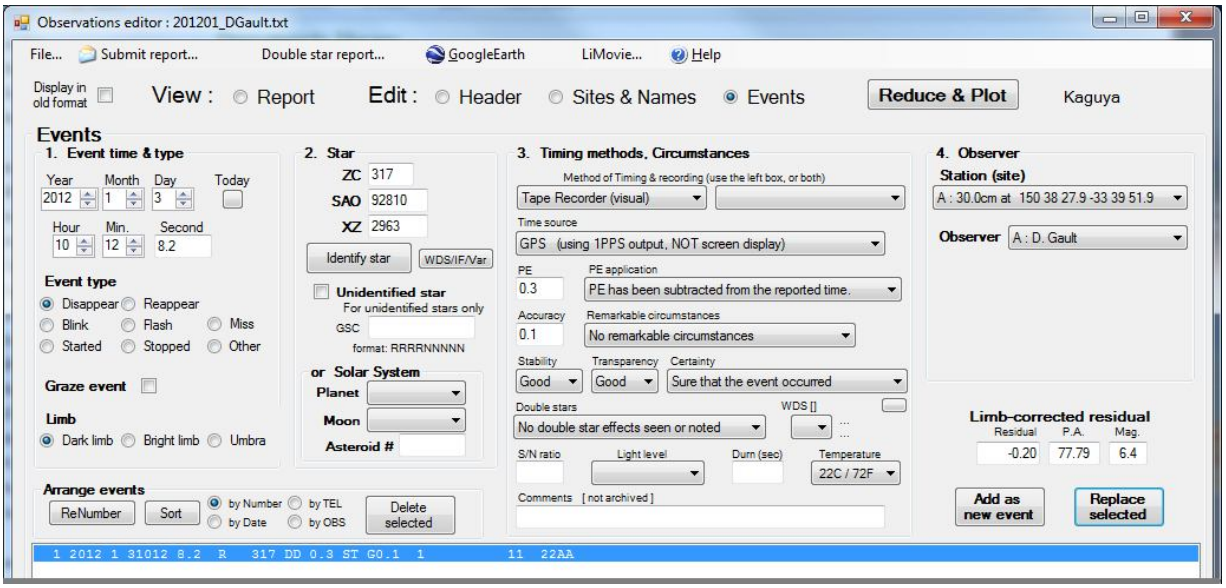
Note the PE value is shown as 0.26 sec and should be considered the base value in perfect conditions. In the real world, observing a star through at telescope the value should be considerably larger – probably between 0.3 and 0.4 sec would be realistic and probably larger still if the conditions are difficult or the event is a reappearance.

So, for this event, the corrected event time is;

10:12:08.472 UT
subtract 0.300 PE

10:12:08.172 UT
10:12:08.2 UT rounded to the nearest 1/10th second

Note that visual observations should only ever be reported to the nearest 1/10th of a second. Reporting a higher accuracy for a visual observation is meaningless).

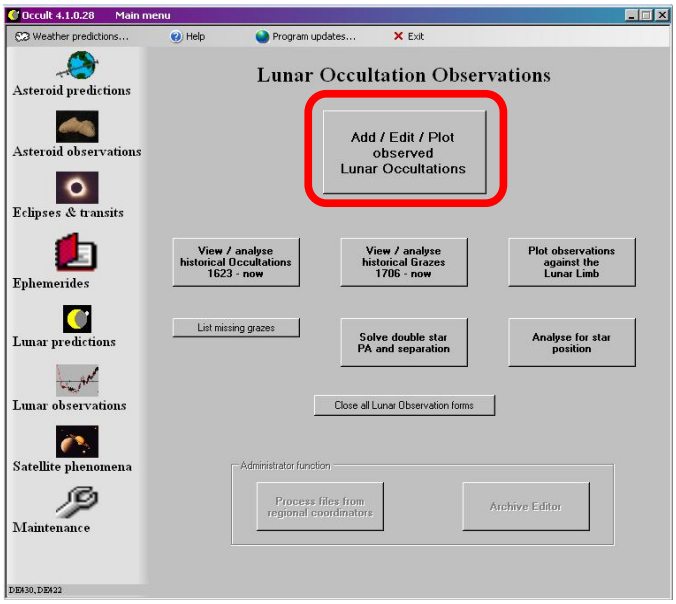


Fill out the Report Form and remember to insert your best estimate for the event accuracy.

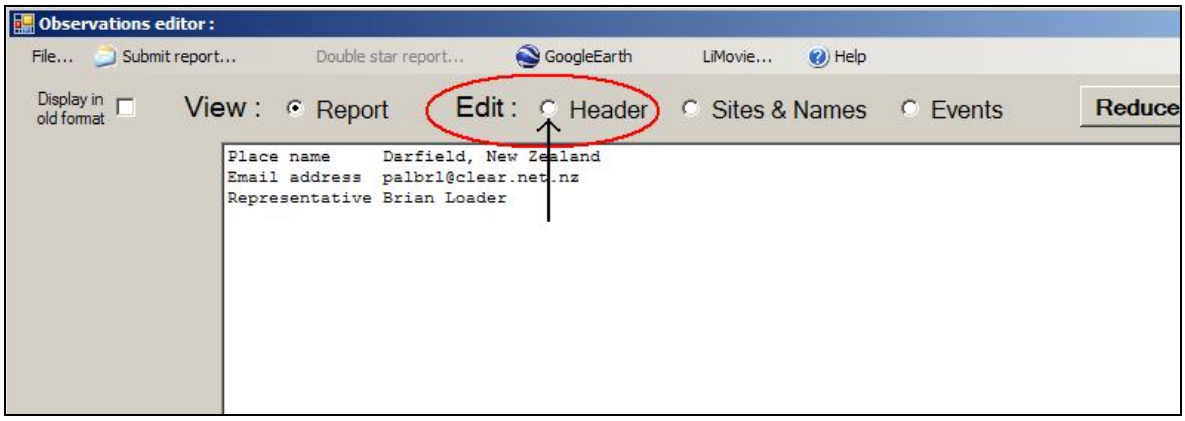
If you have any questions, please email me at davegault@bigpond.com

Appendix 8: How to fill out a Monthly Lunar Occultation Report (including Double Star Reports)

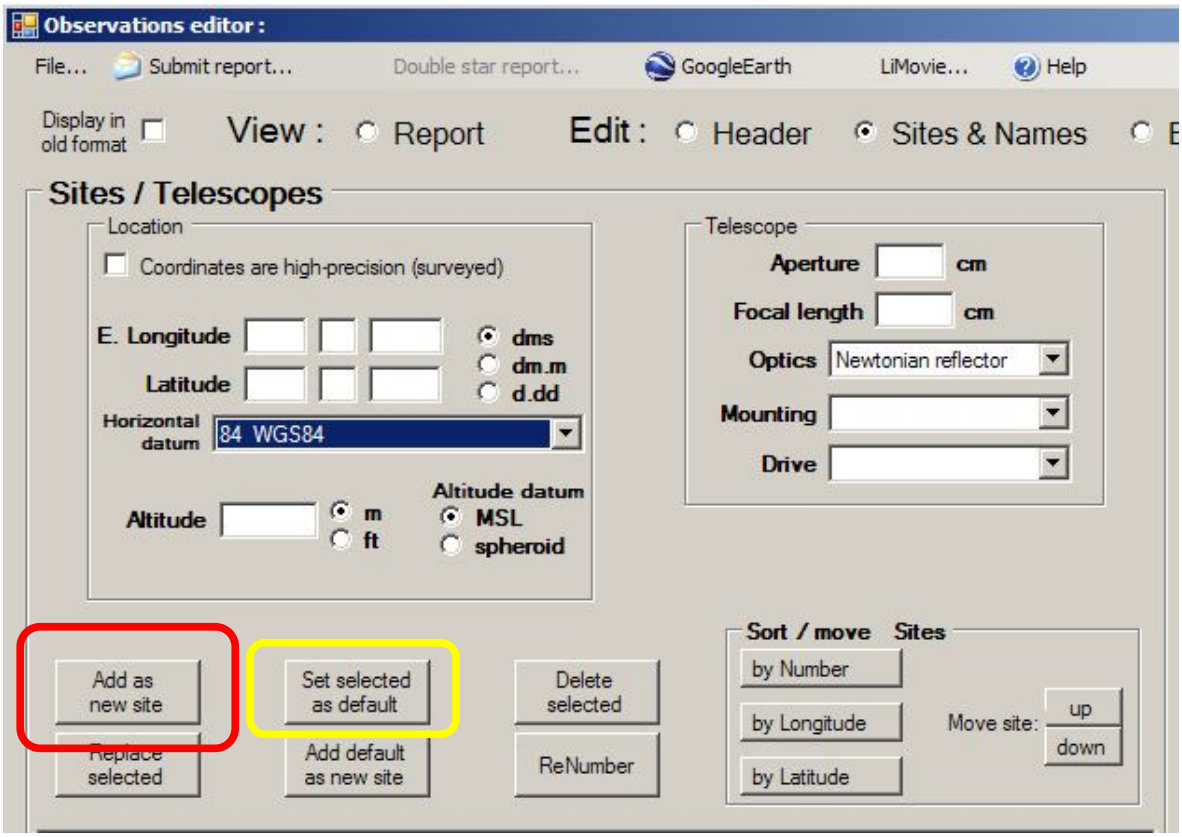
Open *OCCULT* and go to the Lunar Observations page. Choose the Add/Edit/Plot button



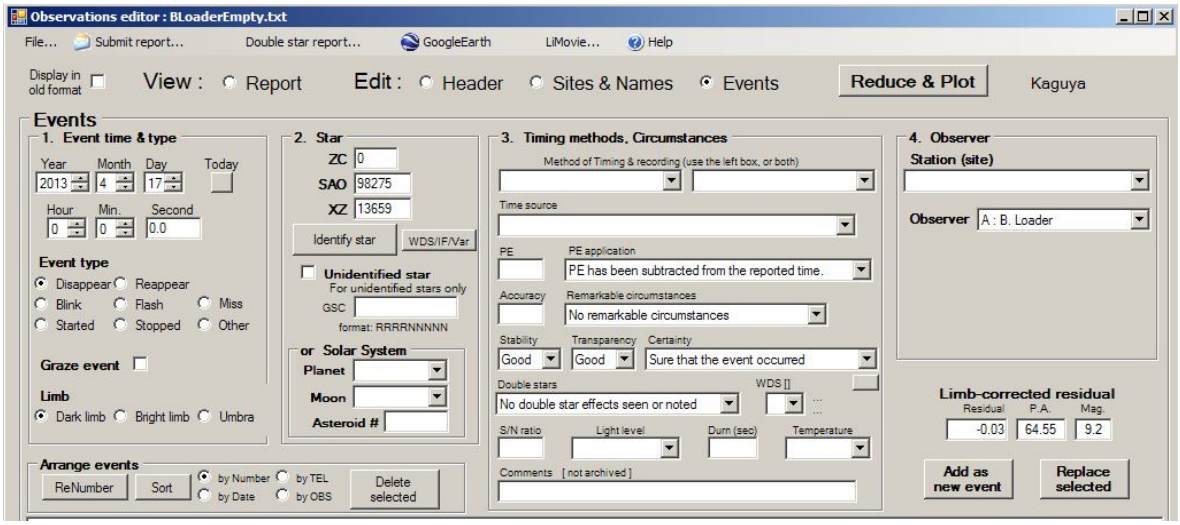
To start a new report, choose the "Header" radio button and fill out the details required.



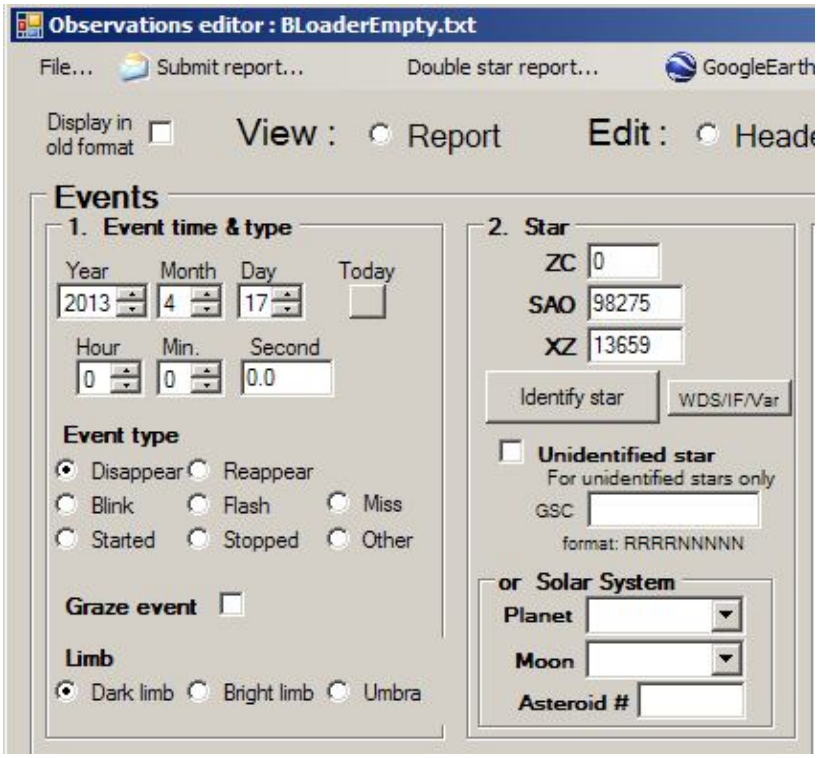
Next, choose the "Sites & Names" radio button and fill out the details there for your location, your telescope and your name. The layout of the form allows for multiple observers or multiple sites Once you have done that you should add it as a new site. You can also set it as a default for the future.



Now you can go to the Events section of the report.
To make this section work as intended you must have the previous section filled in first.

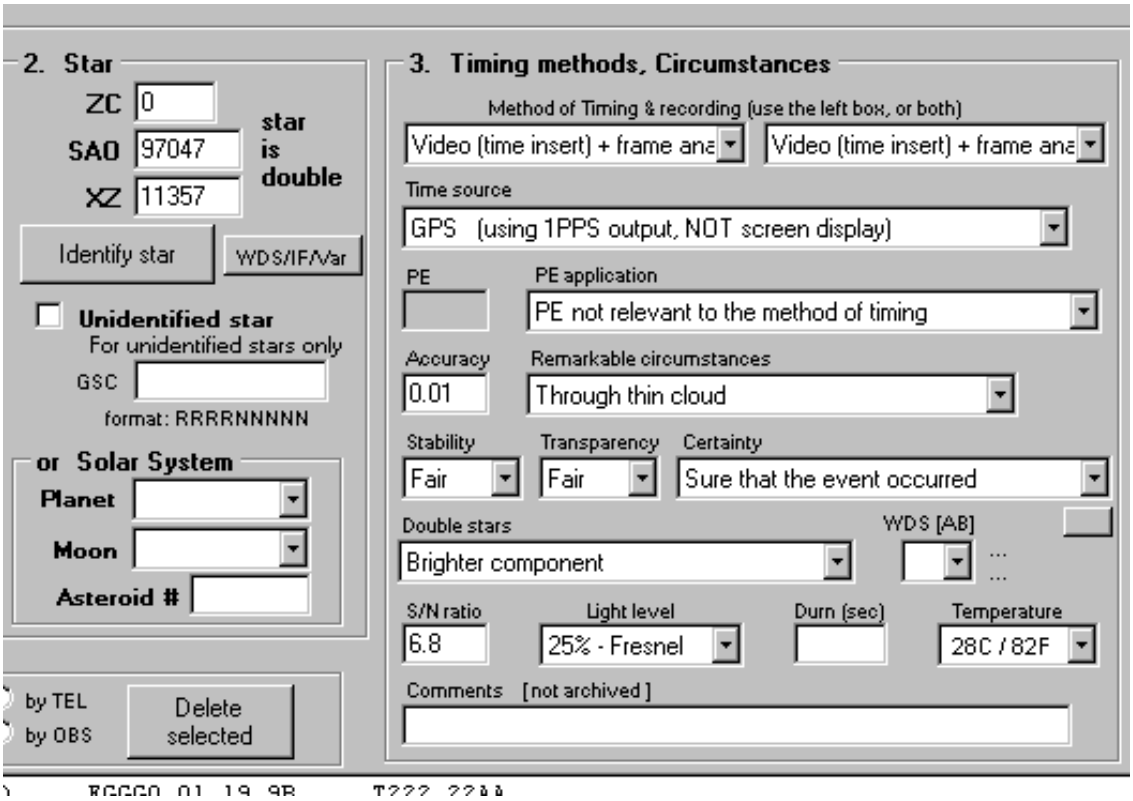


Start by filling out the date and time of the event, what kind of event it was, what limb of the Moon it occurred on and the catalogue number of the star in the appropriate boxes.



Fill out the timing methods and circumstances of the event.
You will notice there are a lot of drop-down menus available here. Have a look and choose the most appropriate option for your circumstances.

- Fill out your method of timing and recording.
- Accuracy should be given as 0.02 if it was analysed to a Frame and 0.01 if the frame was split into fields for inspection.
- If the star is a double you need to indicate if it was the A or B star or Brighter or Fainter if you're not sure of the designation (there are several options there).
- The Signal to Noise ratio should be added.
- Don't forget to add the ambient temperature in!

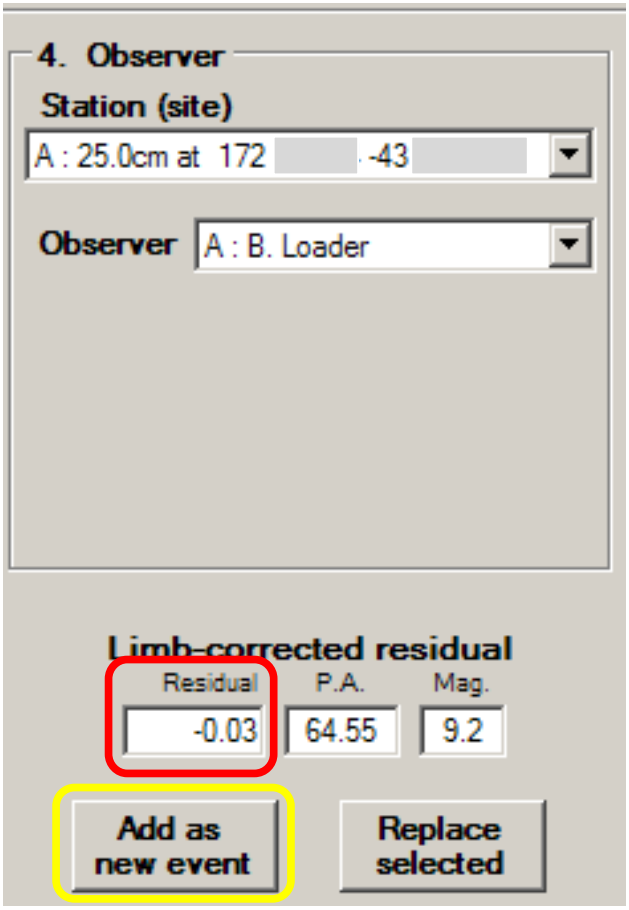


On the right hand side your site information and name should be displayed. These are generated from the Header and Site & Names sections.

Make sure you check the Residual value. It should be between -1.0 and 1.0, but occaisonally it may be within -2.0 and 2.0. Anything larger than this and you should carefully check the other details you have added, such as date, time, star catalogue number etc., for a mistake. Most problems are from simple data entry errors.

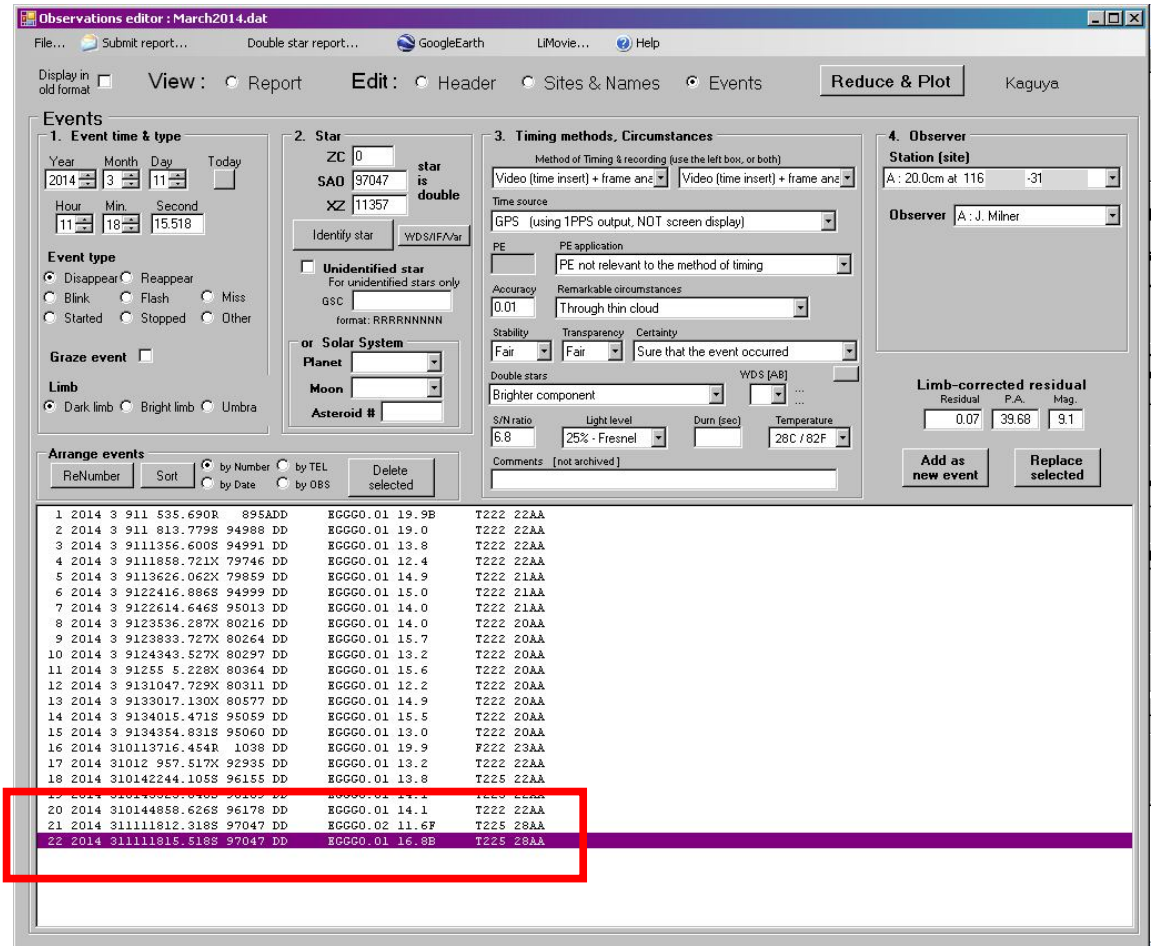
And finally don't forget to add it as a new event!

If you make a mistake this is no problem; just click on the line to be edited, make your changes and then choose "Replace selected."

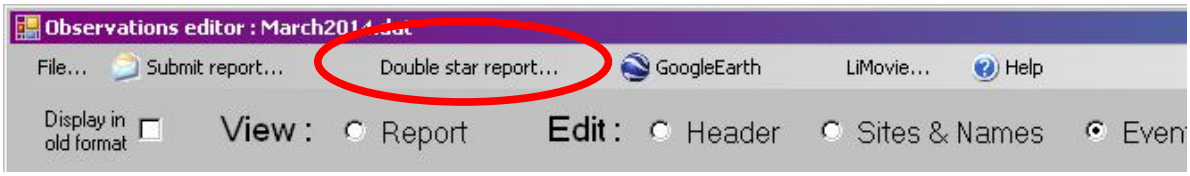


To send a double star report:

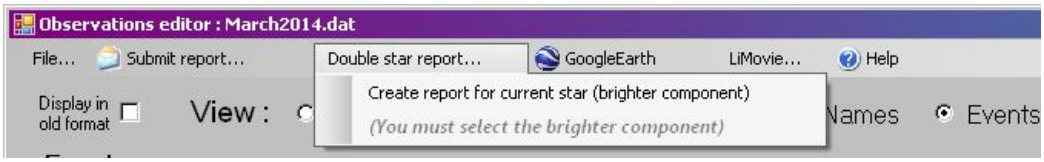
In the observations editor click on the entry for the **brighter or A** component of the double star to highlight it.



Click on the "Double star report..." menu at the top of the box...

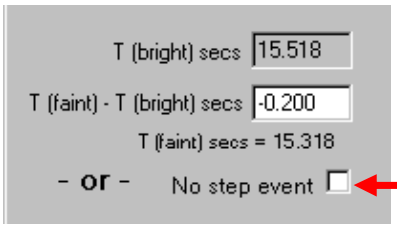


...and then click on "Create report for current star". It reminds you to make it for the brighter component.



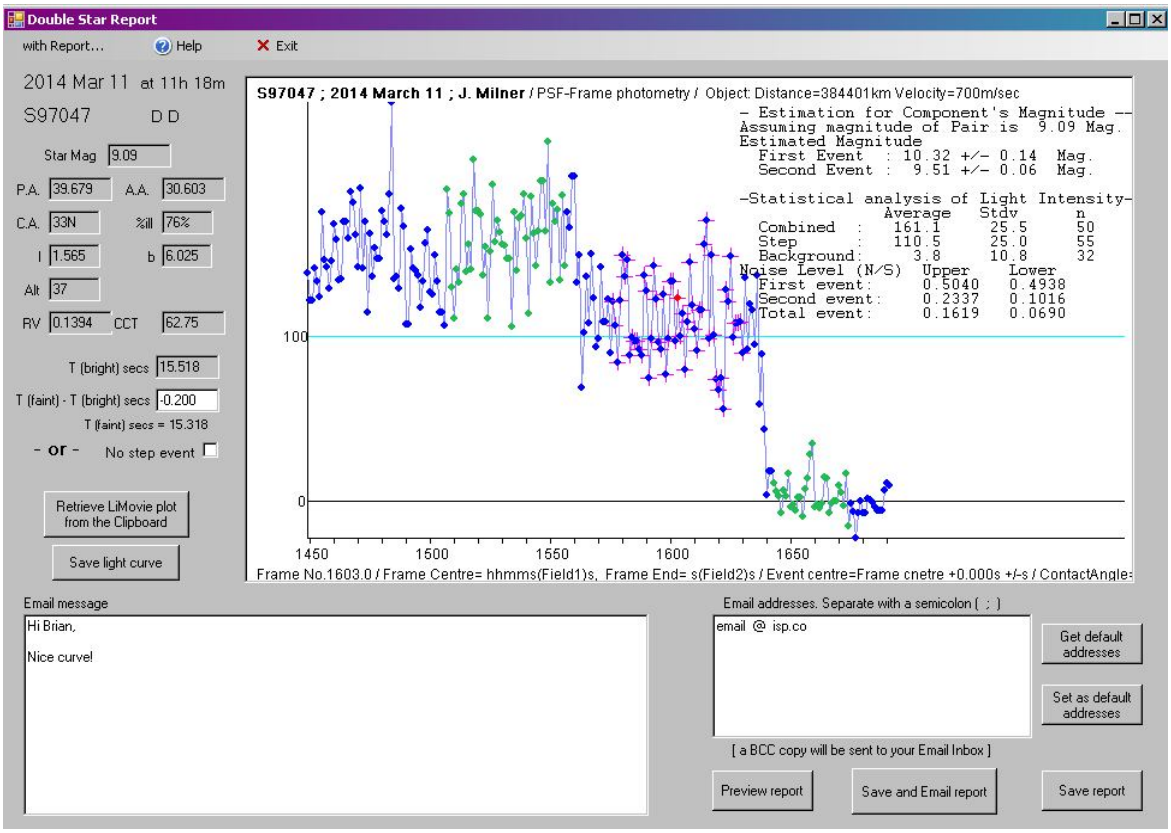
Add the saved light curve graphic generated by *LiMovie* that should still be in your clipboard. You will have to come straight from *LiMovie* to here so the graphic is not lost, so it helps to have already set up the lunar occultation report beforehand. Unfortunately it doesn't work if you save the graphic of the curve for later use, **the report form only looks at the immediate clipboard contents**.

Fill out the T(faint) – T)bright value, i.e. the time of disappearance of the fainter star minus the time of disappearance of the brighter star. You can work this out from the times you have given in the main reporting form. **If the fainter star is occulted first, the value should be negative.**



Tick the No Step Event box if this report concerns a *suspected* double star that was flagged for further observation but for which your observation and resulting light curve does not show an obvious step. You do not need to fill in the T(faint) – T)bright value if this is the case.

Finally, add in Brian Loader's email in the box on the right and make any comments you think are necessary about this event on the left. Press "Save and Email report" to finish. A copy should be sent to your email as well as Brian's.



Glossary (including abbreviations)

1 sigma line	Limit of the first unit of standard deviation from the centre of the normal distribution curve for the accuracy of a given event prediction.
AOTA	Asteroidal Occultation Time Analyser (part of *OCCULT*)
Aperture photometry	Photometry method in which the pixel counts (of a star image) within a circle centred on the object is measured and then has the average count of the background sky subtracted from it.
appulse	The very near approach of two astronomical bodies but not close enough that an occultation occurs.
astrometry	The measurement of the positions of astronomical bodies
AVI	Audio Video Interleave. Common file format for video
Avisynth	Software for converting video files into AVI format.
Beeper Box	A small low cost 'standalone' portable unit able provide audible time signals and a pulsing LED for timing reference.
Beeper Sync	Software to coordinate time on a Beeper Box
CCD	Charged Coupled Device. Commonly refers to a type of camera.
centreline	The centre of the path of the shadow.
codec	A device or computer program capable of encoding or decoding a digital data stream or signal.
combined magnitude	For asteroid occultations, when an asteroid is so close to the star that they appear to be merged as one object.
CSV file	Comma-Separated Value file.
cusp (lunar)	The point where the bright limb and the terminator join, roughly near the pole(s) of the Moon.
datum	A reference system for geographical measurement, e.g. WGS84, GDA94
Dawes limit	The diffraction resolution limit of a telescope, described as 116/Dmm arc seconds, where D is the aperture of the telescope in millimetres.
Dec	Declination, celestial latitude. 0^0 at the equator, increasing to 90^0 at the poles. The southern hemisphere has negative declination
DVR	Digital Video Recorder

field	Half of a video frame. Two fields are interlaced to make one frame of video footage.
Field of View	The area of sky visible within a telescope eyepiece or camera
FOV	Field of View
frame	One complete captured image in a video made of two interlaced fields.
framegrabber	A device for converting video from analogue to digital format.
frame rate	The number of frames captured per second.
graze	A grazing occultation
grazing occultation	When a star just skims the limb of the moon and may disappear behind mountains and reappear in valleys as the moon passes the star.
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision. The indication of how accurate the fix of a GPS reading is in the horizontal e.g. your latitude and longitude. The closer to 1.0 the number is the more accurate it is.
IOTA	International Occultation Timing Association
ILOC	International Lunar Occultation Centre
light curve	Graph of changes in brightness over time.
limb	The edge of a celestial body against space.
LiMovie	Software for analysing occultations.
Lossy compression	Data encoding method that compresses data by losing or discarding some of it.
LOW	Lunar Occultation Workbench. Software for predicting and organising lunar occultation observations.
lux	Unit of light measurement.
magnitude	The brightness of an object.
MSL	Mean Sea Level
NACAA	National Australian Convention of Amateur Astronomy. Held every second year. See http://www.nacaa.org.au/ for more details.
NTSC	An acronym for the National Television System Committee. The analogue television system that is used in most of North America and parts of South America.
occultation	An event that occurs when one object is hidden by another object that passes between it and the observer.

OW	Occult Watcher. Software for planning and coordinating planetary occultations.
PAL	Phase Alternating Line. The analogue television colour encoding system commonly used in the Australia/New Zealand region.
Personal equation	Your personal reaction time. The time between seeing an event occur and being able to react to it.
Ph mag	Photographic magnitude
Photometry	The measurement of the brightness of an object.
Point spread function	The irradiance distribution that results from a single point source in object space.
PSF	Point Spread Function. Where the relative intensity of the pixels across a star image are fit to a Gaussian curve distribution. The background noise level is subtracted. Saturated pixels are discarded from measurement.
RA	Right Ascension. Celestial longitude, given in hours. There are 24 hours of RA.
Rank (prediction)	Indicates how accurate an asteroidal occultation prediction is considered. A rank of 100 indicates the prediction is considered very accurate. The lower the ranking the less certain the prediction is (and the more important it is to observe the event).
RASNZ	Royal Astronomical Society of New Zealand. http://www.rasnz.org.nz/
seeing	The condition of the sky overhead in terms of steadiness and transparency.
sigma line	Limit of a unit of standard deviation, based on the standard deviation of the normal distribution curve for the accuracy of a given event prediction.
Tangra	Software for analysing occultations
TNO	Trans-Neptunian Object
TTSO	Trans-Tasman Symposium on Occultations. Alternately held at NACAA in Australia during even numbered years and the RASNZ Conference in New Zealand in odd-numbered years.
UCAC	USNO CCD Astrograph Catalog.
USNO	United States Naval Observatory
UT	Universal Time (replaced Greenwich Mean Time)
VCR	Video cassette recorder
VizieR	An astronomical catalogue service provided by Centre de données astronomiques de Strasbourg. http://vizier.u-strasbg.fr/
Vmag	Visual magnitude
VTI	Video Time Inserter

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