**vTTSO 14, 2020 April 13 by video**

**Double Star video occultations 2007-2020**

When using these notes in conjunction with the corresponding PowerPoint presentation, the display needs to be advanced to a new screen at each **bold numbered heading**, the number corresponding to the screen number.

**1. TTSO14, 2020April 13: Lunar Occultations of Double Stars**

This presentation gives an update of the paper presented at TTSO13 following the RASNZ conference held at New Plymouth in May 2019. The TTSO13 report covered up to 2019 May 1.

 Aims of Observing double star occultations

1. Determining the separation and position angle of a pair of stars. Requires at least two occultation observations well spaced round the moon’s limb. Preferably made on the same night, but often ones made on different nights can be used.
2. Estimate the magnitude difference of the pair of stars. With a knowledge of their combined magnitude, an estimate of the separate magnitudes of the stars can be determined. This can be done with a single observation.
3. Detect previously unknown double stars.
4. Confirm or refute the duplicity of stars previously reported as possibly double as a result of visual occultation observations, mostly dating from the 20th century.
5. And contribute light curves to the Kepler2 programme where appropriate.

A review of a number of instances involving at least one 2019 observation and where it was possible to find a solution of the PA and separation of the pair will be given

**2. Double star Occultation Light Curve with magnitudes.**

The occultation of SAO 79686 was observed by Alex Pratt in the UK on 2019 April 12. The double nature of the star is clearly shown by the step in the light curve produced by LiMovie. The step lasted for 0.72 second with the brighter primary star occulted first as shown by the relative depth of the light drops. The magnitude difference and hence the magnitudes of the component stars can be calculated from the height of the steps. The data, circled, was determined by LiMovie using the selected points, and then added to the graphic by programme. The resulting magnitudes are shown enlarged.

A further observation is needed to determine e separation and PA of the pair. In the case of SAO 79686 there is an earlier observation by Dave Herald dating from 2018 April 22.

**3. SAO 79686, a solution from 2 observations**

Using the results of the two observations a solution for the double can be made. The diagram in this screen shows a graphical representation of the result. The two star are represented by the yellow spots, the primary, brighter, star being the larger. The two coloured lines represent the position and angle of the moon’s limb at the instant the fainter star was occulted for each observer. Herald’s limb line is in blue while Pratt’s is green. For each observer the secondary star has to be somewhere along their line, its actual location is at the intersection of the two limb lines.

In this case the two lines are well inclined to one another giving a sharp intersection. From the calculation the position angle and angular separation of the component stars of the double system can be determined. Data and results are shown on the left as are the calculated magnitudes. The display box represents an area of the sky 1.2” square as shown below it.

**4.**. **SAO 98888: observations made on the same night, close limb PAs**

The two previous observations were almost a year apart, those for SAO 98888 were on the same night, 2019 May 12. The two Daves are not far apart in terms of the moon limb, hence the two limb lines for the event have only a small angle between them. The limb PAs need to be corrected for the limb slope so allowing for the limb topography. The corrections are shown in the data on the left. Applying the slopes slightly increases the difference in the limb angles

The resulting PA and separation of the pair are shown as well as the values determined from WDS data.

Although a solution can be determined from just two observations at least three are needed to get an indication of accuracy. There were no such cases involving stars observed during 2019.

**5. ZC3446, 2019 November 7, with very close limb PAs.**

There were three observers for this event, the two Daves and Peter Anderson of Brisbane. Peter is a visual observer which leads at best, to a lower accuracy. ZC3446 is a fairly wide double with a catalogued separation of 6.9 arc-seconds. The limb PAs for of the two Daves are almost the same, Peter’s is about 10° less, but the difference is decreased when corrected for limb slope

As can be seen the limb lines are nearly parallel. Those for the two Daves slowly convergetowards the top of the display. Peter’s line converges towards the others off the bottom of the box. Note the box size here is 6 arc-second.

The result is an unreliable solution with the apparent separation more than 4 times the catalogue value. The red warning is produced by Occult in processing the event.

**6. Numbers of reported observations by year.**

Switching to some statistics. The double star programme was proposed at TTSO1 in 2007 but some observations submitted date back to 1999. In the seven years from 2009 and 2015 there was an average of 230 per year. Since then the number of observations have declined by about 50 per year. Part of the decrease is due to a lack of reports from Japan and from Europe. Both had made a major contribution before that. There has also been a decline from the USA.

**7. Observers for 2019**

As can be seen there are now few active observers.

This leads to a question of the viability of continuing the programme. One recent development which may increase interest could be the use of cameras with a higher frame rate. These would enable even closer doubles to be detected. An indication of this will be shown in the next few slides.

**8. ZC 654 = OCc 921; a possible Brief Step**

ZC 654 (OCc 921) is a possible close double. It was discovered at a lunar occultation in 1995.

Dennis Lowe obtained this light curve in 2014, it looks to show a possible brief step, lasting about 0.12 second. The value labeled as Rv,.0.0598 arc-sec/second is significant. It indicates the moon’s limb approaching the star rather slowly. The occultation took place at a high latitude round the moon’s limb. A typical rate for a more central occultation is about 0.3 arc-sec/second. The slow rate in this case enabled the detection of this possible double. However it being a case of Fresnel diffraction cannot be ruled out.

**9. ZC 654 = OCc 921; Occultation reappearance**

Dave Gault observed a reappearance of the star on 2019 July 27. There appears to be no step here, although there is some suggestion of Fresnel diffraction. The value of Rv was about 4 times that for Dennis Lowe.

**10. ZC 654 = Occ 921; Solution**

The lack of a step for Dave’s observation does not mean it cannot be used for a solution. The assumption is that for him the two components were occulted at the same time. As can be seen here the two stars both lie on Dave’s, blue, limb line.

The details of the solution are shown at left, suggesting a very close double, separation only .02 arc second.

**11. ZC 654; another look at Dave’s light curve.**

This is Dave’s light curve again. The intermediate points of what would normally be a sharp light change, could suggest a very brief step. So I asked him to run the video through LiMovie again separating the individual fields of each frame. This gives 50 measures per second instead of the normal 25. I thought it possible the mid point at level about 4000 could be hiding a step…

**12. ZC 654, Occ 921; field measures a possible step.**

This was the resulting light curve, the two fields forming the mid point are virtually at the same level. It could be a very brief step lasting for only 0.04 second. The light levels of them are close to 2000, half the level for the frame measure of the point as might be expected

**13. ZC 654; Solution using D Gault’s step**

This is the resulting solution using the possible 0.04 second step for Dave’s observation. The new solution is in red, the previous in black.

I would certainly not regard this as conclusive, further occultation observations are needed of the star. If it is correct we have an instance where a double first reported as a result of a visual observation of an occultation, has been confirmed.

It does in any case illustrate the possibilities presented by the use of video cameras offering a higher frame rate. Some observers are experimenting with these.

**14. Journal of Double Star Observations, paper number 7**

Results obtained from occultation observations of double stars have been published in the on line Journal of Double Star Observations. The seventh paper in the series, with results mainly from 2017 and 2018 had already been submitted for publication at the time of my 2019 report. It was published 2019 October 1 and is available on line.

**15. Acknowledgements and Thanks.**

To conclude, I wish to recognise those whose contributions have made this programme possible. I particularly thank those 90+ observers who have reported observations and those whose software has been indispensable.

As most will know, I have decided it is time I handed over the recording of the observations to a younger person. So I would also like to thank Martin Unwin who has offered to take on the role. I hope he will be supported with an increased number of observations.

Personally, I have no intention of giving up observing.