# Lunar Occultation of Close Double Stars

**NACAA 2014 April 20, Sunday afternoon occultations session**

***[If these notes are being used while viewing the Power Point presentation, use the pps mode(F5) and advance at each numbered bold header in the text. There are 25 frames altogether, some include changes built in and 4 are a set which automatically advance after the first isd isplayed .]***

## 1. Lunar Occultations of Close Double Stars

Normally when a double star is occulted, the two component stars will disappear, or reappear, at slightly different times. In some cases this is obvious to a visual observer. On the upper right is part of a frame from a video of an occultation of the star R946. The lit terminator of the moon can just be seen on the right. You'll see the double nature of the star.

### 1a. Occultation of R 946

At occultation there was an obvious stepped change which could be seen by a visual observer, in this case the secondary was visible for about 4.5 seconds. Magnitudes are 3.52 and 6.15.

Few close doubles are as clear as this at their occultation. Below is a frame from an occultations of SAO 16149, magnitude 8.5.

### 1b. Occultation of SAO 160149

Here the step lasted just over 1 second and the change was not easy to detect, even lthough I have slightly enhanced the star images. At the eyepiece it would probably have not been noticed

In general video techniques are needed to detect double star occultations. Working at a rate of 25 or 30 frames per second, (50 or 60 fields) the possibility of detecting the light changes due to a double star are much greater.

## 2. SAO 160149 Frame

Insertion of the time on each video field means the times of the occultations can be determined to within one or two hundredths of a second. The mid time of this frame is 8:08:33.731.

The presence of a double star is best shown by analysing the video record with a program such as Limovie.

## 3. Light curve single star

If the star is single then a light curve showing a single drop (or rise if a reappearance) will be obtained. This light curve, obtained recently by Dave Gault, is in fact for a star reported as possibly double. There's no sign of such here. The vertical axis shows the measured intensity of the brightness of the star image. The horizontal axis shows the video frame number, effectively time.

## 4. Light curve for SAO 160149

The light curve for SAO 160149, the second star shown on the 1st screen has an obvious step, characteristic of a double star. Clearly the fainter star was the first to be occulted. The small light drop with the brighter star still visible made this double event difficult to the unaided eye. It is quite clear on the light curve.

## 5. Labeled curve

From the video the time and duration of the step and the relative light changes can be determined.

**6. Curve with data**

The duration of thie step was 1.16 seconds, 29 frame.

An estimate of the magnitude difference of the two stars is obtained from the relative heights of the light changes. In this case the magnitude difference is 0.8. Assuming the magnitude of the combined stars is 8.5, the individual magnitudes of the components are 9.0+9.8. This is of course not high precision photometry.

**7. Fainter star second.**

In this case the fainter star was the second to disappear. With the brighter primary star already occulted, it is likely the secondary star would have been faintly visible, provided it is not too faint to be seen against the background glare of the moon. Some data produce by Limovie has been added to the light curve …

7**a. Data enlarged** with a magnitude estimate at the top

**8. Double star reappearance – R68**

As a final example this shows a reappearance with a brief step, ca 0.2 seconds long. The fainter star reappeared first. The apparent brightness difference is about 2 magnitudes. I will refer to this event again shortly.

**9. Aims of Observing Occultations of close double stars**

The immediate aim is to accurately measure the time difference of the two events. The accuracy obtainable from GPS time insertion is usually needed.

(Auto advance) Determination of the separation and PAs of double stars

This can provide data from which the separation and position angle of the double star can be determined. Two or more observations of the occultation made at well separated sites are needed.

(Auto advance). Magnitudes

An estimate of the magnitude difference of the stars can also be made.

(Auto advance). Discovery

Obviously it is possible that new doubles may be discovered if occultations of other stars are observed.

(Auto advance) Confirmation/rejection

Conversely an observation may show a supposed double star is probably single. More on some of this aspect later.

(Auto advance) Publication

It would hardly be worth making the observation without a prospect of publishing results.

**10. Solution for R68 using Occult**

Earlier we saw a light curve for the reappearance of the double star R68. This is a close double star with a published orbit, the WDS shows a period of 27.4 years for the pair, with a mean major axis 0.16".

The diagrams and calculations used here were made using Dave Herald's Occult programme

Jonathan Bradshaw observed the 2013 July 27 occultation from Brisbane. From his single observation only the vector separation, 0.082" at PA 290.3°, of the stars can be determined. On the diagram the primary star is represented by the larger yellow spot. The blue line is parallel to the moon's limb at the point of occultation. The vector direction is perpendicular to it. The secondary star is shown at its closest position to the primary. In fact the interval between the two occultations would be the same wherever it was situated along the blue line. Exactly where it is not determined without further observations.

### 10a. Second observation

Dave Gault observed from near Sydney, the red line is his limb line. This fixes the position of the secondary star where the two limb lines cross, The separation is 0.084" and PA 269.21° for the pair. No formal error can be calculated from just 2 observations, so further are desirable.

### 10b. Third observation

As it happened there was a third observation, I timed the event from New Zealand with the occultation reappearance at a very different part of the moon. Now an error can be calculated: separation 0.088" ± 0.002" at PA 260.73° ± 1.70°.

### 10c. Prediction from orbit

For this event the 3 observers were well spread out resulting in a quite strong solution. It is comparable to the position from the predicted orbit and should add to the knowledge of the data base for the star.

This is not always the case, in some cases the occultation observations can improve on the data for the star or may show the data is considerably in error.

## 11. Resolution that can be achieved using lunar occulations

(i) To be reasonably certain that a step has in fact occurred, a duration of at least 2 or 3 frames is needed. This corresponds to a step length of about 0.1 seconds.

(ii) Taking a typical value for the rate at which the limb of the moon appears to close in on a star, this corresponds to a separation of 30 to 35 milli-arcseconds.

At the distance of the moon, this corresponds to about 60 m.

For stars at a distance of 100 light years, just over 31 parsec, two stars can be resolved when separated by 1 AU, the distance of the Earth from the Sun. Not bad for a small telescope.

## 12. Progress

The programme of timing double star occultations was started in 2007 following the first TTSO held at the RASNZ conference in Manukau, Auckland. Since then timings have been contributed from observers in Australia and New Zealand, Japan, the USA and a number of countries in Europe. The earliest reports received date from 2004, about the time video started being widely used for occultation observing.

As at 2014 April 6 the total number of reports received stood at 1361, these can be broken down into a number of categories:

## 13. Numbers of observations by 7 categories.

**13a. WDS** includes double stars appearing in the Washington Double Star catalog. 'Double' means observations where a stepped event is seen, 'single' cases where no double was detected. This latter may be due to the stars have been occulted at the same time. They are too close to split by the occultation method. The fainter star could be too faint to detect in the conditions. In a few cases it may mean the star is in fact single.

**13b. OCc** are stars which have been reported as possibly double as a result of a visual occultation observation which the observer thought was not instantaneous. Well over 1000 stars have been recorded as possibly double in this way.

The vast majority are proving to be single, only a very few as definitely double. As the singularity of the stars is confirmed, by at least two observations of occultations, the star can be removed from the double star lists.

**13c. Discoveries**. Of more positive interest is the opposite, when a star hitherto thought to be single shows a stepped occultation. If more than one occultation observation is made then it may be possible to determine the PA and separation of the pair. In the majority of cases only a single observation is available, in which case the vector separation of the pair can be determined. Most have sub arc second separations.

**13d. Doubtful.** Even with the use of video, there are still observations which suggest a stepped event, but are in no way certain.

**13e. Wide doubles.** The technique of determining the position angle and separation by occultation is best suited for stars with separation no more than about 2". Any wider ones reported are archived.

**14. Observers by Country** At present observations are received from the countries shown. For the most part a particular occultation will be only visible from one of the 4 groups. Occasionally an occultation is visible from the eastern USA and western Europe.

**15. Publication**

Results are published from time to time in the on-line Journal of Double Star Observations. http://www.jdso.org.nz. Two modes of publication are used:

**16. Discovery pages** Discoveries or other interesting observations may be published as individual papers written by the observer. These are usually quite short and include a light curve.

**17 General paper front page** More routine observations are published in tabular form in general papers. All observers are listed among the author list. The first was published in July 2010, to date 4 paper published.

18 (auto advance). July 2011, number 2 in July 2011

19.(auto advance) October 2012, the third in October 2012

20.(auto advance) April 2014, and the most recent at the beginning of this month.

A notable feature is the increase in numbers of observers contributing

**21. PA and separation measured**

Included are tables showing the calculated separation and position angle of pairs where multiple observations have been made. For a solution to be suitable for publication at least 2 observations are needed that are well spaced round the moon's limb, at least 10° apart in PA on the limb. As a result suitable observations are not as frequent as we would like. To date 43 such measures have been published.

**22. Discoveries**

Tables of discoveries are included, most of these have only one observation, so only a vector separation can be given. A requirement for inclusion is that the step is reasonably definite. Even with video doubtful observations also occur. Such stars need confirming observations, which may be some years away. Discovery light curves are included with the paper.

A few discoveries have had multiple observations enabling values to be calculated for the PA and separation. In all some 59 new double stars have been published.

**23. Found single**

Many stars which have been reported as possibly double as a result of visual occultation observations have proved to be single. To justify publication at least 2 observations have to be made, again at least 10° apart on the moon's limb. A single observation showing no step could be due to the two components being occulted virtually simultaneously. To date 59 such cases have been published, although many more have only a single observation, or two observations of events too close on the moon's limb.

So fare only 5 of well over 1000 of these old visual occultation discoveries have been shown to be definitely double. On the reverse side there are over 200 which have been observed as single, but many fail the criteria for publication

A few stars shown as double in the Washington Double Star Catalog have also failed to show a companion on video occultations.

**24. Observer separation**

To achieve separations on the moon's limb of 10° or more, an event needs to have observers spaced by several degrees of latitude, hundreds of kilometers on the Earth. Australia, especially along the east coast is well placed to achieve this. Here we see some of the separations. I'll leave you to guess the significance of the smiles.

New Zealand being small, is not so well placed, although the spread from Auckland to the South Island is sufficient. A similar diagram would show some smiles in the south as far north as Wellington, but then …

Further abroad both the USA and Europe have the spread, and some god results are achieved. But the number of observers per head of population is pitiful. Japan does a little e better, but it suffers fom size problems as NZ.

MP occultation observers can make a useful contribution when there are no MP event available. So why not? If you want to have your name associated with a discovery, then you will need to observe lunar occultations on a regular basis. Discoveries probably average about 1 in 80 evens, so are not frequent.

**25. Finis**