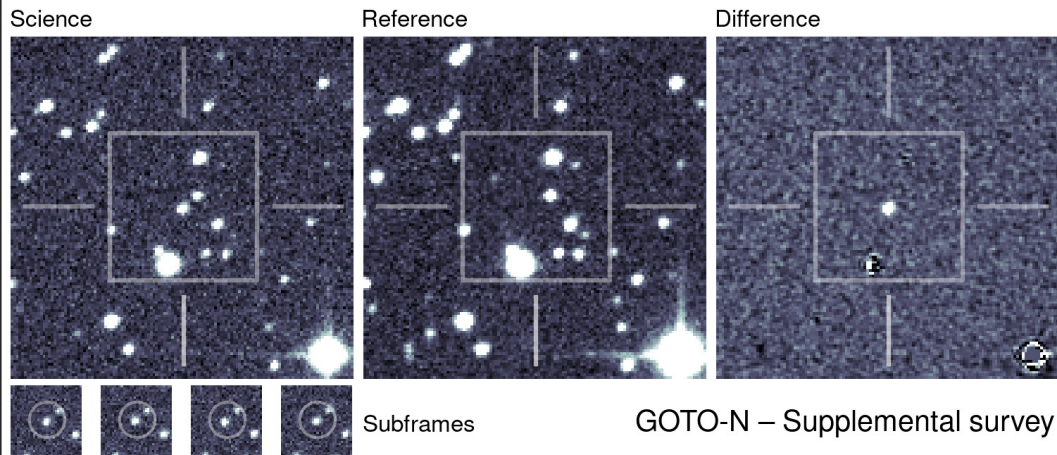
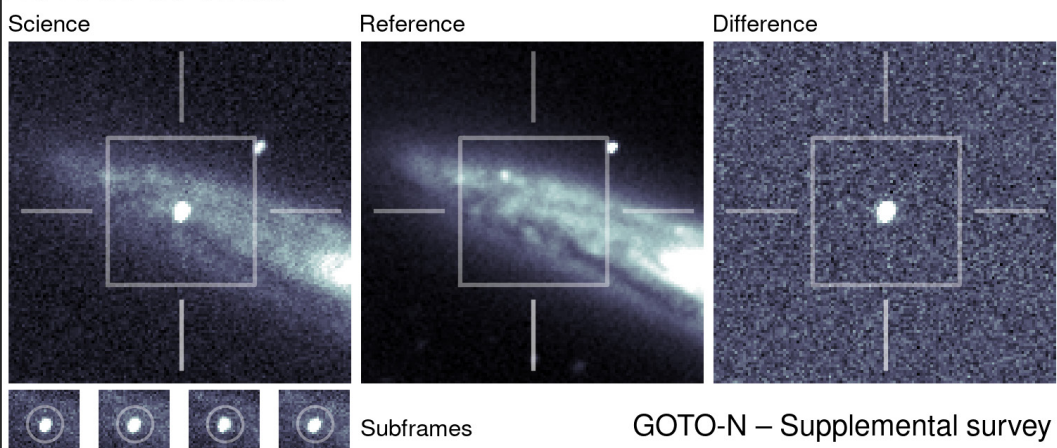


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From Brazil Cledison Marcos da Silva explains how amateurs can contribute to astronomy as citizen scientists even without a telescope. These images from the Kilonova Seeker project show a possible transient or variable star (upper image) and a possible supernova (lower image). For full details see Cledison's article on page 23.

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From the Director – *Mark Blackford*

Welcome to the second edition of the Newsletter for 2024. I'm writing this column somewhat earlier than usual as my wife and I will be travelling to Europe in early April. We start with a Mediterranean cruise before heading to the UK. Both regions are rich in astronomical sites and I plan to visit a few on our travels.

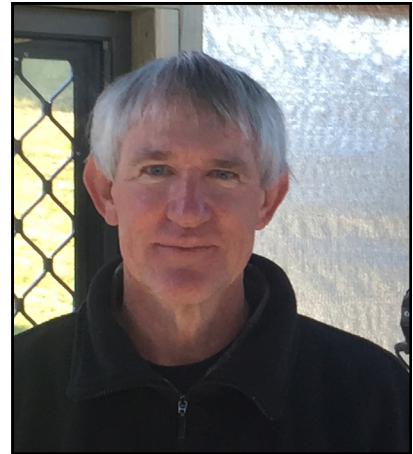
Closer to home, NACAA XXXI in Parkes over the Easter weekend seemed to be successful. I was not able to attend in person due to family visiting from overseas but did catch several presentations via Zoom. Roy Axelsen and Peter Williams co-chaired a discussion session on observing variable stars on Easter Saturday, with me participating remotely.

As mentioned in the previous newsletter, 2024 will be Phil Evans' last year as editor. We need someone to take on this important role in 2025. Phil assures me he will provide any assistance the new editor might need.

Observing conditions at Congarinni Observatory have continued to be dismal, with only a handful of partially clear nights since January. The one saving grace (if you can call it that) is my observatory is still out of action since the roof was damaged on Christmas night, so I haven't missed many observing opportunities. Delays in obtaining materials means reconstruction will have to wait until we return from holidays.

Wishing you all clear skies and good health,

Mark Blackford



My observatory reborn for statewide use – *Tom Richards*

tomprettyhill@gmail.com

In the previous newsletter I reported I was winding up my observing career and selling my equipment. Now everything is sold up, the observatory demolished and the equipment is moving to an exciting new home that will widely benefit amateur and educational astronomy in Australia. The 41 cm telescope, A-P 1200 mount, all accessories and heavy steel pier were sold to the Astronomical Society of Victoria.

The ASV has already moved everything to its future home, a dark-sky property west of Bendigo in a region unlikely to face creeping sky pollution. They will be building an observatory around it and setting it up for remote robotic control. The equipment officer tells me the plan is to make it available to ASV members and associated educational institutions – the ASV has a vigorous operation working with secondary schools in the state. While the equipment will be multi-purpose, I'm told there will be a strong accent on scientific use, with plans to buy a spectrograph as well as a CMOS camera and photometric filters. The ASV is very active in bringing astronomy to towns and cities statewide with star parties and indoor events. The new observatory can tie in closely with that by carrying out real-time imaging for big-screen display.

I cannot imagine a more wonderful rebirth for my beloved equipment.



The 2.9 m dome and all its control equipment was sold to a local astro-imager; everything else to the ASV.

Determining ToMs from sparse photometry revisited – Roy Axelsen

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A procedure for determining times of minima of eclipsing binary stars from sparse photometric data was published by Mark Blackford (2022). The principle involves determining the minimum point of a phase curve for a star with an accurately known period after selecting one observation as phase zero, typically an observation near the mid point of one eclipse. In Blackford's method, data for the variable star light curve are displayed in VStar (Benn, 2012), the phase curve is plotted in Microsoft Excel, and the precise phase of the minimum for the dataset is determined in Peranso (Paunzen et al, 2016) after the phase data are imported from the spreadsheet.

In the alternative method in this paper, the raw light curve data is displayed in VStar, the observation representing phase zero is selected, and the phase curve displayed in VStar. The phase data from VStar are saved initially in a .csv file, displayed in a Microsoft Excel workbook and resaved in .xlsx format. The only purpose of the workbook is to create a spreadsheet of phase and magnitude values which can be saved as a .txt file, and imported into Peranso. The precise phase of the mid eclipse is then determined in Peranso using the Kwee - van Woerden method (Kwee and van Woerden, 1956), identical to the part of the procedure described by Blackford. The distinction between the two methods is minor, but the purpose of this paper is to describe the alternative method in detail, using photometric data from TESS (the Transiting Exoplanet Survey Satellite) for the EW eclipsing binary star NSV 455 as an example.

Method

The procedure requires the installation onto a local computer of VStar, the VStar plugins that allow access to various professional astronomical databases (<https://www.aavso.org/vstar>), and Peranso.

Data is downloaded from the TESS database at the Mikulski Archive for Space Telescopes (MAST) Portal, easily found from an Internet search, using the procedure described by Blackford (2021). Quick Look Pipeline (QLP) data with sparse photometry (1800 second exposure time in our example) is downloaded as a .fits file and saved to local disk.

Data for the EW type eclipsing binary NSV 455 will be analysed as an example. This is a 13th to 14th magnitude system with a period of 0.320236 day, according to the AAVSO's Variable Star Index (VSX).

Search for "NSV 455, r=4s" at the MAST portal, the latter part of the search term nominating a search radius of 4 arc sec. In the navigation pane on the left titled "Filters", check the box against "QLP" (Quick Look Pipeline). At the time this paper was drafted, five records will be displayed. Click the right-facing double arrow (>> symbol) above and to the right of the image of the star field to remove the image from the display. Scroll to the right until the columns "Start Time" and "Exposure Length" are displayed.

The dataset needed has a start time of "2018-08-23 14:51:16", representing the date 23rd of August, 2018, and is the first of the five records in the list. Scroll back to the left of the display, and click the disk drive icon against this record. A Zip file will be saved to your Downloads folder. Unzip it, and drill down through the subfolders until you come to the file `hlsp_qlp_tess_ffl_s0002_0000000340782815_tess_v01_llc.fits`. The "_llc.fits" at the end of the filename indicates that it is a light curve file. Save it to local disk, then open it in VStar.

Select "File>New Star from QLP FITS file version 0.4...", select the saved .fits file, click "Open" and choose the "RAW (SAP_Flux)" option. The light curve shown in Figure 1 will be displayed, showing data from 23rd August to 19th September 2018. Note that the horizontal time axis represents BJD_TDB (Barycentric Julian Date, Barycentric Dynamical Time).

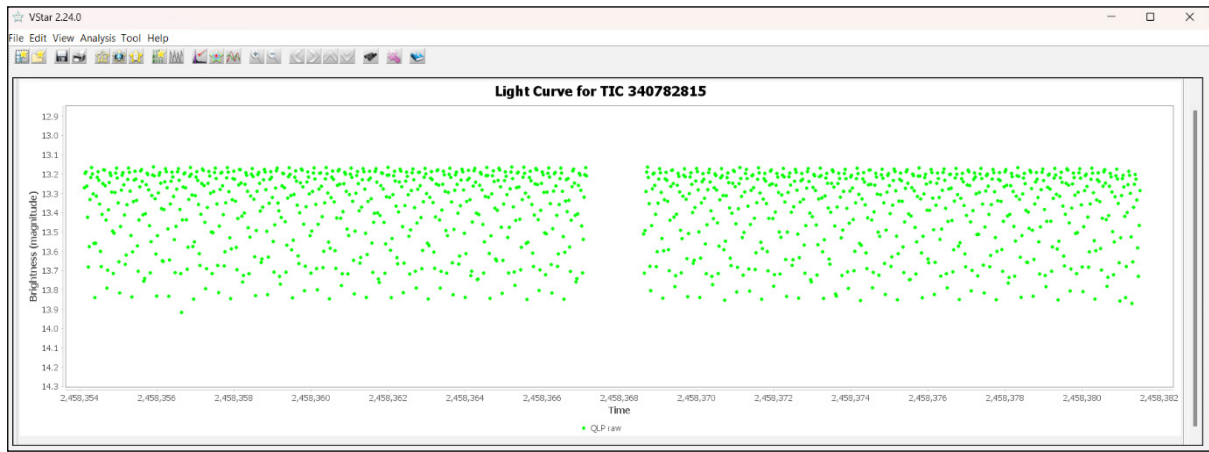


Figure 1. 1800 second exposure TESS QLP RAW (SAP_FLUX) light curve for NSV 455, start date 23rd August 2018.

The light curve represents data collected during two orbits of the Earth by TESS, each 13.7 days long. The gap in the middle of the dataset represents the time during which TESS downloads data to Earth. Figure 2 is a zoomed-in view just prior to the gap.

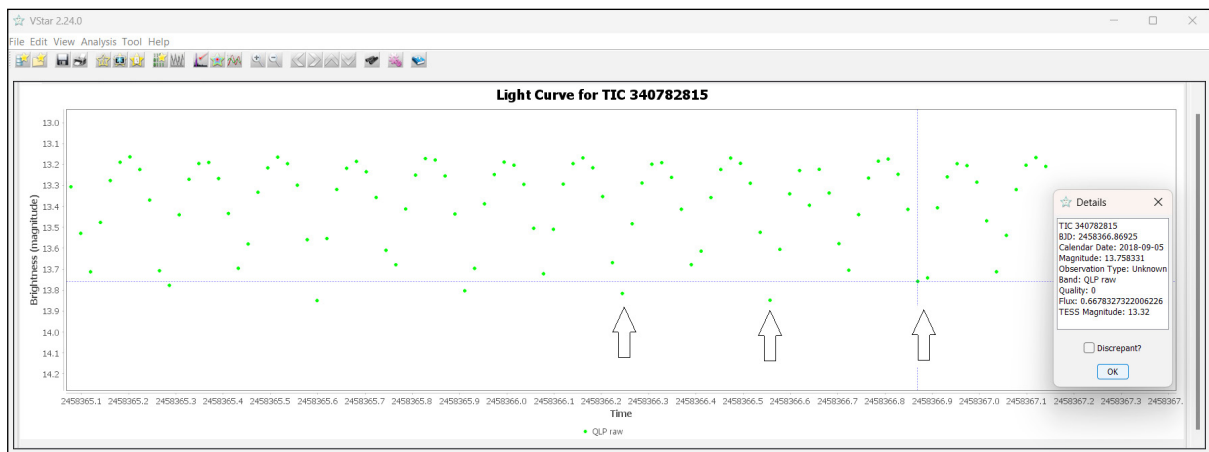


Figure 2. View of the same TESS light curve seen in Figure 1, but zoomed in to show the data just prior to the central gap. The arrows show the approximate times of mid eclipse for three successive primary eclipses. The cross hairs show the selected time of phase zero, T_0 , for the calculation of the phase curve. Note that T_0 is just to the left of one of the times of mid eclipse. The box headed “Details” is displayed by clicking “View>Observation Details”.

On this display in VStar, a datapoint is selected on the light curve to represent phase zero, T_0 , for the display of the phase curve. It is useful to deliberately choose a point which is a little to the right or to the left of the time of the minimum light of a primary eclipse, so that subsequent displays clearly distinguish between the chosen phase zero and the phase at minimum. The data in this light curve are too sparse to use Kwee – van Woerden or a polynomial fitting method to determine times of minimum.

The next operation is to display a phase curve in VStar, using the previously selected zero point (T_0), and a precise period, here chosen to be 0.320236 d, the period listed in the Variable Star Index (VSX) of the American Association of Variable Star Observers (AAVSO). With the light curve shown in Figure 2 displayed in VStar, select “Analyse>Phase Plot...”, and enter the period in days and the epoch from the previous paragraph. Note that the dialogue in VStar displays the time as JD. Ignore that, and enter the time of phase zero in BJD_TDB. Remember, however, that when the time of mid eclipse is displayed at the end of this procedure, the time in BJD_TDB will need to be converted to HJD_UTC. Select “OK”. The phase curve shown in Figure 3 will be displayed.

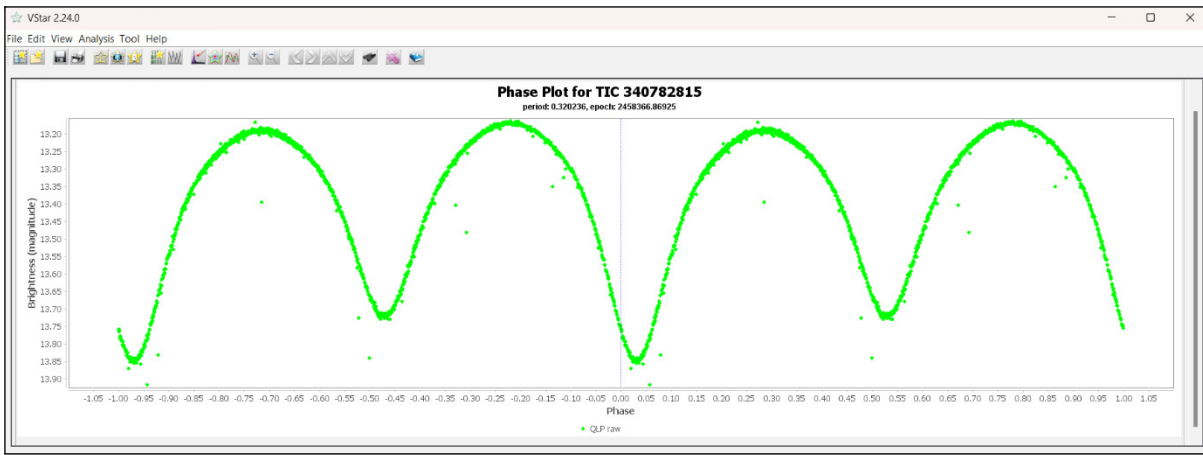


Figure 3. The phase curve of TESS data for NSV 455, displayed in VStar. Note that the vertical line represents phase zero, T_0 just to the left of the minimum for the primary eclipse.

Although two cycles are displayed in the phase curve, only one phase is tabulated in the Observations list. VStar simply replicates the phase values over a second cycle of the phase curve. In the example in Figure 3, the horizontal phase axis values range from -1.0 to zero to +1.0. In displays of other data, the range may be different, for example -1.05 to zero to +1.05.

When the Observations tab is selected, a table displaying the Phase, Time (in BJD_TDB), Calendar Data, Magnitude and various other data can be seen. The tabulated phase values will range from zero (or a value just above zero) to 1.0 (or a value just below 1.0).

With the Observations list associated with the Phase plot displayed, select “File>Save...”, and choose a file name and appropriate folder. A file is saved with a default .csv extension. When it is opened in a spreadsheet, it will be seen that the first three columns, A, B and C, contain, respectively, the phase of an observation, the time (in BJD_TDB) of the observation, and the TESS magnitude. There are several other blank and filled columns which can be ignored. Copy only columns A (Phase) and C (TESS magnitude) to a new spreadsheet (into columns A and B), and save the workbook in .xlsx format. In the first cell in column C of the new sheet, enter “=A1+1”, and copy the formula to fill all the cells in column C beside the filled cells in column B. This procedure creates the second cycle for the phase curve to be imported into Peranso. Next, copy column B (TESS magnitude) into column D, and finally copy the filled cells in columns C and D into the empty cells below the original data in columns A and B. Delete the data in columns C and D.

The completed spreadsheet containing augmented columns A and B, with phase data for two cycles, is saved as a tab-delimited .txt file for importing into Peranso. When the data is plotted as a chart in the spreadsheet, it appears as shown in Figure 5, a two-phase plot with the horizontal axis values ranging from near zero to near 2.0. T_0 is now just before 1.0, not just before zero as it was in the phase plot in VStar. The phase value at the mid point of the primary eclipse in this example will therefore be slightly greater than 1.0. Note that there is no need to display the plot in the spreadsheet, because the only purpose of the spreadsheet is to create data for a tab-delimited .txt file for importation into Peranso. Figure 5 is thus shown here for information only.

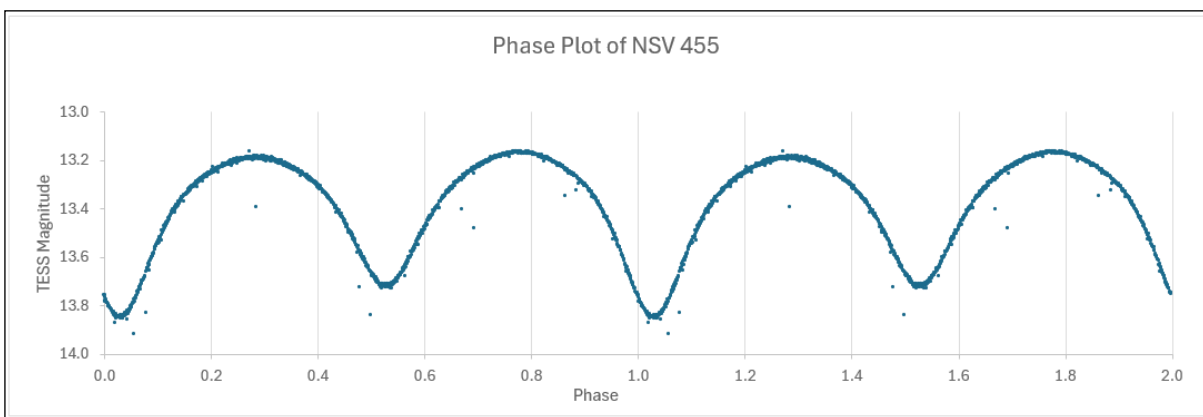


Figure 5. Two-cycle phase plot of NSV 455 as displayed in the spreadsheet from which the tab-delimited .txt file for Peranso has been saved. Note that T_0 now approximates 1.0 rather than zero.

When the data that is plotted in Figure 5 is displayed in Peranso (Figure 6), it can be seen that the horizontal axis is labelled “JD”. This label is ignored, as the imported data contain the phase of each observation based on the nominated phase zero T_0 , not the time in JD. Deactivate any obviously discrepant data points around the eclipse. The phase value at mid primary eclipse is found by placing range markers symmetrically around the eclipse (vertical green lines in Figure 6) and selecting the “Find Extremum” icon on the bar just above the pane of the observation window, which determines the mid eclipse time by the Kwee - van Woerden method.

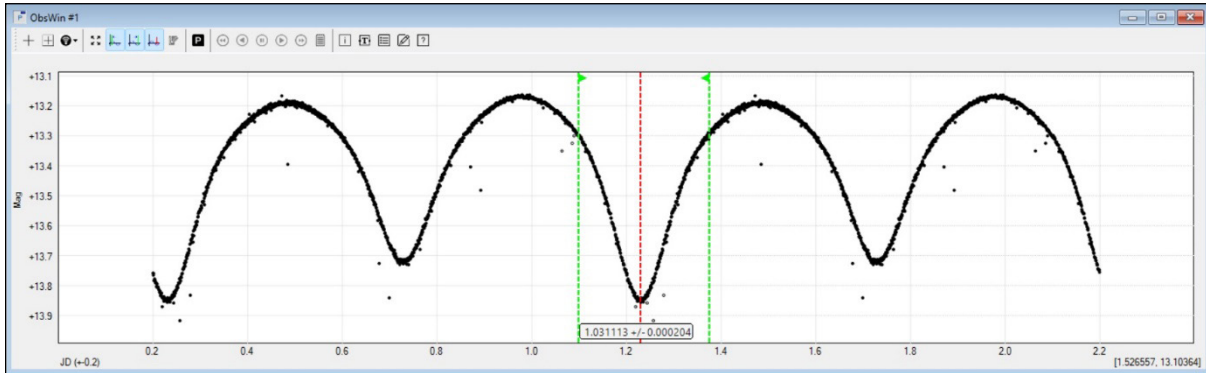


Figure 6. Phase plot of NSV 455 as displayed in Peranso, after the tab-delimited 2-cycle phase data .txt file has been imported. Note that the horizontal axis is by default labelled as JD units, centred near JD 1.2 in this example, with the label indicating the axis scale is JD (+0.2), whereas the horizontal axis units actually represent phase, not time in JD.

The phase value at mid eclipse is displayed in the central lower part of the plot pane as 1.031113 with an error estimate of 0.000204. Therefore the phase difference between T_0 (by definition, zero phase) and mid eclipse (after subtracting 1.0) is 0.031113 ± 0.000204 .

The value and the error estimate are both converted to time in BJD_TDB by multiplying by the period 0.320236 d, yielding 0.009964 ± 0.00007 .

The BJD_TDB of T_0 was 2458366.86925.

Therefore the BJD_TDB of mid eclipse is $2458366.86925 + 0.009964 = 2458366.879214$

This value is converted to JD_UTC using the time conversion utility at <https://astrutils.astronomy.osu.edu/time/index.html>, and the resulting value converted to HJD_UTC in a spreadsheet utility found online and created by Dan Bruton of the Stephen F. Austin Observatory in Texas, USA.

The time of mid eclipse is thus $2458366.87841 \pm 0.00007$ HJD_UTC.

The mid eclipse time was added to a copy of the O-C table from the Phe NSV 455 Minima Analysis Form in the VSS eclipsing binary database. The period on which the cycle count and O-C values are calculated for the purposes of this article is taken from the AAVSO's VSX, 0.320236 d. The data are shown in Table 1, with the mid eclipse time from the phase data in this paper designated as phase zero inserted as the top row. The observations labelled “TESS/RAA” represent TESS data from 600 second exposure images, with the mid eclipse times being the times of minimum values of 6th order polynomial fits. The O-C diagram based on this data is shown in Figure 7. The applied linear fit appears to be correct, with low residuals by visual inspection.

The fitted linear function in the O-C diagram has a slight positive slope, indicating that the true period of NSV 455 may be slightly longer than the period listed in the AAVSO's VSX. The data in Table 1 were therefore used to attempt to refine the period, yielding a value of 0.3202393 ± 0.0000002 d.

HJD of min	HJD error (d)	Eclipse Type	Filter	Observer
2458366.87841	0.00007			TESS/RAA/from Phase curve
2458434.12941	0.00025	P	R	MGB
2458435.08889	0.00020	P	R	MGB
2459088.37799	0.00130	P		TESS/RAA
2459088.53789	0.00185	S		TESS/RAA
2459102.46828	0.00139	P		TESS/RAA
2459102.62836	0.00174	S		TESS/RAA
2459113.99765	0.00199	P		TESS/RAA
2459113.51549	0.00189	S		TESS/RAA

Table 1. Eclipse timing data used to calculate the cycle count and O-C values for NSV 455. The HJD of min calculated in the example described in this paper is on the last line, and is bolded.

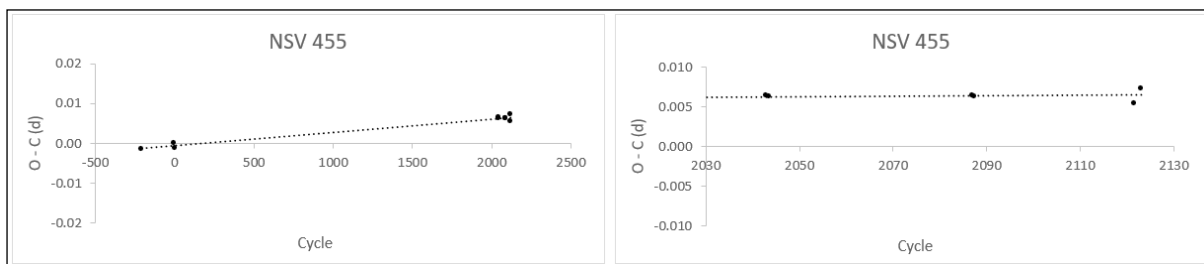


Figure 7. O-C diagram of NSV 455 using data from the VSS Minima Analysis Form in the VSS eclipsing binaries database. The data point at cycle zero (left panel) is based on the earliest HJD_UTC time of minimum already in the Minima Analysis Form. The first data point on the far left of the plot (corresponding to the data in the first line of Table 1), is the value calculated from the phase curve in this article. The right panel is the zoomed-in view of the more recent data.

Conclusion

A procedure is described for determining the time of mid primary eclipse from sparse photometric data. It is a variation on the method published by Blackford (2022), and requires the AAVSO's VStar software, a spreadsheet, and the light curve and period analysis software Peranso. Data for NSV 455 in Phoenix are used as an example, and the results plotted in a copy of an O-C diagram from the VSS eclipsing binary database to validate the method. A linear fit to the O-C data with a positive slope implies that the actual period is longer than the period used to calculate the cycle numbers and O-C values. A refined period was calculated and found to be 0.3202393 +/- 0.0000002 d.

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Blackford, M. VSS Newsletter 2022-1, January 2022, pp. 6-11.
Kwee, K. K., and van Woerden, H. 1956, Bull. Astron. Inst. Netherlands, 12, 327.
Paunzen, E., Vanmunster, T., 2016. Astronomische Nachrichten 337, 239-246.

An astrophysical model for the eclipsing binary CP Sculptoris – *Colin Bembrick.*

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Abstract

The contact eclipsing binary system CP Scl has been modelled using three colour photometry. The smaller, hotter star is close to spectral type G5, with a temperature of 5515K. The mass ratio, q , of the system is 0.42. The parameters match a typical W UMa type system.

Introduction

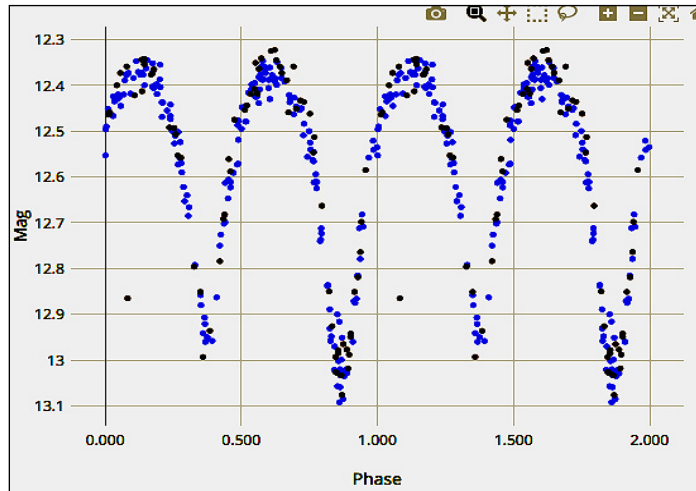


Figure 1. The light curve from ASAS-SN data depicts the variability. Folded with period of 0.3136581 days and epoch 2458124.54832 HJD. Note distinct differing minima and slightly differing maxima.

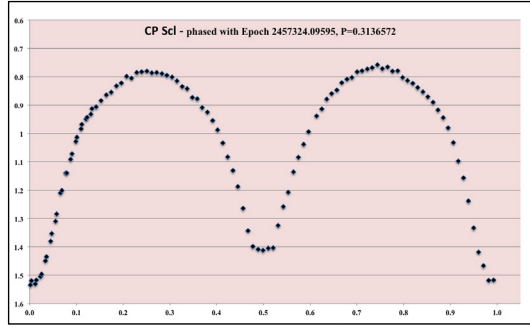
CP Scl (ASAS3 002449-2744.3, GSC 06420 00779, 1SWASP J002449.36-274418.9, ASASSN-V J002449.39-274419.8) is a $V=12.69$ variable situated near the South Galactic Pole in Sculptor, at RA 00 24 49.41, Dec. -27 44 19.1 (J2000). The GCVS lists it as variable type EW W UMa-type contact or over-contact eclipser with nearly equal maxima and minima (Samus et al 2017). Its B-V colour index is 0.82 (APASS DR9, Henden et al, 2016), equivalent to a main-sequence spectral type of K0 and T_{eff} of 5150K (Cox 1999) CP Scl was first described by Pilecki et al (2007) from an analysis of ASAS3 data (Pojmanski 2002). They determined an epoch of primary minimum as HJD 2451868.265, a period of 0.313661 days.,

Variable Stars South (www.variablestarssouth.org) has been gathering photometric data on CP Scl since 2014, providing sufficient minima estimates to enable a deeper analysis of its period and period change. That work is the subject of an earlier paper (Richards 2023) and also Richards (this newsletter). This paper deals with the modelling undertaken by the author.

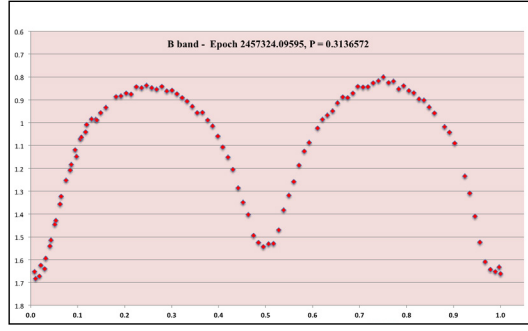
Methods

Data acquisition.

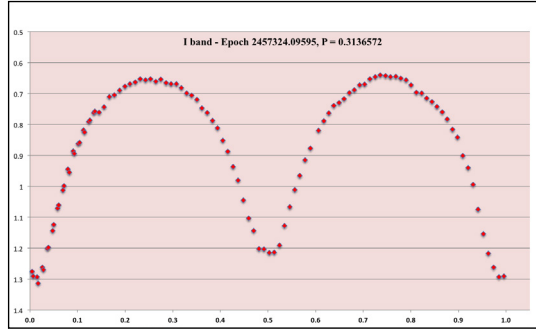
For **shape modelling**, a complete light curve is necessary. Richards' photometry for Sept 2014 provided complete light curves in Johnson B, V and Cousins Ic passbands. (Figure 2). Differential photometry was used, with comparison star GSC 6420 0709. $V = 11.658$, $B-V = 0.761$ (APASS).



a) V-band phase plot



b) B-band phase plot



c) Ic-band phase plot

Figure 2. CP Scl light curves of Richards, Sept 2014. a) B-band, b) V-band and c) Ic-band. Phased with $P = 0.3136572$

Choosing shape modelling parameters

B, V and Ic data were imported into BinaryMaker 3 (Bradstreet 2005. Hereafter BM3) for light curve analysis. From the general shape of the light curve it is assumed that the envelopes of the two stars are in contact, but not necessarily in thermal equilibrium. The initially chosen model parameter settings were as follows:-

1. Filter passbands: B: 4400Å, V 5500Å, Ic 7900Å.
2. Star temperatures: $T_1 = 5150\text{K}$, a compromise from available temperature estimates in the literature. T_2 is an adjustable parameter. For W-type UMa eclipsing binaries the smaller star is hotter and is occulted in the primary eclipse, so by convention it is star 2.
3. Gravity brightening: $G1 = G2 = 0.32$, the value for convective stars, which have $T_{\text{eff}} < 7200\text{K}$ (Lucy 1967)
4. Limb darkening: $X1 = X2 = 0.719$, derived from the Van Hamme (1993) tables.
5. Reflection coefficient: $R1 = R2 = 0.5$, the value for convective stars (Rucinski 1969).

The five adjustable parameters (q, T_2, f_1, f_2, i) are not entirely independent of each other, requiring concomitant adjustments of all five to obtain the best match of a computed light curve to an observed one.

The initial values were set as follows, using the V-band light curve:

1. A search of light curves in Binary Stars, a Pictorial Atlas (Terrell, Mukherjee & Wilson, 1992) showed that BB Peg had similar light curves to CP Scl, so the initial value of q was set to its value of 2.8 – remembering that the mass ratio is *inverted* for W-type UMa systems, where the less massive star is the hotter. Determining a reliable value of q is critical, as it affects the relative sizes of the two stars, affecting all the other adjustable parameters.
2. T_2 was adjusted with respect to T_1 to obtain the correct *relative* depths of the two eclipses.
3. Inclination i of the orbital axis to the observer, was chosen to match the *absolute* depths of the two eclipses. Photometry of the primary minimum on multiple nights clearly showed it was flat, indicating a total occultation, which severely constrains the possible values of i . Fillouts f_1 and f_2 chosen to match eclipse shapes (equal for stars in contact). There are varying definitions of f , but we use Bradstreet (2005), where for contact and over-contact binaries, (i.e. with surfaces in contact and between the inner and outer Roche lobes) $0 \leq f \leq 1$ represents the fractional distance of the surfaces from the inner to the outer Roche lobes.

4. At this stage it is necessary to adjust q from its initial assumed value. This adjustment is more complex, as discussed next; and after obtaining its best value the other adjustable parameters were tweaked to give the best final fit, measured by the sum of squared residuals, SSR , of the synthetic light curve from the observed light curve (This value is just called ‘R’ in BM3).
5. Finally, the resulting values of the adjustable parameters were applied to the concurrent B and Ic light curves, with small modifications to the adjustable parameters to obtain the best overall value for SSR in all three passbands.

To arrive at q , it is customary in the absence of spectroscopic/radial-velocity data to conduct a ‘standard’ “q-search”. This ‘standard’ method has been described in various forms (see e.g. Liakos & Niarchos 2012, Terrell and Wilson 2005, Skelton and Smits 2009, Wadhwa et al 2021) following its introduction by Russo and Sollazzo (1982).

It should be noted that the ‘standard’ form of q-search cannot be implemented in BM3 as the luminosity parameter is not an input variable in this software. Approximating a q-search in BM3 involves many long and laborious manual iterations. Thus, a simplified form of q-search (nicknamed “Quick-n-Nifty” by Bembrick, 2017) was developed which suited the exigencies of BM3, and was conducted over the range $q = 2.2$ to 2.5 (the initial value from BB Peg turned out to be too high), and the SSR values of the residuals from the fit of the synthetic model to each value of q were then recorded. The minimum was at $q = 2.36$ (see figure 3) which was adopted as its final value. The values of the other adjustables were then tweaked in the above order to yield the minimum value of SSR . Figure 4 shows the resulting q-curve together with a q-curve derived from the ‘standard’ (and much slower) approach to q-search.

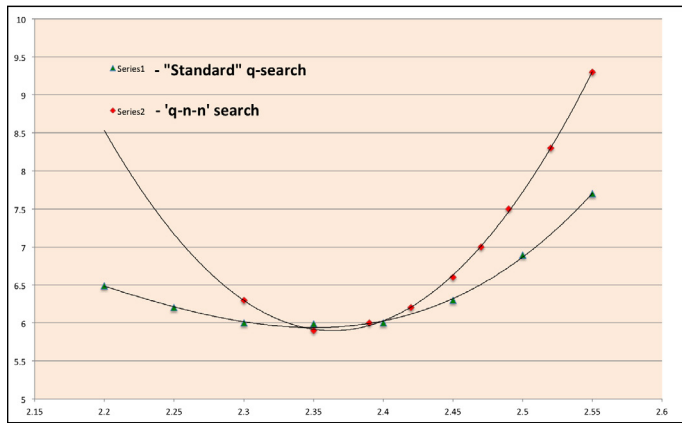


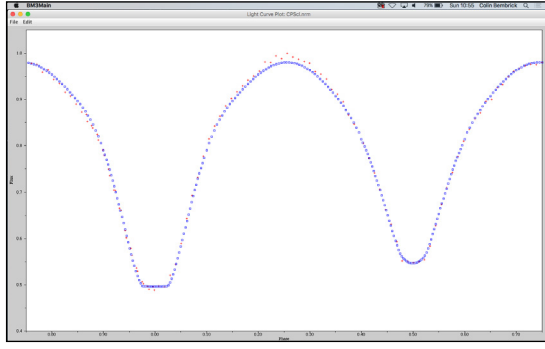
Figure 3. Residuals from fitting a synthetic light curve against q , using the “Q-n-N” method (red) against the “standard” method (blue). (note the x-axis is the inverse of mass ratio, q).

Results and analysis

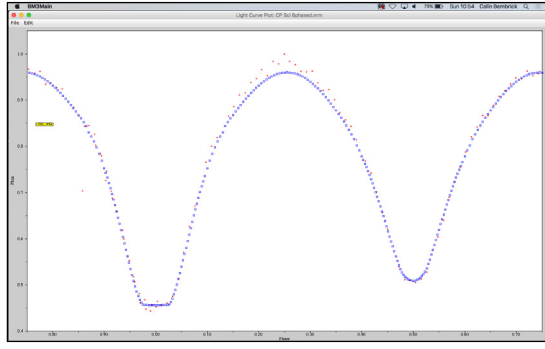
Light curve and shape modelling

Figures 1 and 2 show CP Scl to have a typical EW-type light curve with *nearly* equal maxima and differing minima. The deeper minimum (MinI) is clearly total but only for a short period, showing that the hotter star is smaller than the occulting star. This configuration of the eclipses is confirmed by light curves on three other dates.

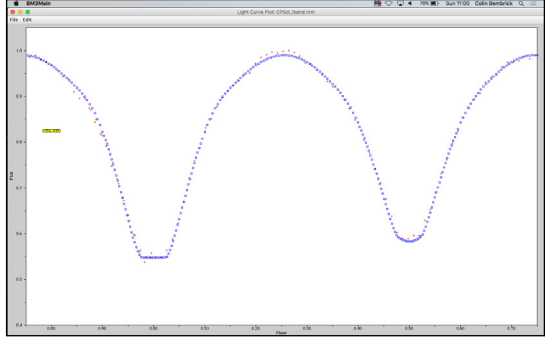
However, the situation is different for the maxima. In Figure 3 the brighter maximum is MaxII (the maximum following MinII). This magnitude inequality ($\Delta m = \text{MaxII} - \text{MaxI} < 0$) is confirmed by inspection of partial light curves in 2014, 2015 and 2016. But by 2017 the inequality is reversed ($\Delta m > 0$), and MaxI is the brighter. A situation which still persists in 2021. The phenomenon of unequal maxima, known as the O’Connell effect (O’Connell, 1951, Davidge & Milone 1984) has received several hypothetical explanations (star-spots, circumstellar matter flow, one-way gas streams) but the switch in maxima inequality observed here would seem to rule out gas streams as a feature more or less fixed in relation to the major axis of the binary system, as with cataclysmic binaries. The O’Connell effect has been modelled in some instances (eg Tavakkoli et al 2017) by the introduction of star spots. However, this exercise is somewhat arbitrary and largely unconstrained by the data, and so has not been attempted here.



a) V-band model fit



b) B-band model fit



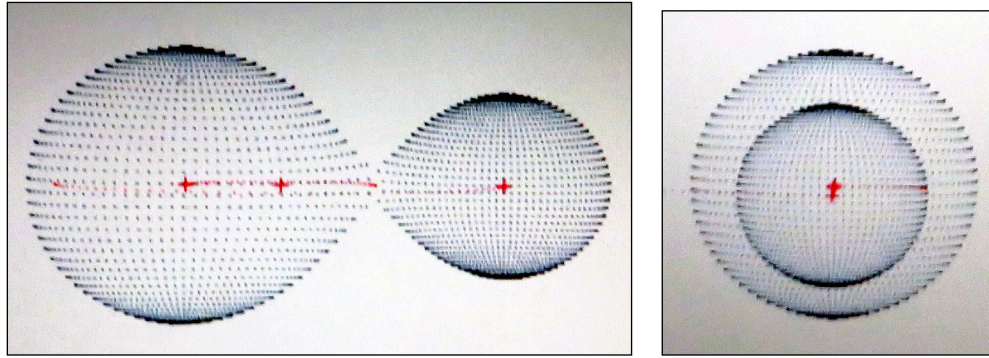
c) Ic-band model fit

Figure 4. The model fitted to the observed light curves in three bands (red - observations, blue - model). Note the primary min is flat bottomed - total eclipse

Table 1. Model parameters for CP Scl.

Parameter ↓ Bandpass →	B		V		Ic	
	Star1	Star 2	Star 1	Star 2	Star 1	Star 2
Assumed						
Effective Temperature T_{eff}	5150		5150		5150	
Gravity brightening G	0.32					
Limb darkening coeff. X	0.86		0.71		0.47	
Reflection coefficient R	0.5					
Adjusted						
Mass ratio m_z/m_1	0.43		0.42		0.42	
Fillout f	0.10		0.08		0.06	
Inclination i (°)	87.0		88.0		87.0	
Effective temperature T_{eff} (K)		5515		5515		5515
Output						
Omega	5.679		5.705		5.744	
Omega inner	5.739		5.753		5.781	
Omega outer	5.133		5.146		5.173	
Radii: r(back)	0.490	0.341	0.489	0.339	0.488	0.336
r(side)	0.461	0.305	0.460	0.303	0.460	0.301
r(pole)	0.432	0.292	0.431	0.290	0.431	0.289
r(point)	0.586	0.413	0.587	0.412	0.588	0.411
Mean r	0.461	0.312	0.460	0.311	0.460	0.309
Surface area	2.813	1.243	2.701	1.234	2.690	1.214
Volume	0.411	0.127	0.408	0.125	0.407	0.123
Relative luminosity	0.597	0.402	0.609	0.390	0.639	0.360
Sum-of-squares residuals	0.0203		0.0059		0.0050	

A 3D representation of the contact binary system derived from the BM3 model is shown below in Figure 5.



a) 0.5 phase

b) 0.75 phase

Figure 5. a) secondary eclipse with smaller, hotter star partially occulting larger cooler star; b) stars in contact or 'overcontact'; note both stars non-spherical. Red crosses indicate the centre of mass of the stars and the whole system.

Conclusion

The parameters determined here (Table 1) are believed to be a feasible astrophysical model for this binary system. The parameters match a typical W-type UMa system. In particular, the photometrically determined value of the mass ratio q , is expected to be in very close agreement to any future mass ratio determination by spectroscopic methods. This follows from the findings of Terrell and Wilson (2005), who have demonstrated that, providing the eclipses are total, there is a demonstrated one-to-one relationship between the spectroscopically determined q and the photometrically determined q . They illustrate this as shown below in Figure 6.

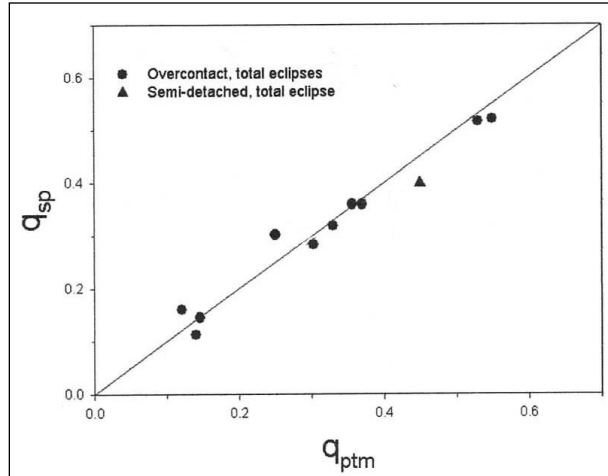


Figure 6. The linear relationship between spectroscopic q and photometric q - for overcontact & semi-detached systems with total eclipses - modified from fig 3 (Terrell & Wilson, 2005).

For the CP Scl system the larger, cooler star (star1) at a modelled temperature of 5150K would fit the main sequence spectral type K0, while the smaller, hotter star (star 2) at a modelled temperature of 5515K would be close to spectral type G5 (Cox, 1999).

Acknowledgements

This analysis was made possible by the provision of three colour photometry by Tom Richards, who is warmly thanked.

This research has made use of the International Variable Star Index (VSX) database (Watson 2014), operated at AAVSO, Cambridge, Massachusetts, USA; and the AAVSO Photometric All-Sky Survey

(APASS), funded by the Robert Martin Ayers Sciences Fund.

This analysis also made use of Peranso software (Vanmunster 2015).

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Abstract

A new linear ephemeris for CP Scl is derived from minima observations over 21 years, significantly different from the ephemeris normally used. From the same data a sinusoidal fit to the residuals from the linear fit indicates the presence of a third body; however considerations of data distribution and other factors make the sinusoidal fit only suggestive.

Introduction

CP Scl is W-type contact eclipsing binary, as shown by Bembrick (2024) in the companion article in this newsletter. That article contains a full research history for the star; all that needs to be noted here is the original ephemeris from (Pilecki *et al* 2007) – hereafter Pilecki.

$$T_0 = \text{HJD } 2451868.265, P = 0.31366304 \text{ d (1)}$$

Data

Minima estimates were derived from all available sources as listed in Table 1. Columns 2 and 3 list the minima estimates and their errors where supplied, column 4 lists the eclipse type (primary – I or secondary – II) based on the Pilecki ephemeris. Column 5 lists the sources of the minima estimates: TR are minima derived from photometry by Richards using polynomial fitting, MGB are from Mark Blackford (VSS) similarly, and OCG is a minimum recorded in the O-C Gateway (<http://var2.astro.cz/ocgate/>). The remainder are derived from surveys: ASAS-3: (Pojmanski 2002), SuperWASP (Kochanek *et al* 2017), Transiting Exoplanet Survey Satellite (Ricker *et al* 2014), and the Zwicky Transient Facility (Graham *et al* 2019). Column 6 lists the UTC dates of the minima.

Method

The minima estimates from all the survey sources were made using Peranso software (Paunzen & Vanmunster, 2016) by folding selected subsets of the data on the Pilecki period, with the time of phase 0 of the fold arbitrarily set to halfway through the date range of the subset. The phase of minimum was then estimated by polynomial fitting and converted to a time of minimum by offsetting from the time of phase 0. As an inferred minimum – whose eclipse curve is not necessarily in the photometric data – it provides a mean estimate of the (O-C) value (residual) over the time-span of the photometric data in any regression or (O-C) diagram. In the case of ASAS-3 and SuperWASP photometry, there were sufficient data points to divide the rather long time periods of the photometry in two halves – adding more data points for the regression fits described as below. It should be noted that the ASAS-3 data are very noisy, making for large errors in minima estimation.

Analysis and results

A linear fit to the Table 1 data was made using Ordinary Least Squares regression (Figure 1)

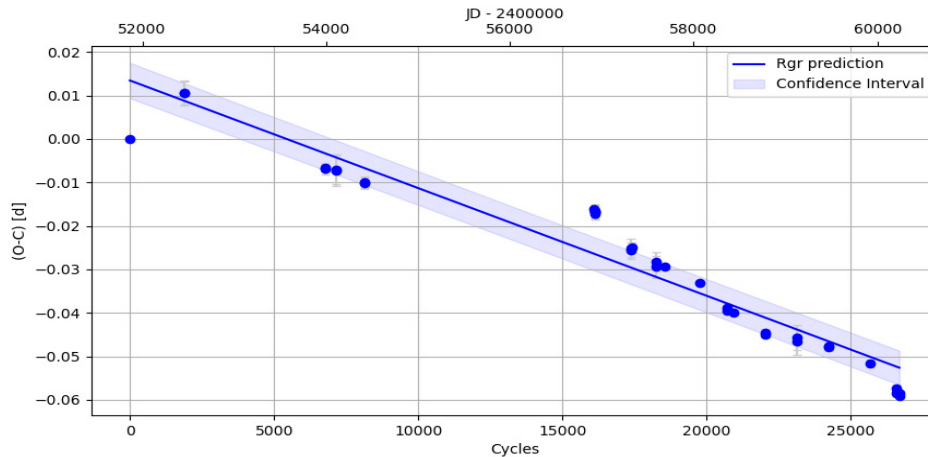


Figure 1. Linear fit to all minima data, (O-C) vs HJD. Reference is the Pilecki ephemeris (1), from which cycles are calculated. Blue band is the 95% confidence interval.

Table 1. *Minima estimates for CP Scl.*

	HJD of min	error	Type	Source	UTC
1	2451868.26500		I	Pilecki	2000-11-19
2	2452455.60969	0.0028	II	ASAS-3 1st half	2002-06-30
3	2452455.76634	0.0028	I	ASAS-3 1st half	2002-06-30
4	2453985.48358	0.0012	I	SWASP 1st half	2006-09-06
5	2453985.64073	0.0010	II	SWASP 1st half	2006-09-07
6	2454105.45938	0.0035	II	ASAS-3 2nd half	2007-01-04
7	2454105.61647	0.0035	I	ASAS-3 2nd half	2007-01-05
8	2454421.94242	0.0013	II	SWASP 2nd half	2007-11-17
9	2454422.09951	0.0013	I	SWASP 2nd half	2007-11-17
10	2456908.65700		II	OCG	2014-09-08
11	2456921.98714	0.0013	I	TR	2014-09-21
12	2456922.14394	0.0017	II	TR	2014-09-21
13	2456923.08454	0.0012	II	TR	2014-09-22
14	2456923.24201	0.0012	I	TR	2014-09-22
15	2457322.99698	0.0021	II	TR	2015-10-27
16	2457323.15324	0.0019	I	TR	2015-10-27
17	2457324.09500	0.0011	I	TR	2015-10-28
18	2457589.29368	0.0022	II	ASAS-SN	2016-07-19
19	2457589.44941	0.0025	I	ASAS-SN	2016-07-19
20	2457686.05779	0.0000	I	TR	2016-10-24
21	2458066.05676	0.0004	II	TR	2017-11-08
22	2458366.85383	0.0011	II	TESS	2018-09-05
23	2458367.01011	0.0010	I	TESS	2018-09-05
24	2458438.99522	0.0001	II	TR	2018-11-16
25	2458778.05987	0.0007	II	MGB	2019-10-21
26	2458778.21715	0.0010	I	MGB	2019-10-21
27	2459129.36088	0.0030	II	ZTF	2020-10-06
28	2459129.51867	0.0029	I	ZTF	2020-10-07
29	2459472.97767	0.0011	I	TR	2021-09-15
30	2459473.13443	0.0008	II	TR	2021-09-15
31	2459919.00254	0.0009	I	MGB	2022-12-05
32	2460203.95971	0.0009	II	MGB	2023-09-16
33	2460204.11538	0.0007	I	MGB	2023-09-16
34	2460235.01120	0.0006	II	TR	2023-10-17
35	2460235.16739	0.0005	I	TR	2023-10-17

The regression fit is good but the original Pilecki datum (leftmost in Figure 1) looks like an outlier. This is likely because although the Pilecki estimate was based on ASAS-3 data which extends from HJD 2451872 to 2455132 (~9 years), the zero epoch was normalised to a time before the start of that time interval instead of being placed centrally.¹ For period analysis purposes, normalising a zero epoch as done with the Pilecki epoch renders it unusable. Moreover where a zero epoch is derived from a light curve folded from a span of data significantly longer than the period, it needs to be placed near the centre of the span since the derived period is a mean for that span. The method described earlier ensures that. For this reason, in the rest of this article the Pilecki epoch is ignored and the zero epoch is changed to the well-de-

¹ This is not the only case in the literature where the zero epoch of a linear ephemeris has been “normalised” away from the data span from which it was derived. If, as in Figure 1, the ephemeris period – represented by $(O-C)=0$ – is in significant error, a time of minimum predicted to occur a time close to a preferred date (in the case of Pilecki, JD 2451868) will have an error proportional to its time distance from the mean of time interval over which it was calculated, and to the period difference. In the present case, the mean of the ASAS-3 timespan is at HJD 2453500; and “returning” the Pilecki zero epoch back along $(O-C)=0$ to that date fits closely to the regression line.

terminated TR minimum estimate, HJD 257686.057790, while keeping the Pilecki period as reference as in Ephemeris (2).

$$T_0 = \text{HJD } 2457686.05779(4), P = 0.31366304 \text{ d} \quad (2)$$

Another OLS regression was applied to the data – without the Pilecki datum – using (2) as reference ephemeris. The result is shown in Figure 3. The ephemeris of the linear fit is

$$T_0 = \text{HJD } 2457686.0548(9), P = 0.31366043(12) \text{ d} \quad (3)$$

This improves over the previous Ephemeris (2): adjusted $R^2 = 0.936$ d and the RMS residual is 0.005 d compared to 0.02 d.

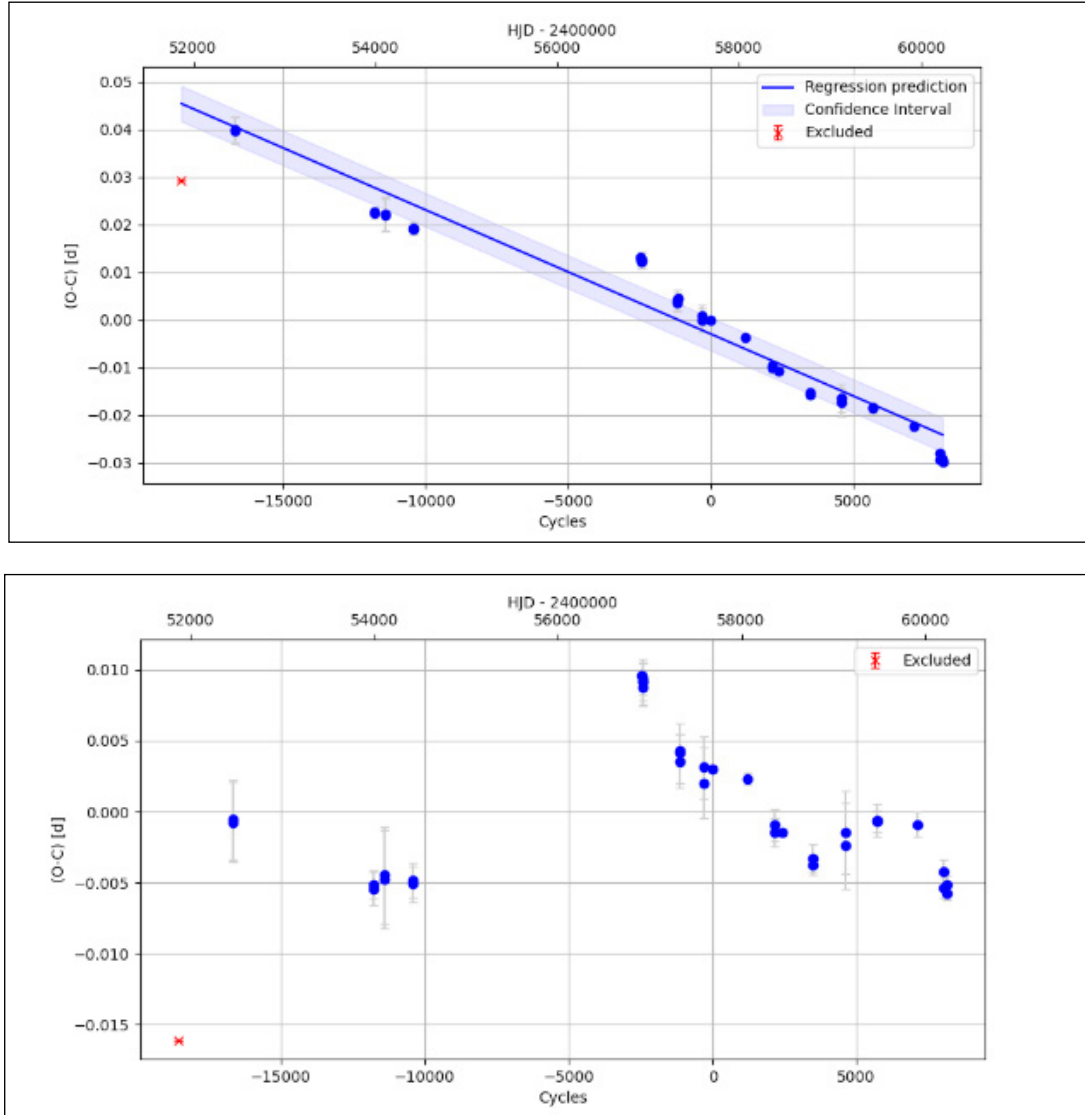


Figure 2. Top: (O-C) diagram of Ephemeris (2) showing best linear fit (Ephemeris (3)). Bottom: (O-C) diagram for the best fit.

The bias in the residuals of the linear fit in Figure 2 suggest a periodic deviation from the regression line. There is little indication of a quadratic component (Adj. $R^2 = 0.378$). Nor is there indication of a cycle count jump, which would happen at $(O-C) \approx 0.08$ d.

More successfully it seems, a sinusoidal (sine + cosine) fit was applied to the data using the new Ephemeris (3) as reference. See Figure 3.

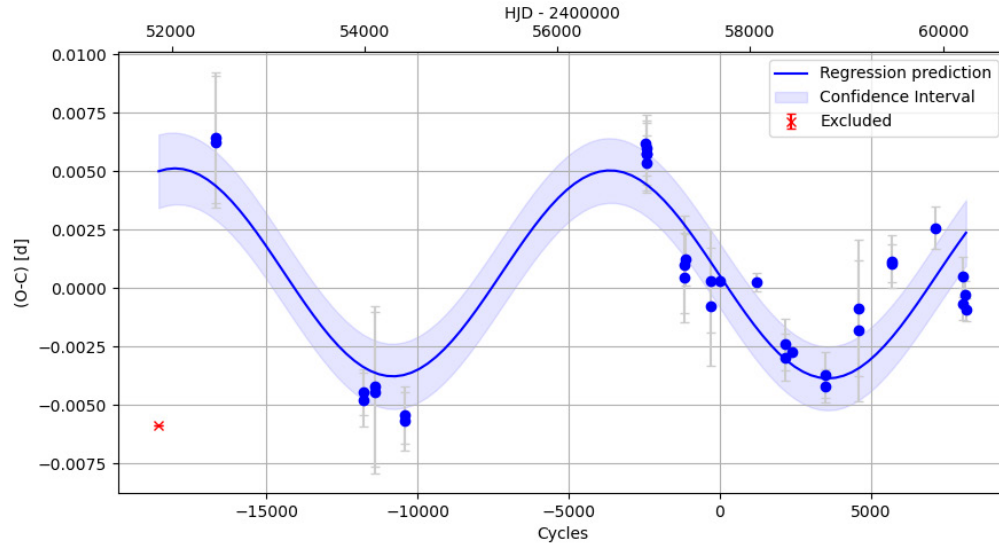


Figure 3. Sinusoid regression on the linear ephemeris (3).

The sinusoidal fit more than halves the residuals (RMS residual = 0.002 d) compared to the linear fit, and with adjusted $R^2 = 0.836$ it appears significantly preferable to the linear ephemeris (3) from which it is derived.

Parameters of the sinusoid are:

Period = 5910(8) d, Amplitude = 0.0061 ± 0.0014 d

Conclusion

The best linear fit to time-of-minimum data in Table 1, covering 21 years, is Ephemeris (3) above, which is strongly preferable to the Pilecki ephemeris (1) derived from ASAS-3 data. (d). This and the sinusoidal fit do not use the Pilecki time of minimum, which is predicted to occur at a time before the ASAS-3 data from which it is inferred. Since the prediction is based on a significantly erroneous period it is too incorrect to use.

A sinusoidal fit to the data using the linear Ephemeris (3) as reference ephemeris has adjusted $R^2 = 0.836$ and an RMS error of the residuals of 0.002 d, comparable to a typical error in a minimum estimate. See Figure 3. That suggests it is a preferable solution to observed period behavior compared to the Ephemeris (3).

The curve exhibits equal maxima and minima (no residual slope) which indicates no period change for the binary. It indicates the presence of a third object in the system with the binary in a circular orbit around the system's barycentre (maxima occur halfway between minima). The curve's amplitude of 0.0061 d equates to an orbital radius of the binary around the system's barycenter of 1.05 AU. Without radial velocity data it is not possible to estimate the mass or orbital radius of the hypothesized third body. However Bembrick's light curve analysis (2024) does not suggest contamination by a third light, suggesting it would be a relatively faint star (unlikely) or a planet.

However the minima data used in this analysis (Table 1) are far from evenly distributed in time making a curve fit somewhat arbitrary, and some data are not independent of others. Nor is it possible to validly employ weightings in the analysis since many data points lack error estimates, and not all error estimates are calculated in the same way using the same algorithms. Further, the algorithm to find the best fitting sinusoid tries many values for the sine period, calculating for each a sinusoid fit and its sum of squared residuals (SSR); until it finds a minimum SSR. That is returned as the best fit. In this way the algorithm will find just about any portion of a sine curve that yields a good fit. Whether the curve represents a real periodic change in minima times is then up to the analyst to decide.

These difficulties particularly affect the interpretation of the sinusoidal fit in Figure 3. It is reasonable to doubt that it approximates a "true" periodic change in minima times. This is reinforced by the poor fits to

the sinusoid of recent estimates from around cycle 5000 onwards. But the bias of the residuals from the best linear fit (Ephemeris 3 and Figure 2) strongly indicate some sort of periodic behavior. So the main value of the sinusoidal interpretation of the minima data is to encourage acquisition of more minima data in the hope of finding a reliable periodic solution. Meanwhile, the best result of this study is a new and more reliable linear ephemeris (3) as a basis for future period analyses.

Acknowledgement

I am very grateful to Col Bembrick for a long and fruitful research collaboration on this star.

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R Hydrae - what is this Mira doing? – Stan Walker

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Introduction

One of the earliest discovered Mira stars is R Hydrae which dates back to the mid-seventeenth century. In 1666 its period was in the low 500 day range but when the third measure was made more than a century later it had fallen to 485 days. It has been presented as a good example of period changes resulting from a helium flash. One would, however, expect a smooth decay from a single flash event and the O-C curve of Figure 1 certainly does not show this.

The changing period

In Figure 1 are depicted the intervals between two consecutive observed maxima during a 350 year interval. The first two epochs are widely separated in time and possibly not reliable but from the mid-nineteenth century the greater number of measures provided a clearer picture.

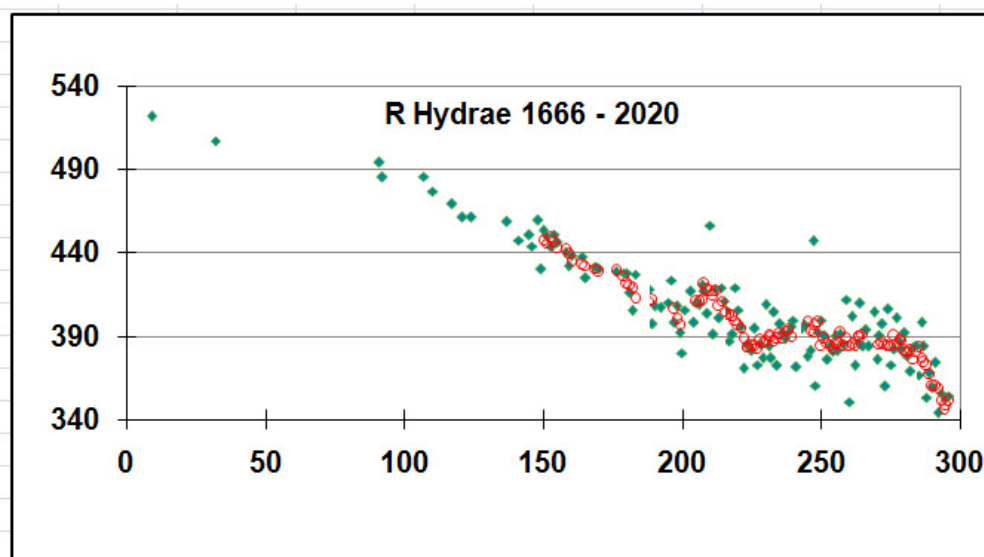


Figure 1. This periodogram provides a clear picture of the period variations. The vertical scale is the period of each cycle, the cycle number since 1666 is shown horizontally. There are some interesting features which are discussed in the text. The last few epochs from 2017-2024 are treated separately in Figure 2.

The decline in the period length continued, with some interruptions, until ~JD 2458000 at which time the Sun was interfering with the ability to make measures. The epochs from this period onward are shown in Figure 2.

The measured epochs of Figures 1 and Figure 2 have been combined as Figure 3 which shows an abrupt change back to a longer period. This may be of considerable significance if real. But the historical period change has not been constant. Why not?

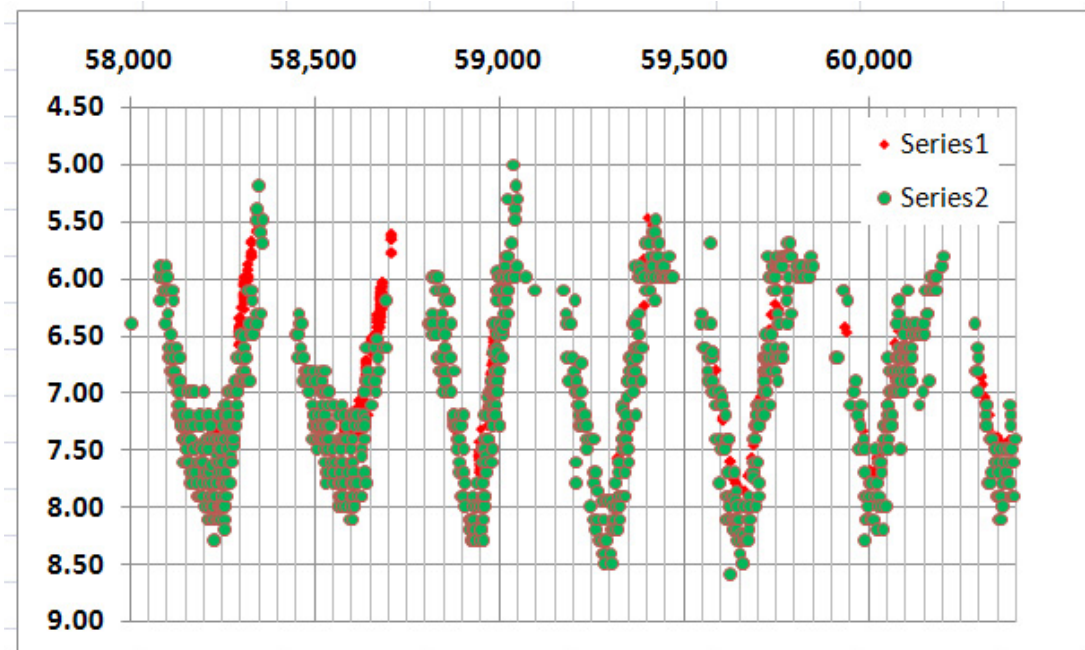


Figure 2. *V*, series 1, and visual measures, series 2, from late 2017 onward. Brightness on the vertical scale, a modified Julian Date on the horizontal. Due to solar proximity it is difficult to determine individual epochs of maxima. The clearer epochs of minimum, with an appropriate offset correction, have helped in the determinations. The minima over the six cycles show a mean period of 355 days.

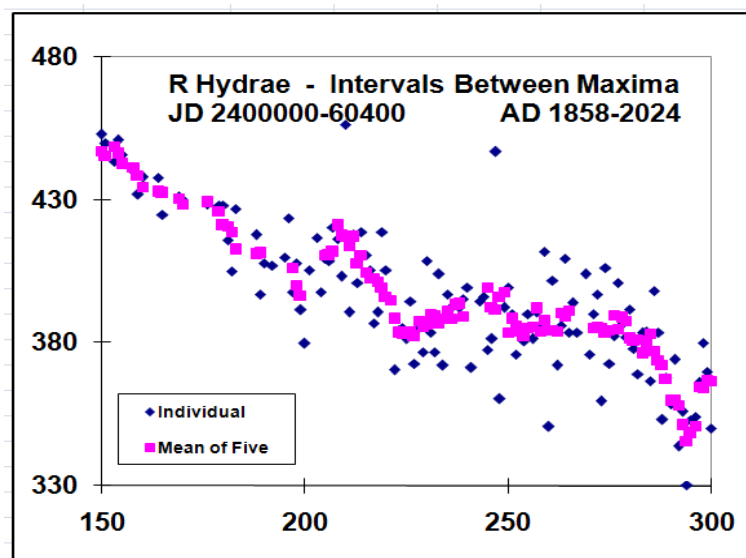


Figure 3. This shows the well observed period of R Hydrae. Scales are as in Figure 1.

This is an updated presentation of Figure 1. It's not simple to be certain about what is happening but the latter cycles appear to be fainter at maximum, to have a flat and wide maximum and possibly a hump in the maximum region. Are we seeing the birth of a dual maximum Mira?

The Dual Maxima Mira stars

A few Mira, five for certain at this time, show two maxima per cycle. Is it significant that three of these also show period changes? Is R Hydrae about to become such?

We can consider the BH Crucis behaviour in reverse. That star seemed a stable dual maxima star but then it changed in various ways. The period increased by $\sim 25\%$, the overall brightness increased and it became a single maxima Mira with a hump at times on the rise replacing the first maxima. The overall amplitude, which was not large by Mira standards at ~ 2.3 to 2.5, increased slightly. The rather broad maxima bright part of the light curve decreased in width or duration.

In R Hydrae at present we can see the broadening of maximum - a second maxima may be developing but the close presence of the Sun in the sky each year makes this uncertain. The period has been decreasing and the overall amplitude is now smaller. A discernable hump on one or two of the last dozen maxima may yet develop into a permanent second feature.

Spectra

BH Crucis is a carbon star so its spectrum is not comparable to R Hydrae which has a more normal M type spectrum. But another DM Mira, R Centauri, has a similar spectrum to R Hydrae. These spectra, by courtesy of Tom Love, are presented in Figures 4 and 5.

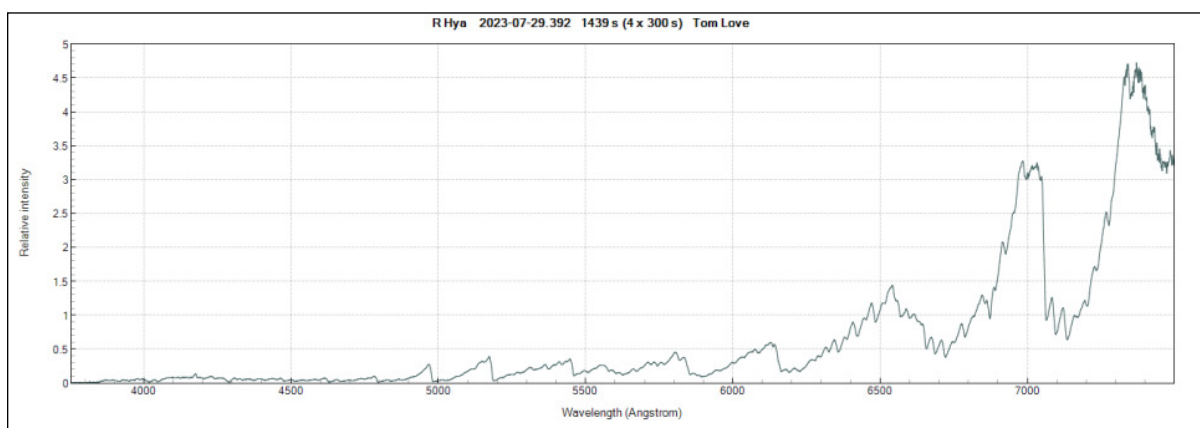


Figure 4. *Spectrum of R Hydrae. Perhaps a small sign of the expected hydrogen emission line at 6563 Angstroms is seen but is certainly not as strong as expected.*

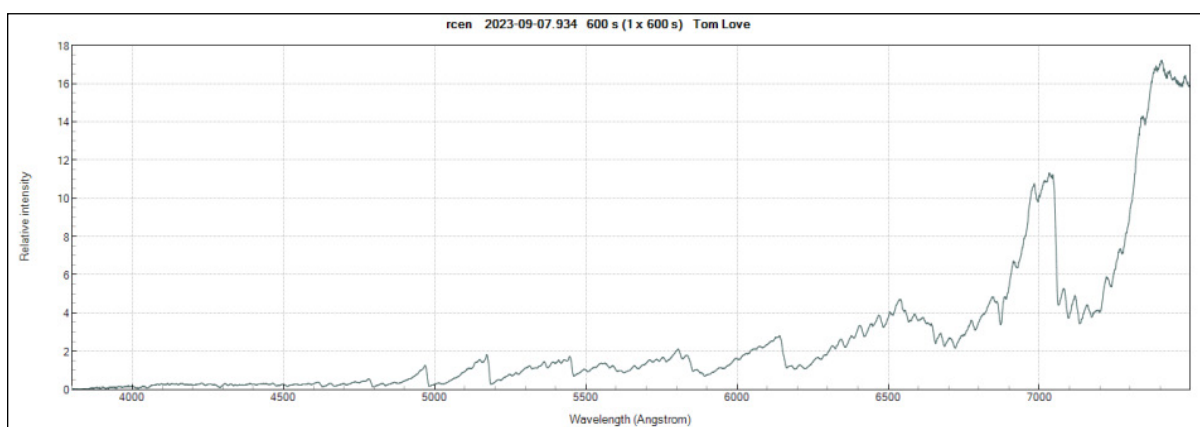


Figure 5. *Spectrum of R Centauri. This is very similar to that of R Hydra except at the red end. The stars themselves were rather different in apparent magnitude when measured.*

Note the use of intensity as the vertical scale instead of magnitudes. I'm unaware of the sensitivity response with wavelength but there is little difference between the two spectra.

General comments

R Hydrae was measured in UBV on 23 occasions from JD 2444710 to JD 2445889 $V = 5.783$, $B-V = 1.550$, $U-B = 0.530$. The $B-V$ is bluer than normal for a Mira and the $U-B$ suggests an active gas component at that time. R Centauri was also extensively measured at Auckland. These filters, however, use a part of the spectrum from 4000 Å to 5000 Å which is in a very low sensitivity region of the spectra shown here. The Auckland measures show some non-periodic $B-V$ and $U-B$ variations.

For the reasons outlined above this may be a false alarm. If not, and R Hydrae does evolve into a DM Mira it will be the first time such an event has been observed.. Measurements of the next few cycles will provide an answer. Measures V and B every 5-10 days at maximum are required although the frequency can be less as it becomes fainter.

Variable Stars South has a project related to the discovery of DM Miras,. There is a list of possible targets but a better method of finding such objects amongst the hundreds of known Miras is needed. Searching for stars with changing periods is not efficient. There is an alternative method, the parameters of which are being established. This is nearing completion and will be described in the July Newsletter although it may be on the web site earlier than that.

I have been unavailable due to an unfortunate illness which was rather persistent but am now almost fully recovered. I would welcome further discussion of R Hydrae or any of these stars with changing periods or unusually shaped light curves.

Citizen science – ways to do science in the comfort of your home – *Cledison Marcos da Silva*

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Many people think that scientific activities are restricted to large laboratories and are the responsibility of highly qualified and academically qualified scientists who pursue research as a way of earning a living, working solely for the purpose of researching and publishing. Well, not long ago, we can say, it was like that. But things have changed and now “ordinary citizens”, sometimes without any academic training, can do research and, most importantly, obtain credit and recognition for their activity. Of course, without salary compensation. There are several opportunities to contribute, from cloud photography to counting butterflies to searching for black holes that cause gravitational microlensing in their companion stars.

The term “citizen science” simply means this: science carried out by any member of the community.

In this article I will present two projects in which I am a volunteer. Two different projects, in one we have to collect the data and carry out a quick processing stage, and in the other we analyze images made available by the observatory team that takes them. They are “Hunting Outbursting Young Stars (HOYS)” and “Kilonova Seekers”.

Hunting Outbursting Young Stars (HOYS)

The project works under the leadership of Dirk Froebrich with amateur astronomers on long-term photometric monitoring of young star clusters to find explosions and other interesting objects for detailed monitoring, as well as studying the processes of star and planet formation.

Participants collaborate by taking images of targets predetermined by the project. These targets were chosen because they are star formation regions with a lot of activity and a wide range of objects that can be studied exclusively, or in conjunction with the entire star formation region and its surroundings. Some targets studied by the project are: Christmas Tree Cluster, Rosette Nebula, Orion Nebula and NGC 1333.

With just over nine years of activity, the project currently has more than 100 participants from more than 15 countries, these participants have already delivered more than 100,000 images from which more than 360 million measurements of star brightness have been made.

To join the team of collaborators, the person must register on the project website (<http://astro.kent.ac.uk/HOYS-CAPS/accounts/register/>), fill in the boxes with the available information and submit. Anyone is welcome, even those who don't have their own astrophotography equipment. I, for example, use remote observatories to take the images I send. I consider this option very useful in current times with several options for requesting images available on the internet. Those who have their equipment will simply take the images as they would on any other night of observation.

After taking the images, participants must stack the frames and send the stacked FITS image, containing the total exposure time used and send each image of each filter used separately, as seen in Figure 1.

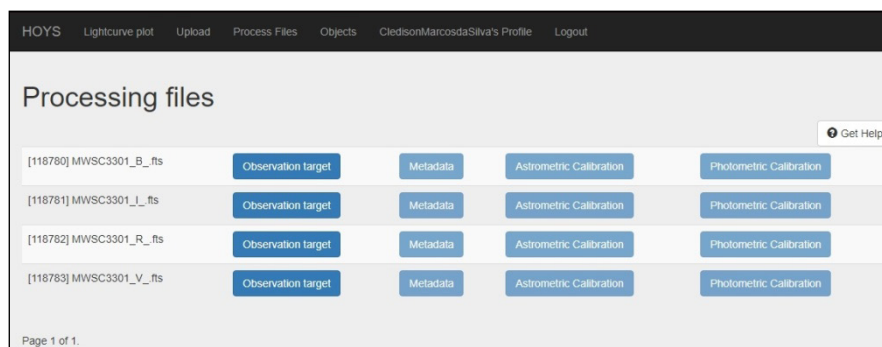


Figure 1. Uploading data to the HOYS database.

As the project has a wide range of object options to be monitored, the second step is to select the option compatible with your images. See Figure 2.

Figure 2. Selection of option compatible with the images sent.

The reader may be wondering why the first image shows MWSC 3301 and the second shows PCyg, they are the same regions, but with different names. P Cyg Cluster or MWSC 3301 is an extensive star-forming region within the Cygnus X region.

The next step is a review of your image data, it is essential to check what we call the “FITS reader”, which is the entire set of information relating to your image.

File Name	Observation target	Metadata	Astrometric Calibration	Photometric Calibration
[118780] MWSC3301_B_.fts	[Button]	[Button]	[Button]	[Button]
[118781] MWSC3301_I_.fts	[Button]	[Button]	[Button]	[Button]
[118782] MWSC3301_R_.fts	[Button]	[Button]	[Button]	[Button]
[118783] MWSC3301_V_.fts	[Button]	[Button]	[Button]	[Button]

Figure 3. Metadata option.

The metadata check page will then open, and will look like Figure 4.

```

SIMPLE =                    T
BITPIX =                   -32 / 8 unsigned int, 16 & 32 int, -32 & -64 real
NAXIS =                      2 / number of axes
NAXIS1 =                     6280 / Fastest changing axis
NAXIS2 =                     4210 / next to fastest changing axis
DATE-OBS= '2024-03-01T11:52:46' / UTC date/time of exposure start (averaged)
EXPTIME = 9.000000000000E+001 / [sec] Duration of exposure
EXPOSURE= 9.000000000000E+001 / [sec] Duration of exposure
SET-TEMP= -10.000000000000000 / CCD temperature setpoint in C
CCD-TEMP= -10.000000000000000 / CCD temperature at start of exposure in C
XPISZ = 3.7599999999999998 / Pixel width in microns (after binning)
YPISZ = 3.7599999999999998 / Pixel Height in microns (after binning)
XBINNING= 1 / Binning level along the X-axis
YBINNING= 1 / Binning level along the Y-axis
XORGSUB= 0 / Subframe X position in binned pixels
YORGSUB= 0 / Subframe Y position in binned pixels
READOUT= 'Normal' / Readout mode of image
FILTER = 'B' / Filter name
IMAGETYP= 'LIGHT' / Type of image
FOCALLEN= 542.6 / Focal length of telescope in mm
APTDIA = 0.0000000000000000 / Aperture diameter of telescope in mm
APTAREA = 0.0000000000000000 / Aperture area of telescope in mm^2
EGAIN = 1.0000000000000000 / Electronic gain in e-/ADU
$HIERARCH = 'MaxIm DL Version 6.21 190225 0CT90' / Name of software
$SERIAL= '0CT90-9705H-8048K-5K2C2-NVTVY-HQ' / Software serial number
  
```

Figure 4. Cheking the metadata

Your image is already loaded into the HOYS database. The next steps are astrometric and photometric calibration.

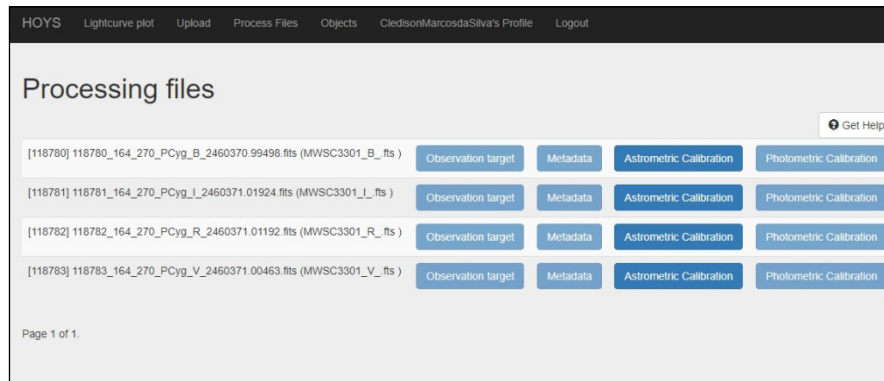


Figura 5. *Astrometric calibration option.*

Astrometric calibration is basically checking the stars in your image with an internal HOYS database, made with positions based on Gaia DR3, the most current and accurate catalog of star positions in our galaxy.

The reader will see in the image below that stars have a red dot superimposed on them, each red dot is a position previously established by Gaia. Software developed by the researcher will measure the brightness of each object in the image, thus facilitating monitoring of the entire extent of the photographed region, which will generate a useful amount of data to be used later.

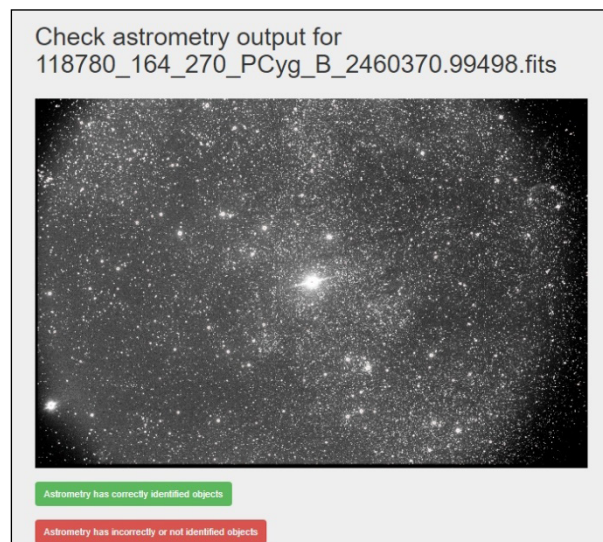


Figure 6. *Astrometric calibration of the image with DR3.*

In the image above you can see two options, one green and one red. Generally the images are loaded correctly and you just need to select the first one, but if the image is not loaded, the reason is that an image from an incorrect region was sent incorrectly, or astrometry did not recognize any object in the image, leaving it to be deleted.

The last step – photometric calibration – is what may present the most difficulty to the collaborator, but in the case of a better quality image the process is quite quick.

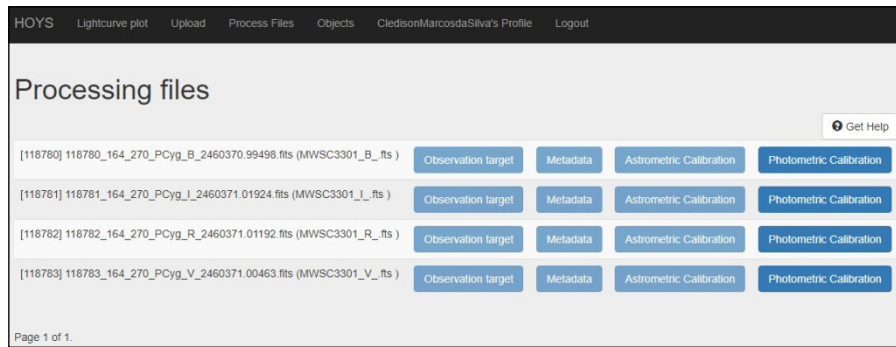


Figure 7. Photometric calibration option.

At this stage of the process you will see two graphs, the upper one are all the stars recognized in the image with their respective uncalibrated magnitudes. And the lower one with the calibrated magnitudes.

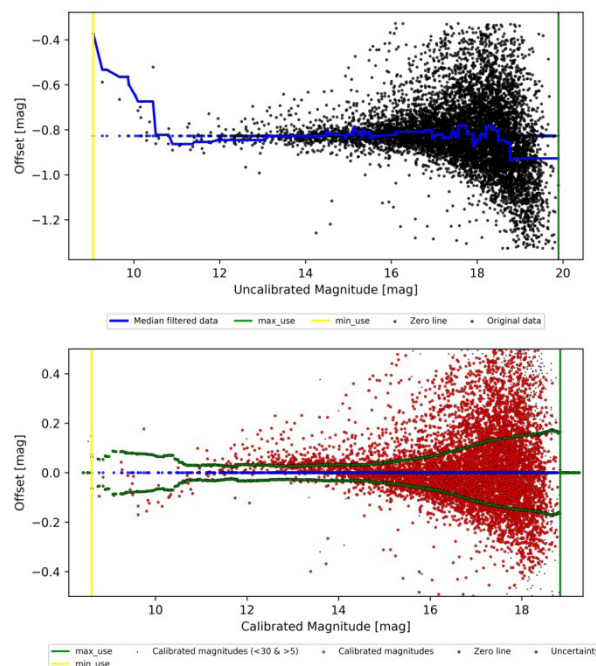


Figure 8. Photometric calibration graphs.

As seen in the image above, there is a blue line that corresponds to the median filtered data in the top graph and a dotted line in the bottom graph that corresponds to the uncertainty in the measurements. The project accepts uncertainty up to 0.3 and if your image presents any portion of the graph with uncertainty greater than this value, you will be informed at the bottom of the graphs. Both graphs show the “offset” that will be used to assist in visual inspection of the graph.

The objective here is to place the blue line in the upper graph as close as possible to the “zero line”, this horizontal line present in both graphs. To do this, in the image used as an example I cut that fraction of the “median filtered data” in the upper graph that was leaving the zero line towards brighter magnitudes that could compromise the image brightness measurements. For this I used the options available below the graphs in conjunction with information available on the graph, which is the vertical yellow line, called “min_use”. After a visual inspection of the top graph, I decided that the ideal value for “min_use” was 10.5 and simply filled in the available option, as seen in Figure 9.

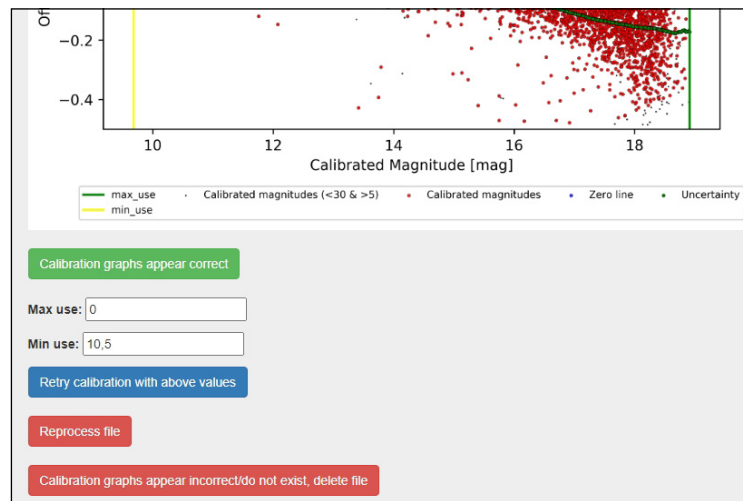


Figure 9. *Photometric calibration options.*

After selecting the blue option “Retry calibration with above values”, the image will be cropped and calibrated with the values proposed in the filling:

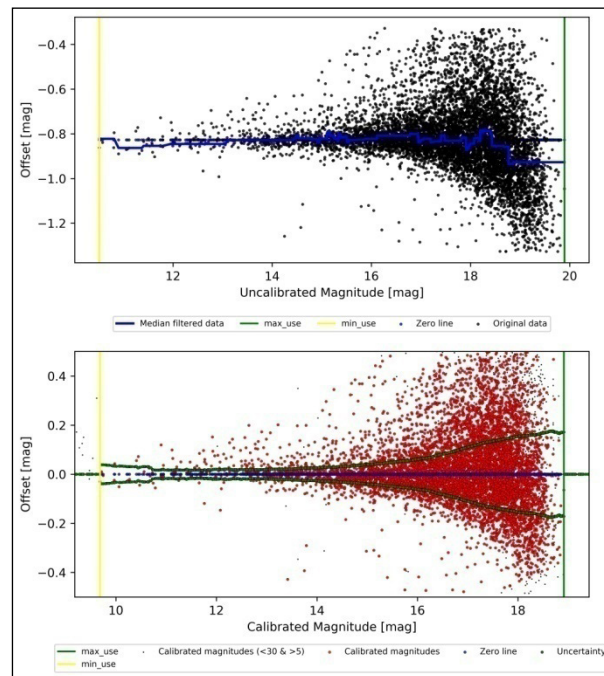


Figure 10. *Same image after calibration*

The median filtered data is close to the zero line and the uncertainties are less than 0.3, so this image can now be finalized, just click on the green option “Calibration graphs appear correct” and that’s it, you have made your contribution to brightness measurements of young stars without much effort.

The HOYS citizen science project publishes its results in a recognized scientific journal, and since its inception there have been more than 10 publications containing as co-authors the collaborators who sent their images. Also the data has supported 2 research masters thesis and 4 PhD thesis projects. New publications will be made in the future and the database is waiting for your images. If the volunteer encounters difficulties in any of the processes, on each page there is the “GET HELP” option that can be accessed to watch a video relating to the process being carried out. face doubts about what to do.

To learn more about the project, visit its website at: <https://hoys.space/>.

The publications made by the project are listed at the link: <https://hoys.space/science/>

Kilonova Seekers

The second project I would like to show in this article is the “Kilonova Seekers”, the project is maintained by the Gravitational-wave Optical Transient Observer (GOTO) which consists of a series of wide-field optical telescopes, designed and optimized for tracking electromagnetic counterparts for gravitational wave sources.

The observatory was designed using “off-the-shelf” components to minimize costs and increase reproducibility, while ensuring fast response time to alert triggers and balancing sky coverage and depth. GOTO is currently comprised of two different nodes, GOTO-North at the Roque de los Muchachos Observatory on La Palma, Canary Islands, and GOTO-South at the Siding Spring Observatory, Australia, each hosting two mounting systems containing eight 40-inch fast unit telescopes, operating together. As La Palma and Siding Spring are on opposite sides of the world, this allows for constant observation, meaning when one location is closed, the other will take over. These observation locations and time frames allow the GOTO system to survey the entire sky every 2-3 days.

The main focus of GOTO is the rapid response system, targeting the initial localization of GW sources from LIGO, Virgo and KAGRA. When the GOTO system receives an alert of a GW event, it is able to rotate all telescopes to point at that location within 30 seconds and begin scanning that area for the predicted EM counterpart.

Along with this fast response mode, GOTO operates in survey mode, observing the entire sky every few days, making it an ideal tool for time-domain or transient astronomy, monitoring any changes in the sky, such as the appearance of supernovae, variable stars, active galactic nuclei and many others.

Once images are taken, they are immediately processed and sent to the dedicated GOTO Marshall for visual inspection by the team. At the same time, candidate objects for this citizen science project are uploaded to the Zooniverse platform, allowing this project to run in near real-time.

The volunteer needs to analyze 3 images: a science image taken on the day it was uploaded to the project database, a reference image made by the team months ago and a difference image, created by subtracting the model image from the science image. What remains in this image is new light, not seen in the reference images - a potential new transient.

Under ideal weather conditions for observations to be made, images are uploaded to the website every hour.

The workflow is very simple, all you need to do is visually analyze the images and click “Yes” or “No”, as seen in Figure 11.

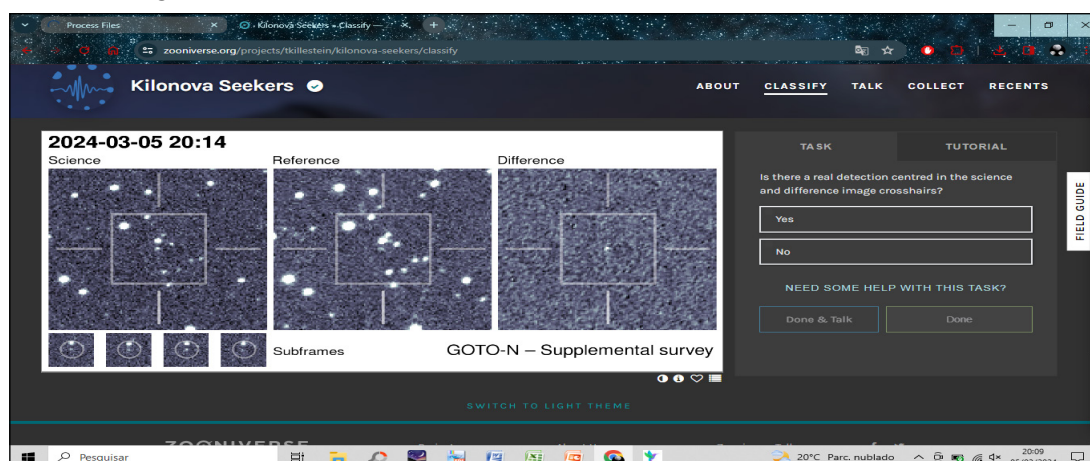


Figure 11 - *Kilonova Seekers workflow.*

In the image above, you can see a bright source in the science image and a source, in the same place, but less bright in the reference image. In this case, it could be a transient in a faint galaxy or a variable star that had different brightness on the nights each image was taken. For this, the answer must be “Yes”, since variable stars are useful for training the algorithm that automatically recognizes transients.

In Figure 12, you can clearly see a bright spot in the center of the scientific image that is not visible in the reference image. Therefore, it could be a possible undiscovered transient:

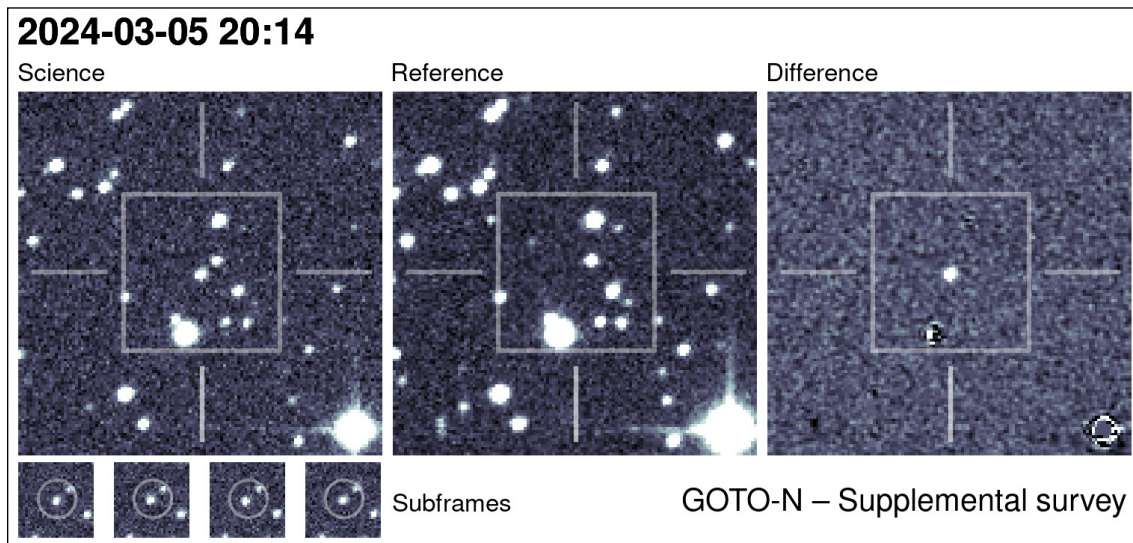


Figure 12. *Images to be analyzed by the volunteer.*

An interesting thing about this project is the possibility of exchanging opinions between volunteers and the main team through comment pages for each set of classified images. This is useful for knowing other people's opinions, as well as for announcing discoveries and other matters relating to the project.

The project was launched on the Zooniverse platform on July 11, 2023, with just 8 months of activity it has already yielded very interesting discoveries and also confirmations of events previously discovered by other surveys and observers, such as SN 2024gy discovered by Koichi Itagaki on January 4 2024 and shown in Figure 13.

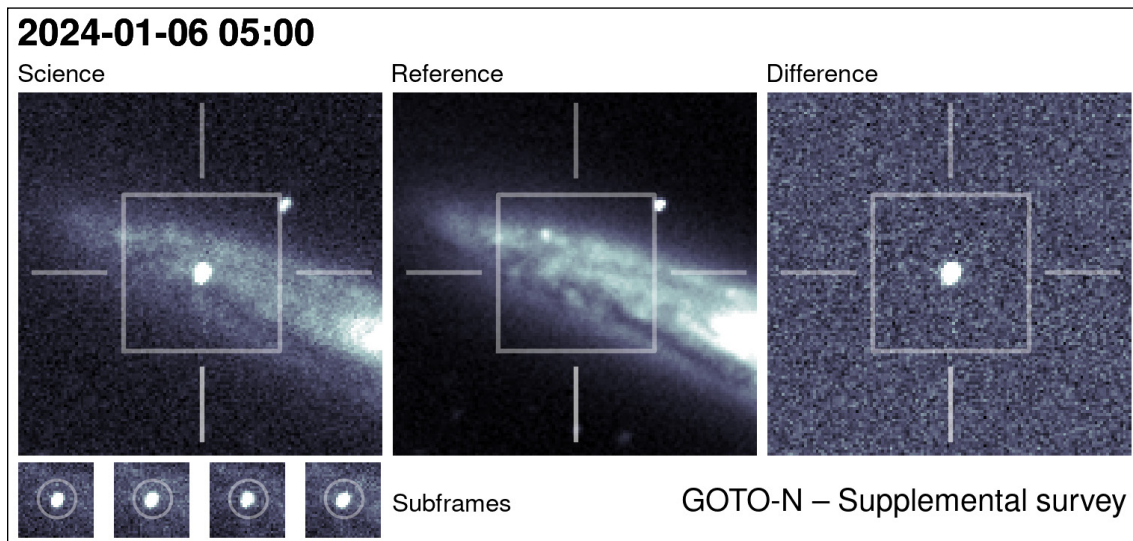


Figure 13. *Photo image of SN 2024.*

What makes this project also worth highlighting is the humility of the team responsible for also recognizing the volunteers and collaborators with credits in the transient reports made to TNS.

As a Kilonova Seekers volunteer, I have performed more than 57,000 image classifications since the project launched. These classifications gave me 11 official discoveries recognized and credited to me and other volunteers on the IAU Transient name Server. Of the 11 discoveries, 3 are supernovae and 8 are unclassified transients.

To learn more about the project, visit:

<https://kilonova-seekers.org>

The discoveries are listed at the address below:

<https://www.zooniverse.org/projects/tkillestein/kilonova-seekers/talk/5855/3062481>

Acknowledgements

My thanks go to the project teams who kindly gave me permission to publish this short promotional article, including Dirk Froebrich (HOYS) for all the teaching and opportunities at HOYS and the KN Seekers team, Tom Killestein, Lisa Kelsey and Emily Wickens who are always in contact with the volunteers, but I would like to thank the general GOTO team for all their support.

I would also like to thank Mark Blackford, director of Variable Stars South, for the opportunity to write this promotional article in a VSS newsletter.

The first UBV measures of this star at the Auckland Observatory began in 1971. But this was not by chance, even though it is close to the celebrated eta Carinae in our sky. We had been observing variable stars for a month or two, perhaps more, when the Auckland Observatory opened in 1967. There are several stars of similar apparent magnitude in this region which were recommended by Albert Jones as comparisons for eta which was around 6.0 to 6.5 at the time. Reports of a ‘flare’ on eta Carinae were made by some of our observers and it was added to our target list.

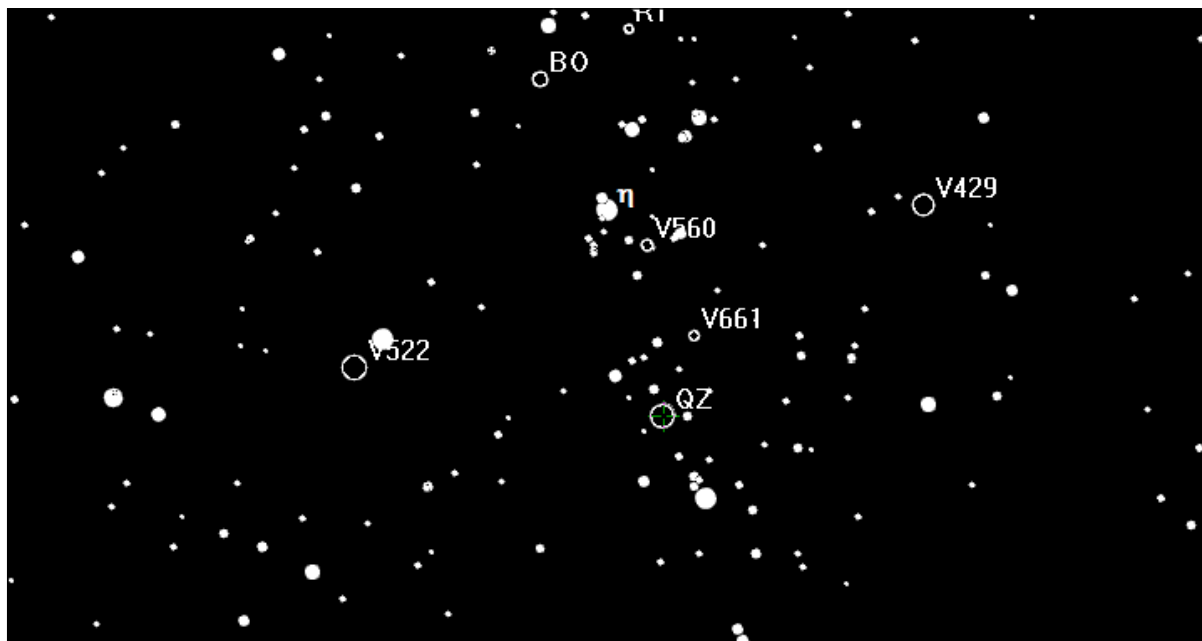


Figure 1. A chart from Guide 9 shows the stars of interest. The limit is about magnitude 9. Eta Carinae is now about $V = 4.5$ and slowly brightens as the surrounding nebula expands.

The above map shows some stars of interest, quite a few variable. These stars are labelled V + number with the exception of eta which uses the Flamsteed bright star code and QZ, which is the last lettered variable in Carinae. Variable stars are shown as unfilled circles. Our comparisons were HD 93206 which is the bright star next to V522, HD 93206 which is QZ and the bright star to its south, HD 93195 which is a Wolf Rayet star HD 93919. Two are variable at the 1% level, the other was QZ itself.

Brian Marino and I quickly became convinced that one or two of these were variable but these were the visual days. We did, however, see an interesting comment by Feinstein and Marraco in which they noted variations to eta Carinae in the RASNZ VSS observations and attributed these to the large number of new observers making bad estimates. We were later to prove the visual observers correct. But this awaited the building of our photoelectric photometer - which was ‘state of the art’ in those days.

The current scene

So here we are in 2024. A rather complex pair of papers by Harmanec et al 2022 and Broz et al, 2022, which both included many useful measures by amateur observers was published. A short popular review and explanation of the purpose and results to date was published in the RASNZ newsletter, March, 2023, by Stan Walker and Mark Blackford. This is well worth your time to look up and read.

The amateurs involved have all contributed to the construction of an O-C diagram of the mutual orbit of the two main pairs of stars in what is believed to be a nine star system. The 2022 papers adopted an orbital period for this of 42.045 years. Whilst this appears to fit the measures well it is largely based on spectroscopic measures over a relatively short interval of the orbit.

For this reason it is important to check this period. Up to 2022 there were 62 annual epochs with David

Blane of South Africa a strong observer over the last few years. However, his shift away from the east coast has restricted his observing. We are fortunate in that John Martin of the USA has been making measures in 2023 and 2024 using one of the AAVSO's bright star monitors. The 2024 measures to mid-April, about a month after opposition, are shown below in Figure 2.

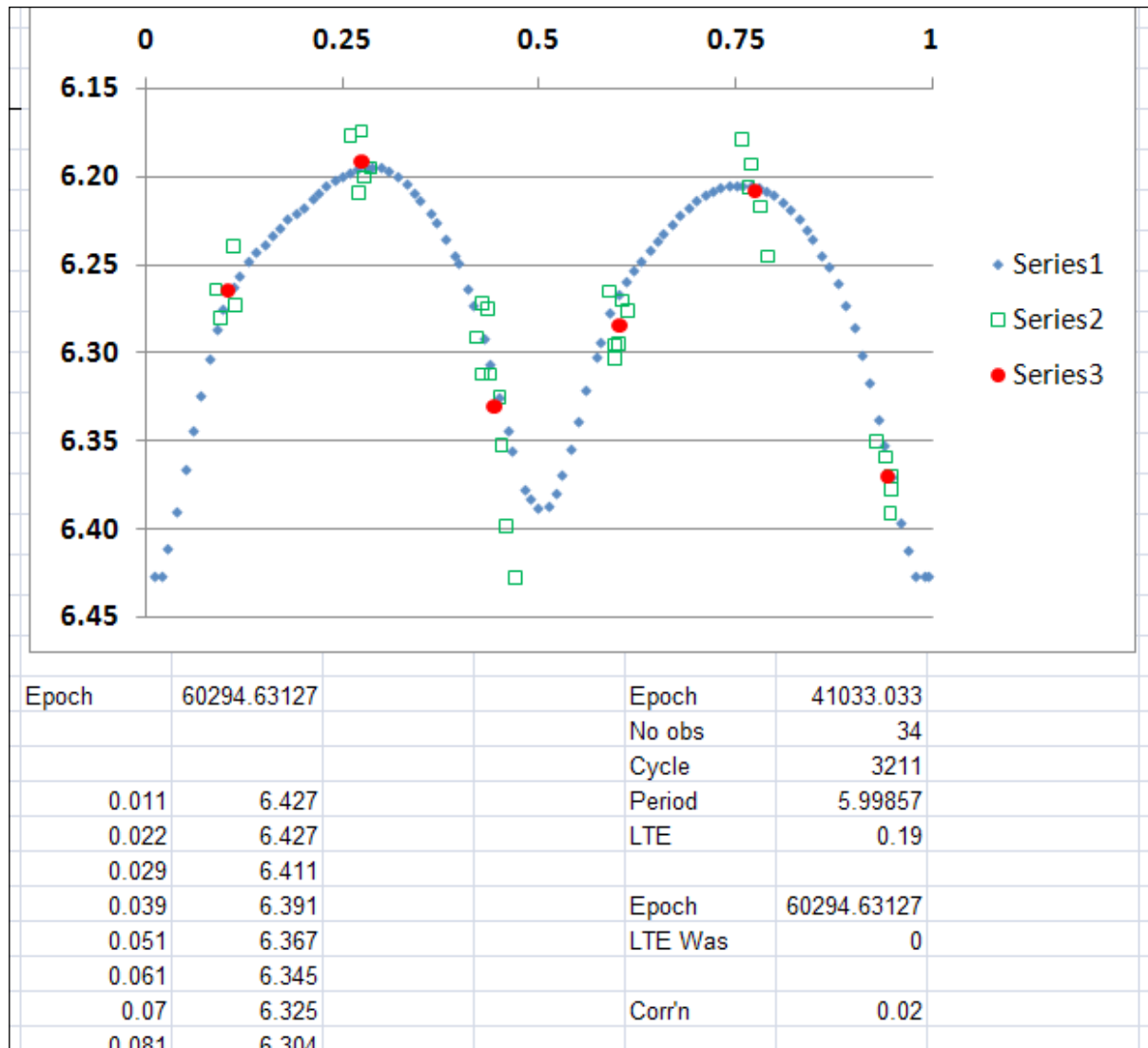


Figure 2. This shows the measures from John Martin as described. The mean light curve, derived from measures by the BRITE satellite, is shown with small blue points. Individual observations are represented by open green squares and means of the latter are shown as filled red circles. Overall it is part of a spread sheet analysing the observations.

Given the period of a few seconds under a day and the long and slightly variable depth of the eclipses it is possible to time eclipses only from a narrow range of longitudes each season. Depth of eclipses varies by ~5% indicating very active stellar surfaces. An alternative approach must be used. This comprises determining the mean phase and magnitude of six separate parts of the light curve of the eclipsing pair.

John has been fortunate in observing this star at the ideal time, We can construct six mean observational sets which provide a very good epoch of central eclipse when fitted by eye. The correction shown in Figure 2 is needed due to the slight variations between eclipses and is determined by the overall fit. The most important value is the light time effect, LTE, derived by trial and error to achieve the best fit of the six mean points to the mean light curve. The cycle number and epoch follow from these fits.

If the orbital period of 42.045 years is correct then the O-C diagram should show epochs repeating their positions from epoch 2560. Figure 3 explores this concept by plotting epochs since discovery but also folds the graph at the 2560 cycle mark by plotting subsequent epochs as observed cycle - 2560. Thus the left

part of the plot now shows an overlap of two cycles. The vertical scale is in minutes, negative values are early eclipses of the 6 day period, positive values late.

The fit is surprisingly good with the second cycle values (those from 2560 onward occurring between 0 and 60 minutes early with an average of 25 minutes early..

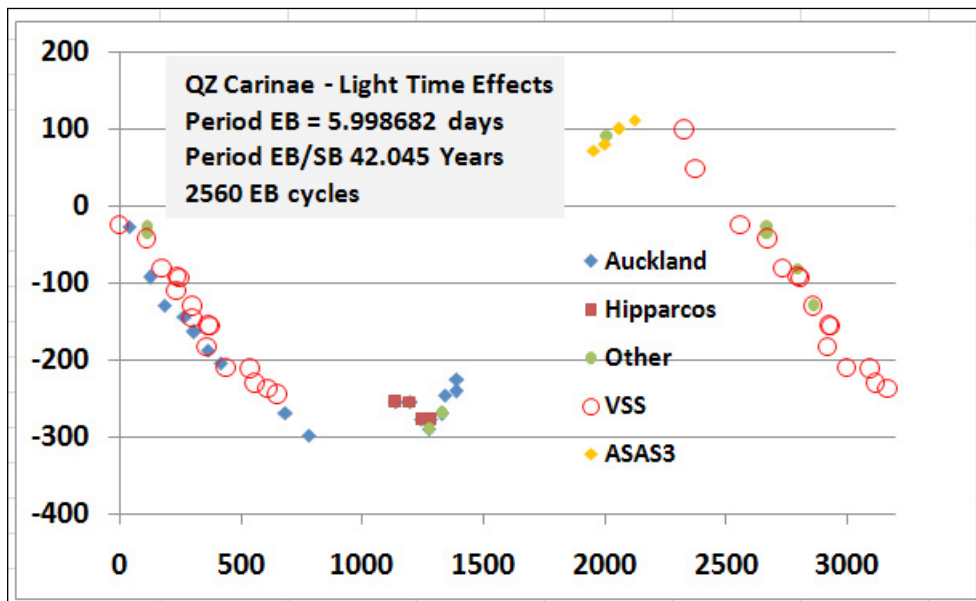


Figure 3. *The O-C of eclipses of the 6 day system as described in the text. The offset of the vertical scale is not significant - zero epoch was the first eclipses measured.*

It was clear from eclipses observed by ASAS3 and Terry Bohlsen that the orbit was quite elliptical. This produces the sharp turnaround at cycle ~2200. Other observations have shown that we are observing from close to the plane of the system so the observed eclipses are close to a straight line linking the two extremes. The 6 day eclipsing system is approaching us at the moment with the 20.73 day spectroscopic binary receding.

Until the other orbital extreme occurs and is measured the exact position of the measures where we suspect the orbit is being duplicated cannot be certain. Unfortunately the epochs around 1200 to 1300 are very inaccurate and there are large gaps in the cover.

The popular article by Stan Walker and Mark Blackford based on all available papers and measures at 2022 appeared in the RASNZ Journal, 267, May, 2023, pp 9-13 The Massive Nine Star System of QZ Carinae. This is well worth reading.

A conclusion of sorts

This project began in 1971 and has led to a variety of interesting papers. The realisation that a simple binary system was in fact two pairs of binaries - and has now grown into a nine star system - was unexpected. I think there are further surprises waiting there.

Next month I will be 92 and I will not see all of these. I hope that others like John Martin will continue to observe and explore the various aspects of this system. All of the visual measures used in these diagrams are available to anyone interested. The Auckland measures are mostly UBV which adds a further dimension.

About

Variable Stars South is an international association of astronomers, mainly amateur, interested in researching the rich and under-explored myriad of southern variable stars.

Renamed from the Variable Star Section of the Royal Astronomical Society of New Zealand, it was founded in 1927 by the late Dr Frank Bateson, OBE, and became the recognised centre for Southern Hemisphere variable star research.

VSS covers many areas and techniques of variable star research, organised into projects such as Beginners' Visual Observations and Dual-Maxima Miras. The goal of each project is to obtain scientifically useful data and results. These may be published in recognised journals, or supplied to international specialist data collection organisations.

VSS is entirely an internet based organisation, working through our website <http://www.VariableStars-South.org> and its e-group <http://groups.google.com/group/vss-members>. It also encourages members to work in with major international organisations such as the British Astronomical Association, the Center for Backyard Astrophysics and the American Association for Variable Star Observers.

To find out more, please visit our website, where, incidentally, you will find PDF copies of all our newsletters. Our website has a great deal of information for VSS members, and for anyone interested in southern hemisphere variable star research. All VSS project information and data is kept here too.

Who's who

Director Mark Blackford

Treasurer/Membership Bob Evans

Newsletter Editor Phil Evans

Webmaster David O'Driscoll

Visit our website to see a list of our area advisers, and to find out about our projects and how to contact their leaders

Membership

New members are welcome. There is no annual subscription but donations would be gratefully received. Find out how to join by visiting the VSS website. There you will find out how to join by post, email, or directly online. If you join by email or online and wish to make a donation you will get a link to pay by PayPal's secure online payment system, from your credit card or bank account.

After you've joined and received your membership certificate, you will be signed up to the VSS-members egroup (see above), and you will also receive a password to access the members' areas of our website.

Newsletter items

These are welcomed and should be sent to the Editor (phil@astrofizz.com). I'd prefer Microsoft Word (or compatible) files with graphics sent separately. Don't use elaborate formatting or fancy fonts and please do not send your contribution as a fully formatted PDF file.

Publication dates are January, April, July and October, nominally on the twentieth day of these months and the copy deadline is the thirteenth of the month though earlier would always be appreciated.

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