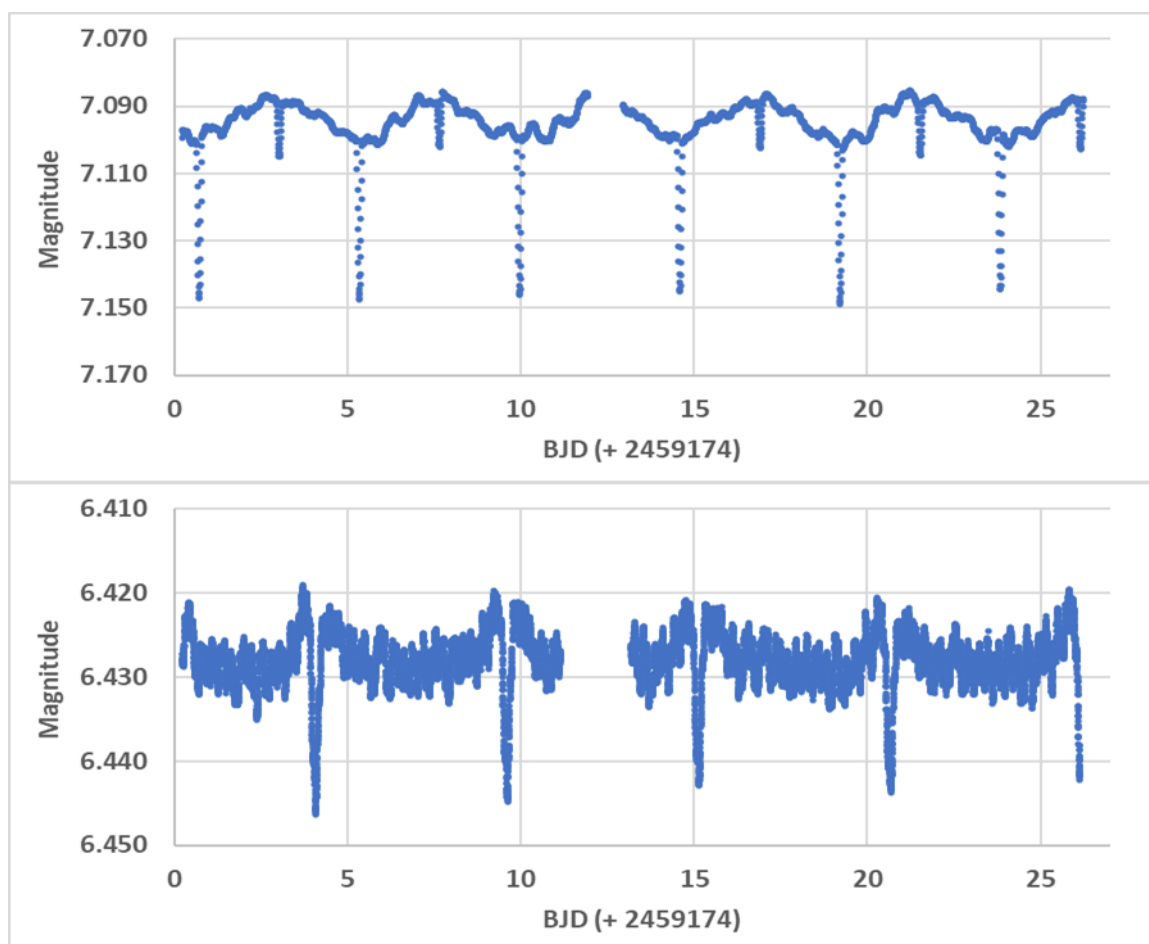




TESS light curves of two new eclipsing binaries with pulsating components near VV Orionis. See article by Mark Blackford on page 11.

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From the Director - *Mark Blackford*

Welcome to the final edition of the Newsletter for 2022 and thanks to all our contributors. Col Bembrick reports on his analysis of the eclipsing binary OQ Luppi using observations from the ASAS-3 and ASAS-SN archives. David Moriarty updates the light curve modelling of BF Velorum which he wrote about in the previous Newsletter. Mati Morel looks at the R Coronae Borealis and DY Persie type variables in the LMC. Finally, my article reports the identification of two eclipsing binaries with pulsating components and several other pulsating variables in Orion.



The much delayed Sixth Variable Stars South Symposium was finally held via Zoom over three sessions in late October and early November. The quality of talks was exceptional. There were a couple of late changes to the program, Andrew Pearse could not present due to travel commitments, so I stepped in at the last minute to fill his time slot. Stan Walker's second talk was cancelled due to illness, and Jeff Byron's COVID isolation on Norfolk Island meant his presentation had to move to a later session. Never-the-less, the symposium ran smoothly under David O'Driscoll's calm and competent oversight. A special thankyou to our presenters and viewers from Europe, USA and South America who stayed up late or woke up very early to participate.

PDF's of all the presentation slides are now on the VSS website, and at the time of writing the first session videos were also available. David set up a Variable Stars South YouTube channel for these and future recordings.

Congratulations to Dr. Brian Kloppenborg on being appointed to the role of Executive Director of AAVSO. Back in 2013 I met Brian at a workshop at AAVSO headquarters in Boston to plan the DSLR photometry manual and worked closely with him to write the first iteration of the manual. I look forward to continued cooperation between VSS and AAVSO under Brian's leadership. His recent letter to AAVSO members is reproduced elsewhere in this Newsletter.

Like most of the Australian east coast, observing conditions at Congarinni observatory were very poor over the last few months. Observing was possible on only half a dozen nights with most of those affected by intermittent cloud. Bureau of Meteorology forecasts of wetter than usual conditions over spring and summer don't auger well for astronomy in the near term.

Wishing you all clear skies and good health,

Mark Blackford

Letter from AAVSO's new director, Dr. Brian Kloppenborg



October 17, 2022

Dear Colleagues,

Today marks my one month anniversary as the Executive Director of the AAVSO, so I thought it prudent to introduce myself, describe what I am doing, and preview where we will be heading.

The most important thing I want to convey is how excited I am to be joining the AAVSO. It is an honor to lead one of the world's oldest and most successful astronomical organizations.

As you may know, I served as a Professional Liaison in the AAVSO's Citizen Sky program from 2010 to 2012. During that time, I was completing my Ph.D. at the University of Denver. I wrote my dissertation on Epsilon Aurigae, which underwent its famous two-year long eclipse and utilized AAVSO data as part of my research. As the Liaison, I helped four citizen science teams define and execute their own scientific programs and led the DSLR Photometry Team. Some time later, I served as the editor of the first edition of the DSLR Observing Manual. My work with the AAVSO left me with utmost respect for the organization and the community it represents.

Since Citizen Sky, I acquired skills that will prove useful to the AAVSO. I learned agility by working a startup, finance by running a small business, team building by scaling a project from 7 to 70 people, and program management through my role as Lead Engineer on a \$120M program. I'm a strategic thinker who can envision a future and establish a pathway to get there.

The AAVSO and its role within the broader astronomy community changed considerably over the last decade. Because of this, my first month focused on learning about the AAVSO, identifying areas for improvement, and strategizing how we should adapt for the future. Like many organizations, the AAVSO faces its share of challenges. We want to strengthen ties with our sister organizations, improve the quality of our data, build our membership, and find our niche in the automated sky survey era. The challenge I now face is how to accomplish these goals in a way that ensures a sustainable future. This type of change must be approached systematically and will take time to realize. I know I can count on your support.

I want to pay tribute to Dr. Stella Kafka and her seven years of service to the AAVSO. Early in her tenure, the AAVSO faced an unprecedented financial crisis. She made a series of exceptionally difficult decisions that reduced our draw on the endowment and ensured the long-term financial stability of our organization. I would like to thank her personally for her hard work and wish her the best in her new role at the American Meteorological Society.

I look forward to exchanging ideas with many of you during the Annual Meeting in Tucson in early November.

Regards,

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Analysis of a Rob McNaught Eclipsing Binary: OQ Lup – Col Bembrick, Mt Tarana Observatory

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Introduction

In a recent VSS Newsletter Mati Morel published (Morel, 2016) a ‘validation’ of a list of 22 possible variables discovered by Rob McNaught in the 1980s. Most of these are now confirmed variables and include (Morel, 2016) 15 long period red variables, one nova and one EA eclipsing binary. Morel presents ASAS-3 light curves for the 15 red variables, but does not discuss the eclipsing binary, OQ Lup. This will be the subject of this paper, where the first binary analysis and model is presented.

History

With access to McNaught’s original hand sketched finder charts and the ASAS-3 database, Morel (2016) positively identified “star C” in the McNaught chart (dated 1987) as NSV 6842 or OQ Lup.

With hindsight, we can now see that this ‘discovery’ by McNaught is actually a re-discovery. The sequence of events now appears to be (Morel, pers comm) as follows.

- 1938 – reported in a list of variables by Luyten.
- 1951 – included in a Russian list of suspected variables as CSV2210.
- 1968 – plotted as suspect variable on RASNZ VSS chart 201.
- 1982 – appears in NSV catalogue as NSV 6842.
- 1987 – noted by McNaught in his photographic survey.
- 2005 – period determined, reported in IBVS 5586
- 2008 – officially designated as OQ Lup in IBVS 5863.

The data presented by Morel (2016) in his Table 1 are as follows:

OQ Lup = NSV 6842, RA14:53:45.01, Dec-54:38:14.6 (J2000), V magnitude range 12.62-14.4, Period 1.83777, type EA. The quoted magnitude range is taken from the ASAS light curves and the period from the VSX database. A literature search by the author has not turned up any more recent papers regarding this star.

Modern Data Sources

Given its deep southerly position, it is not surprising that there are no data available via the AAVSO Variable Star plotter. However, with the advent of ‘modern’ databases such as ASAS (Pojmanski, 1997) there is now a wealth of photometric data publicly available for this system.

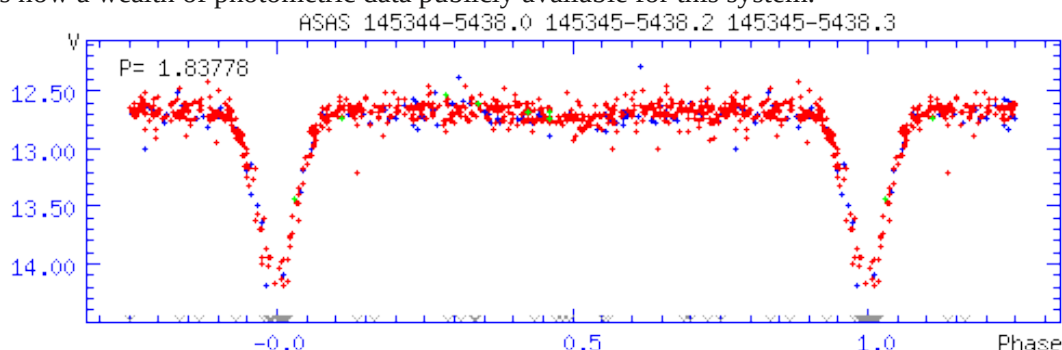


Figure 1. Phase-folded data from ASAS using Epoch and period from Otero et al, 2005. A very distinctive primary eclipse with very subtle secondary.

The raw data download from ASAS-3 (shown above in Figure 1) gives the impression that there is little evidence for the secondary eclipse and the out-of-eclipse light curve is virtually flat. However, the ASAS-SN data (Shappee, 2014) gives a better rendition - shown below in Figure 2.

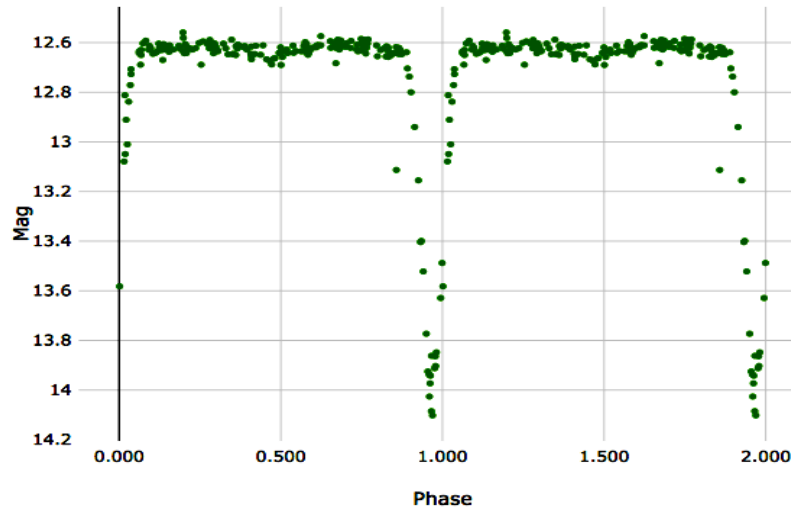


Figure 2. The plot from the ASAS-SN webpage, showing a distinct secondary and variability out of eclipse. However, note that the primary eclipse does not fall exactly at zero/1.0 phase, so the period (or Epoch) used here may be slightly incorrect.

Discussion

Inspection of the ASAS-SN data set showed that it gives a clear representation of the light curve, so this was the data set chosen to use in the binary modelling. The epoch and period were chosen from the VSX data which appear to be based on IBVS 5586 (Otero et al, 2005). Thus, the V band data (5500 Å or 550nm) were phase folded with Epoch HJD 2452635.842 and period 1.83778 days. This data set was then used as input to the Binary Maker 3 program (Bradstreet, 2005).

A general examination of the light curve features (Figure 2) immediately reveals it is an Algol-like system, with widely disparate eclipse depths. This implies that the temperatures of the two components will be very different. The fact that the out-of-eclipse light curve is not quite flat also implies that at least one component may be non-spherical. The primary eclipse has no flat bottom, so the eclipses are partial. Also evident is the fact that the secondary eclipses are half-way between the primary eclipses, indicating we are dealing with circular orbits.

All of these initial general observations of the light curve inform us of what to expect from the modelling exercise.

Binary Modelling

To initiate modelling of a (poorly studied) binary system using Binary Maker 3 (Bradstreet, 2005) several estimates of some critical parameters need to be made, based on a combination of factors. The first of these is the effective temperature (T_1) of the primary star. This can be derived from the spectral type or B-V colour index if the former is lacking. The VSX database (Watson et al 2014) gives no spectral type but does quote a colour index of 0.61. From this, using the Ballesteros formula (Ballesteros, 2012), we can derive an effective temperature of 5919K. This compares well with the temperature of a main sequence star in the spectral range G0-G2 (Cox, 2000). A further search of the VSX database, using the VizieR facility, yields several catalogue values for the effective temperature. Derived temperatures range from 5085K (Anders et al, 2019), through 5777K (Tonry et al, 2018) to 6076K (Bai et al, 2019). From these values a compromise initial input effective temperature (T_1) was assumed as 5500K.

The other parameter which needs to be (at least approximately) estimated is the mass ratio ($q = m_2/m_1$), which determines the relative sizes of the two stars. In this case an inspection was made of the Binary Stars Pictorial Atlas (Terrell et al, 1992) to find a similarly shaped light curve. As the light curve of OQ Lup is not dissimilar to that of Algol (β Persei) we assume for the moment that it is a semi-detached system and choose an initial mass ratio of 0.25. As the cooler secondary star is expected to be at its Roche limit, the BM3 manual recommends (Bradstreet, 2005) setting the star radius to -1 as this forces the program to make the secondary star fill its inner Lagrangian surface.

In running this initial BM3 model we use gravity brightening coefficients $G1 = G2 = 0.32$ for convective stars (less than 7200K) and also reflection coefficient $R1 = R2 = 0.5$. By adjusting the secondary star temperature ($T2$) we can get the model to match the relative depths of the primary and secondary eclipses. The inclination i , of the orbital plane (together with the mass ratio) adjusts the absolute depth of the eclipses. From a consideration of the two star temperatures, we adjust the limb darkening coefficients ($X1, X2$) from the tables of van Hamme (1993). An initial 'first pass' model is thus derived in BM3.

To refine the value of the mass ratio in the model we can run a modified “q-search” using the ‘Quick-n-Nifty’ method (Q-n-N - Bembrick, 2017) whereby the value of mass ratio q is varied in discrete steps and the resulting goodness of fit of the observed light curve to the model is judged by the minimum of the least squares residuals, R . In this case the best value of q was obtained at an R value of 0.100. (See Figure 3).

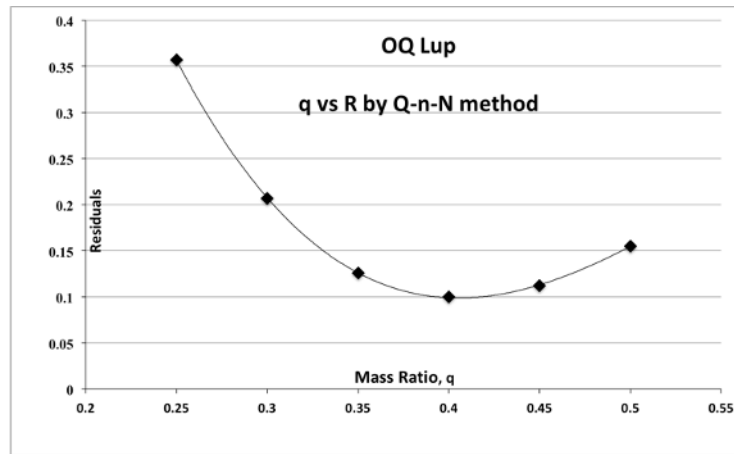


Figure 3. Plot of mass ratio, q , vs least squares residuals, R , showing q of 0.4 at minimum R of 0.100 – fitted with 3rd order polynomial.

Using our new preferred value of q and making some minor adjustments to the other parameters, such as $T2$ (and thus limb darkening, X) and inclination i , we arrive at the final model. The fit to the observed light curve is shown in Figure 4 below.

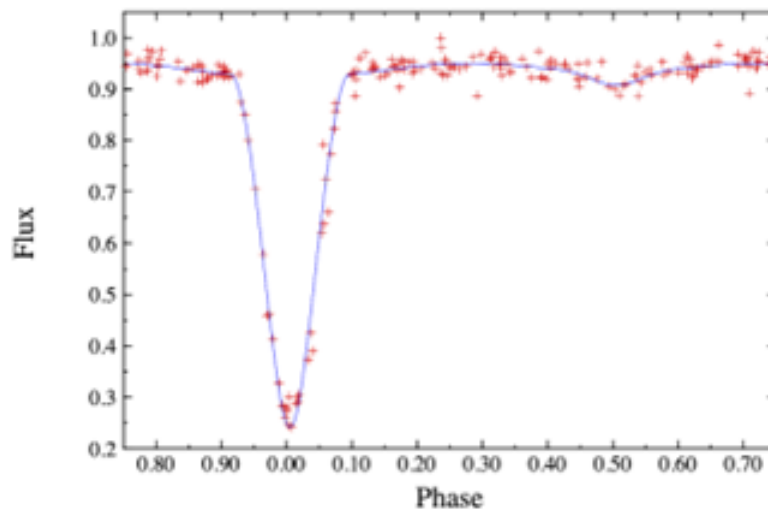


Figure 4. The red crosses represent the ASAS-SN data and the blue line is the fitted model. The linear vertical scale is flux - scaled to 0.95 at 0.75 phase. The primary eclipse is seen to be partial. The secondary eclipse occurs at 0.5 phase – thus no significant eccentricity. Note the model curve is not flat out of eclipse - due to the non-spherical secondary.

Conclusion

The final suggested model gives us a semi-detached binary star system with the larger, cooler secondary star filling its inner Lagrangian surface – ie an Algol-like binary, with a mass ratio, $m_2/m_1 = 0.4$. The inclination i , of the system is 81° . The model fit (Figure 4) to the observed V band data produced a sum-of-squares residual of 0.100.

System Parameters are as follows:

	Star 1	Star 2
T eff (K)	5500	3125
Gravity coeff: G	.32	.32
Limb darkening: X	.68	.91
Reflection: R	0.5	0.5
Radii: r(back)	0.250	0.327
r(side)	0.247	0.294
r(pole)	0.245	0.282
rpoint)	0.250	0.407
Mean radius:	0.247	0.301
Surface area:	0.772	1.161
Volume:	0.063	0.115
Rel. Luminosity:	0.961	0.038

(The length unit for radii, surface area and volume parameters is orbital major axis = 1).

The ASAS-SN light curve (Figure 2) shows the mean uneclipsed V magnitude of the system is approximately $m = 12.62$ (This is also the value quoted in VSX from IBVS 5586). From the modelling herein, star 1 contributes 0.96 of the luminosity (L) of the entire system, so (using the luminosity/magnitude relationship, $m = -2.5\log L$) we derive a V magnitude for star 1 as $m_1 = 12.66$. The absolute V magnitude (M_v) of a main sequence star intermediate in G0-G2 spectral class is +4.55 (Cox, 2000, Table 15.7), so the distance modulus, $m_1 - M_v = 8.11$. Then, following from the relationship modulus = $5\log d - 5$, this equates to a distance of 418 pc. However, this does not account for reddening due to interstellar extinction, which may be substantial in the direction of Lupus.

The 3D representation of the system is shown in Figure 5 and the diagrammatic outlines of the Lagrangian surfaces in Figure 6.

OQ Lup - 3D model

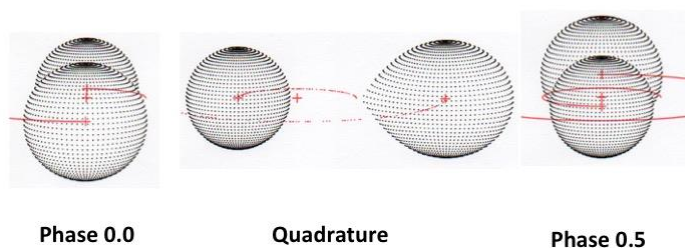
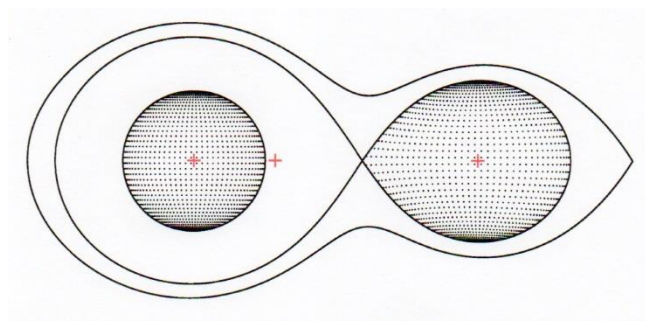


Figure 5. 3D representation of the system - note the secondary is not spherical. The red arcs represent the orbital traces of the stars and the red crosses the centre of mass for the individual stars and the whole system.

Figure 6. Diagrammatic representation of the binary system, showing the inner and outer Lagrangian surfaces, with the red crosses depicting the centre of mass of the individual stars and the whole system. Note the secondary completely fills its inner Lagrangian surface.



Postscript

Mati Morel has pointed out that there is a close 'companion' to OQ Lup, some 3.1" away. This star is very red (2MASS J-K= 1.84), but at approximate V mag 14.4 would be close to the limit of the ASAS system detection. It is not anticipated that this would make a significant difference to the model advanced here, so no attempt has been made to model this by means of "Third Light" in BM3.

Acknowledgements

My thanks to Rob McNaught for inspiration and encouragement in the field of variable star observing. My appreciation to Mati Morel for providing historical information and other details. Tom Richards and Jeff Byron provided useful comments which improved the manuscript.

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RCB Variables in the Large Magellanic Cloud – *Mati Morel*

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Summary

I present a summary of recent efforts at charting LMC stars of the RCB class.

Introduction

Variables of the RCB type have been known in the Large Magellanic Cloud (LMC) for many decades, for at least the brighter members of the class. Recent deep surveys of the LMC by surveys such as **MACHO** and **OGLE** have added more members, bringing the total to 13 (Alcock 2001). To this number can be added four stars which closely resemble galactic DY Per variables. The latter class are of large amplitude ($>2\text{mag}$) but are cooler and their decline is slower. Alcock's list was republished by Skiff (2003) with improved coordinates. I copy the list here as Table 1, with the stars rearranged in order of Right Ascension.

Table 1. RCB stars in LMC, including DY Per stars.

GCVS Name	RA (J2000)	Dec	s	V	Remarks	Chart
<u>RCB Stars</u>						
LMC V0635	05 01 00.36	-69 03 43.1	U	15	HV 12524	VSS 1
LMC V1394	05 11 31.37	-67 55 50.6	M	15	HV 5637	VSS 2
LMC V1667	05 14 46.20	-67 55 47.4	M	15	HV 2379	VSS 3
	05 15 51.79	-69 10 08.6	M	15	MACHO 79. 5743. 15	
MSX LMC439	05 20 48.21	-70 12 12.5	M	15	MACHO 6. 6575. 13	
LMC V2242	05 21 47.98	-70 09 56.9	M	15	HV 942	VSS 4
LMC V2314	05 22 57.37	-68 58 18.9	M	16		VSS 5
LMC V2643	05 26 24.52	-71 11 11.8	U	14	W Men	VSS 6, 7
LMC V2629	05 26 33.91	-69 07 33.4	M	16		VSS 8
	05 32 13.36	-69 55 57.8	M	16	[KDM2001] 4676	
LMC V3334	05 33 48.94	-70 13 23.4	M	16	HV 2671	VSS 9
LMC V4263	05 45 02.88	-64 24 22.7	U	14	HV 12842	VSS 10
	05 46 47.74	-70 38 13.5	M	15	[KDM2001] 6148	
<u>DY Per Stars</u>						
	05 03 44.65	-69 38 11.7	M	17	MACHO 10. 3800. 35	
	05 16 51.96	-68 45 16.8	M	16	MACHO 2. 5871. 1759	
	05 19 55.93	-69 48 05.9	M	16	MACHO 78. 6460. 7	
LMC V4358	05 46 13.27	-71 07 40.4	M	16	[KDM2001] 6099	

Notes. Sources (col. s): M = 2MASS; U = UCAC1. V refers to maximum brightness.

General

Table 1 originated from Alcock (2001), with revised positions from Skiff (2003). The positions can no doubt be improved further from Gaia DR3.

I have plotted a set of ten charts, for selected variables, numbered VSS 1 to 10. The field size is small, usually 4 arcmin, to allow plotting to faint limits. Reference is made to existing AAVSO sequences, but these may only be useful when the variable is at maximum. Several stars have no sequence (too faint) and I have selected Gaia EDR3 G-mags for guidance. These should be within 0.1mag of V. Comparison magnitudes have been carried over from existing AAVSO charts where possible. VSS charts are available upon request from the writer, by email. Any chart(s) from Table 1, with a VSS number can be requested.

Additional Notes

I noted the following issues while preparing the deep charts.

LMC V0635. Comp. star 000-BMY-144 “159” $V = 15.861$ $B-V = 1.124$
(J2000) 05 01 11.40 -69 03 11.6

This star seemed a little discordant. Close study revealed it to consist of three stars, within 2.5 arcsec. The Gaia G-mags are 16.6, 17.3 and 17.5. When combined the blended G-mag = 15.87, consistent with V. The VSP position is probably a blend.

LMC V2242. = HV 942. Historical ranges are 15.8 -17.8p OR 14.4 - 16.7p. It has three close companions, from Gaia EDR3.

1. $G = 17.29$ (J2000) 05 21 47.79 -70 09 53.2
2. $G = 18.32$ (J2000) 05 21 48.32 -70 10 00.5
3. $G = 18.90$ (J2000) 05 21 48.61 -70 09 58.3

When first detected this RCB star had a small range. Probably the minimum magnitude was a blend of the companions.

W Men = LMC V2643. Comp. star 000-BJK-978 “170”. This comparison star comes from the p.e. sequence LMC-VI by Martin (1977). His star 7 is given $V = (17.01) \pm 0.15$ $B-V = (0.79) \pm 0.50$. The brackets indicate an unreliable value. More recent values have become available, as:

$V = 16.789$	(err 0.163)	$B-V = -0.727$	(err 0.27)	APASS (29)
$V = 16.74$	(err 0.440)			GSC2.3
$G = 16.459 \pm 0.0028$				Gaia EDR3

Taking these into account I estimate that the true value of ‘170’ is likely to be 16.7 ± 0.1 V.

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Skiff, B., 2003 email post re [vsnet-id 875] LMC RCB stars

Some interesting stars in the field of VV Orionis – *Mark Blackford*

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Introduction

VV Orionis (HD 36695) is a bright ($V = 5.31 - 5.66$) eclipsing binary composed of two early type stars in a circular orbit of period ~ 1.485 d. A number of studies have been published since its discovery in 1903 (Barr, 1905). Ed Budding, Michael Rhodes, Tim Banks, Tom Love and I are currently involved in a new study to try to resolve several outstanding questions about the system. But VV Orionis is not the subject of this article, not directly anyway.

We needed new multi filter light curves to model, so over ten nights between December 25th, 2018, and February 12th, 2019, I recorded images of a 90×60 arcminute field centred on VV Orionis. A total of 5637 images through BV Rc filters were calibrated with bias, dark and flat frames then aperture photometry used to measure instrumental magnitudes of VV Ori and seven other bright stars selected as possible comparison stars. It is these seven stars that I will be discussing here.

Analysis

Obviously, stars need to be non-variable if they are to be useful as comparison or check stars, or at least exhibit only very low amplitude variability. Only one suitably bright comparison star, labelled 53, was shown on the AAVSO Variable Star Plotter (<https://app.aavso.org/vsp/>) chart. The AAVSO's SeqPlot program (<https://www.aavso.org/seqplot>) was used to identify another six potential comparison stars.

Figure 1 show the field imaged, VV Ori and the seven stars in question are labelled. Table 1 lists relevant information about each star.

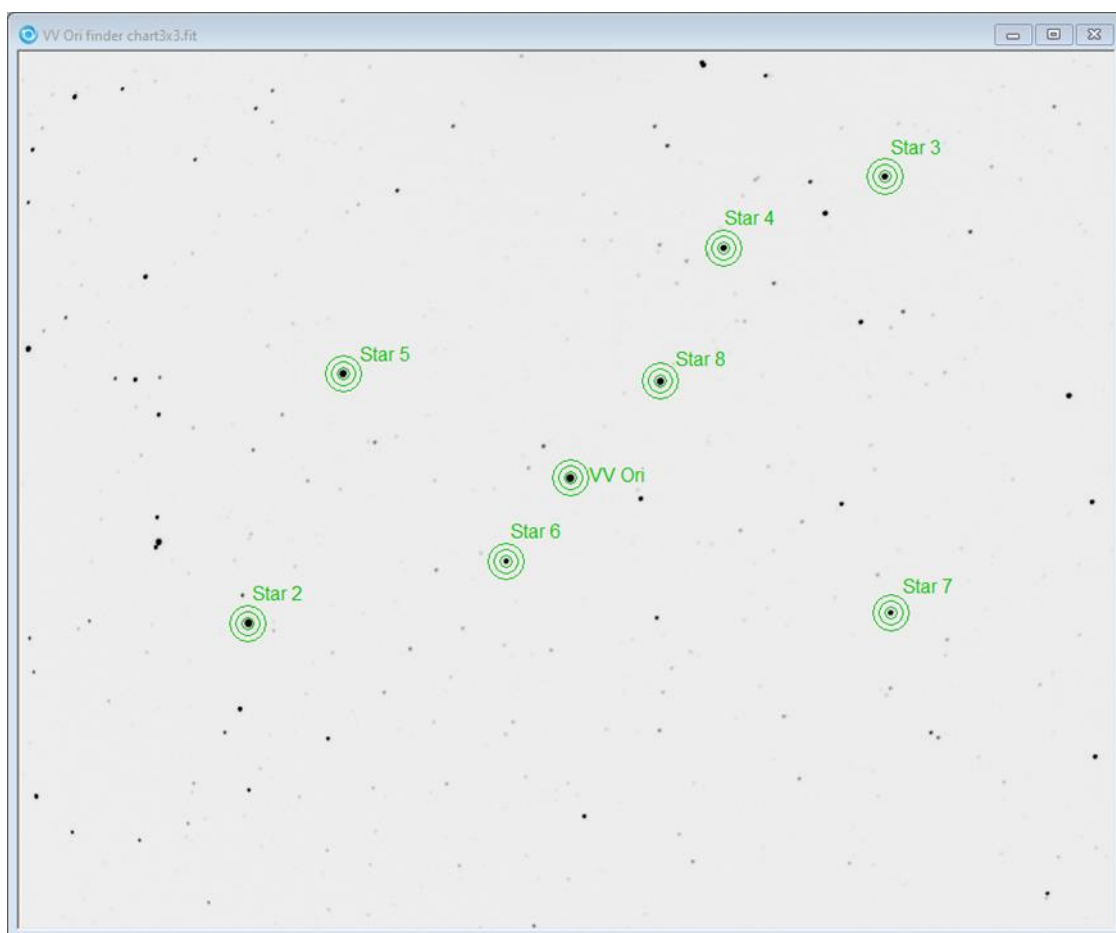


Figure 1. Finder chart for VV Ori and potential comparison and check stars.

Table 1. Catalogue identifications, photometric properties, and spectral types of each star.

	HD	TIC	NSV	V Catalogue	(B - V) Catalogue	(V - R) Catalogue	Spectral Type
VV Ori	36695	50897998		5.369	-0.175	-0.071	B V, B7 V
Star 2	36591	50790250	2107	5.346	-0.188	-0.076	B1 IV
Star 3	36954	427378979		6.975	-0.126	-0.050	B3 V
Star 4	36882	427377510		6.986	1.100	0.659	G5
Star 5	36780	427347488		5.895	1.540	0.844	K5 III
Star 6	36628	50789967		7.952	-0.034	-0.014	B9 V
Star 7	36605	50789528		7.951	0.075	0.033	B9
Star 8	36779	427347825	16351	6.223	-0.165	-0.067	B2.5 V

Stars 2 and 8 are listed in the New catalogue of Suspected Variable stars (NSV) but there doesn't appear to be much information about the range or type of variability. So, I decided to look at light curves recorded by the Transiting Exoplanet Survey Satellite (TESS, see my article in the VSS Newsletter 2021-4). All seven potential comparison stars were checked, and some surprises were found.

TESS observed the VV Ori field in Sector 6 between December 15th 2018 and January 6th 2019 and again in Sector 32 between November 20th 2020 and December 16th 2020. Sector 6 data were recorded at either 2-minute or 30-minute cadence, and Sector 32 either 2-minute or 10-minute cadence. Data from the Sector with the highest cadence are plotted in the figures below.

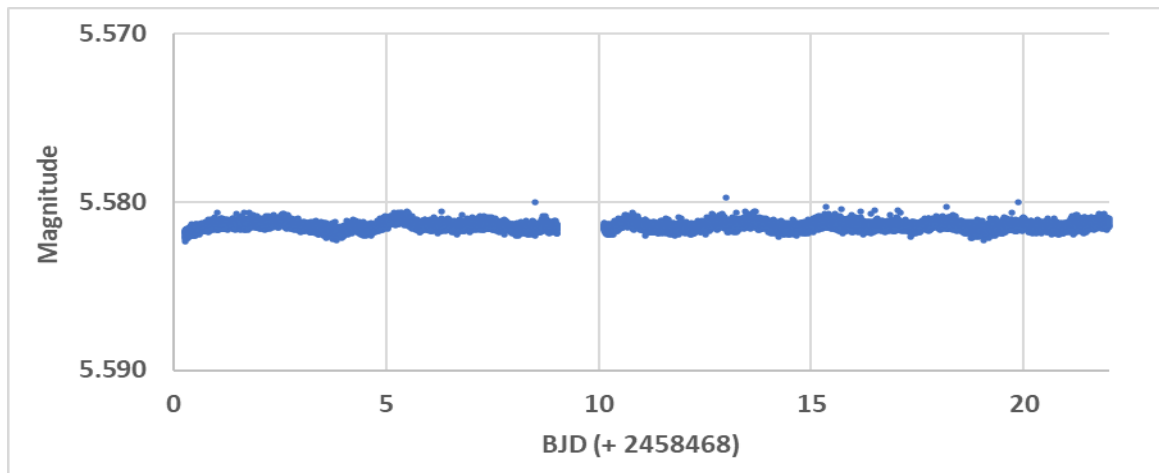


Figure 2. Star 2 (HD 36591, NSV 2107) shows variability on the 1-2 mmag level, however it may be suitable as a comparison star for ground-based photometry where mmag precision is rarely achieved.

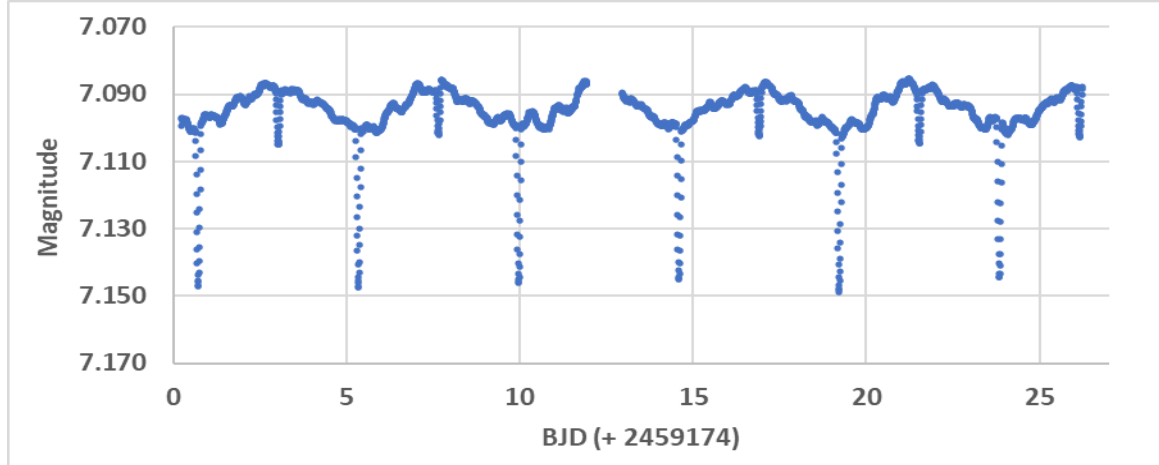


Figure 3. Star 3 (HD 36954) is not suitable as a comparison star. It is an eclipsing binary of period ~ 4.623 d, with additional variation due to pulsations. This appears to be a new discovery.

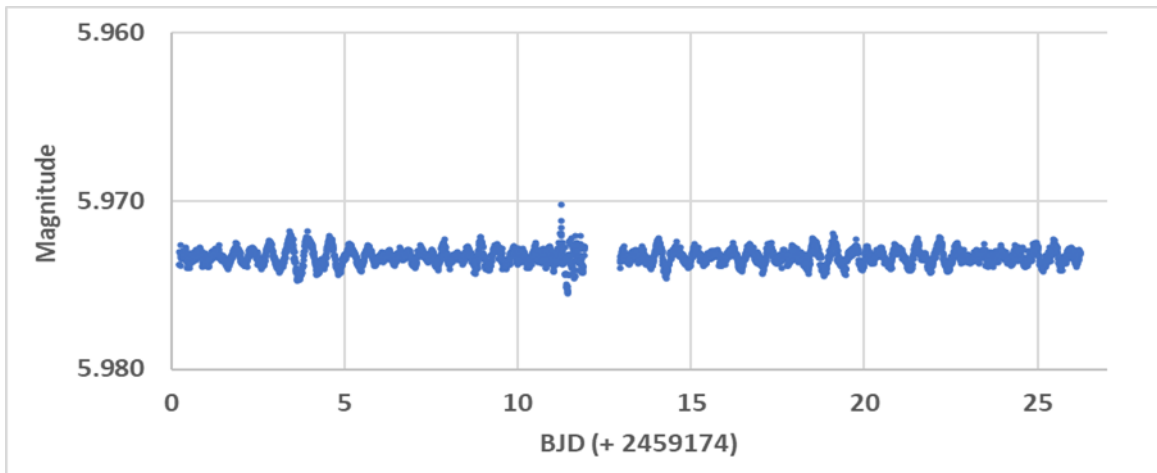


Figure 4. Star 4 (HD 36882) shows variability on the 3 mmag level due to pulsations and should not be used as a comparison star

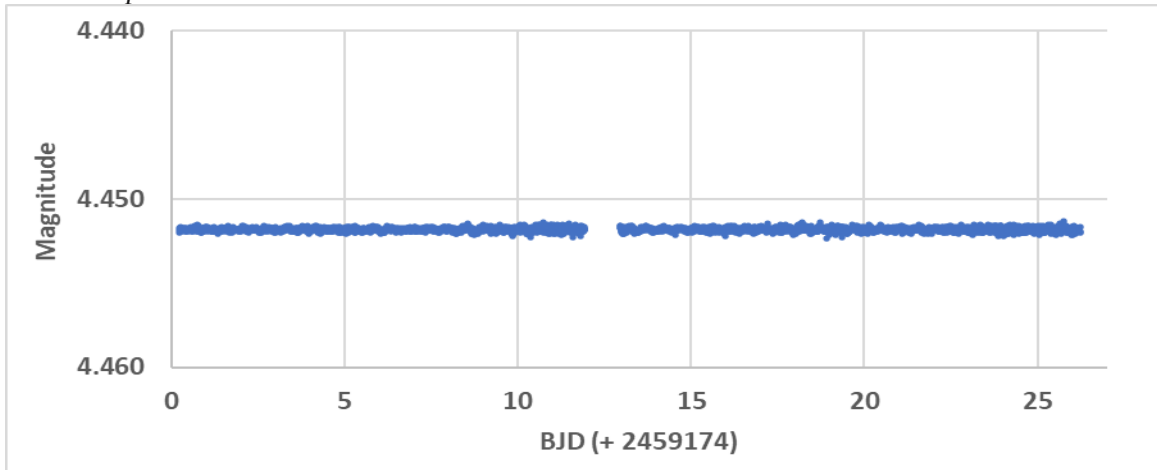


Figure 5. Star 5 (HD 36780) shows pulsations of amplitude less than 1 mmag and is potentially a suitable comparison star.

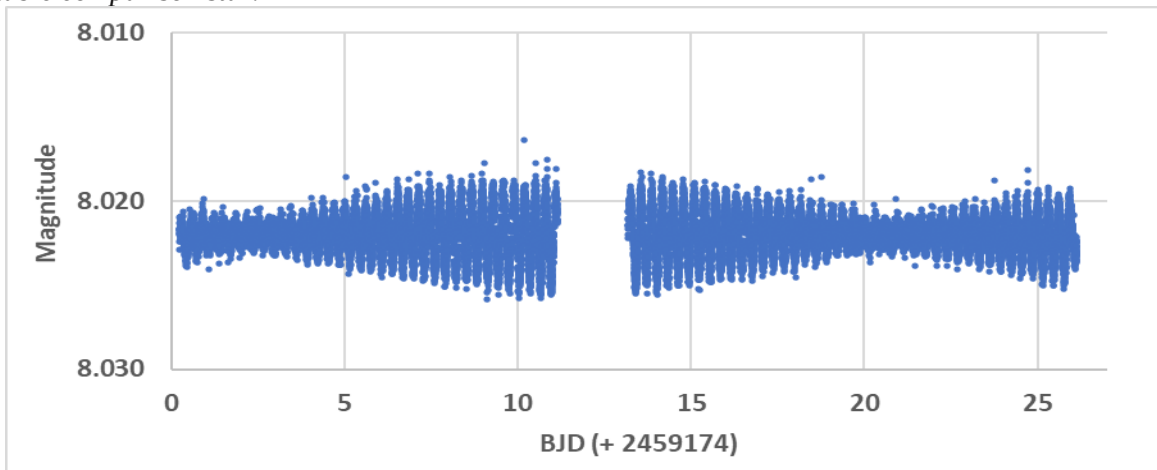


Figure 6. Star 6 (HD 36628) is not suitable as a comparison star due to its pulsations which can reach amplitudes of ~8 mmag.

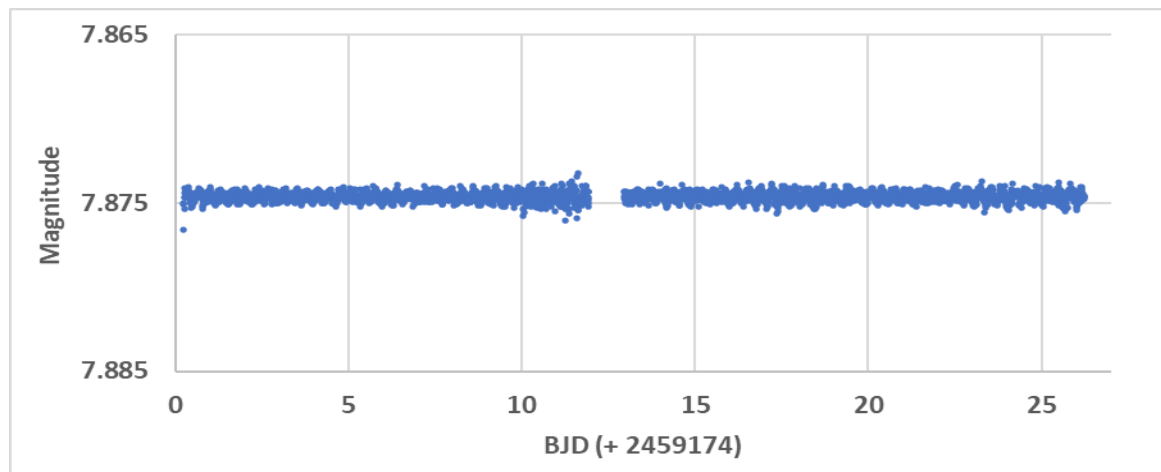


Figure 7. Star 7 (HD 36605) shows pulsations of about 1-2 mmag but may be suitable as a comparison star.

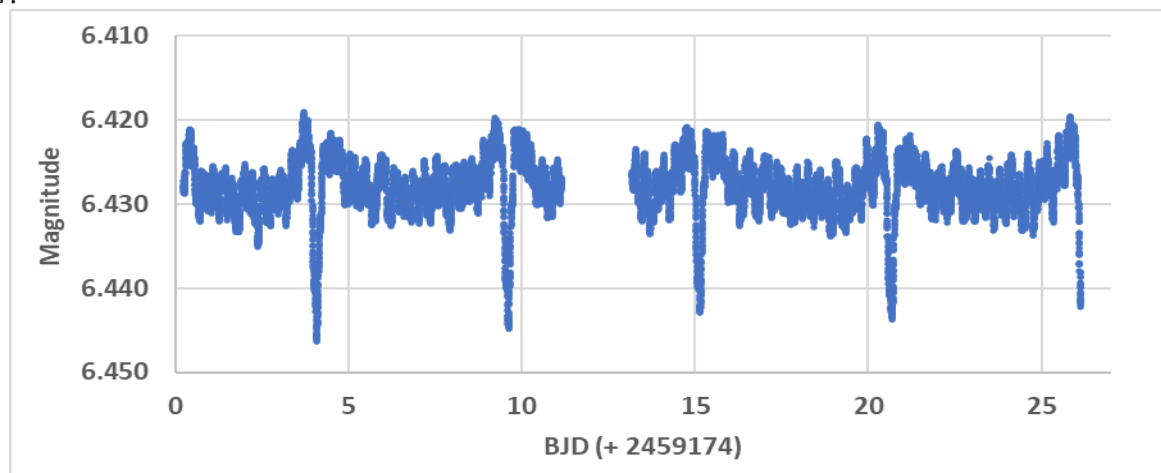


Figure 8. Star 8 (HD 36779, NSV 16351) should not be used as a comparison star. It is an eclipsing binary with additional variation due to pulsations. The EB period is ~ 5.32 d if secondary eclipses are not visible, or ~ 10.64 d if primary and secondary eclipses are of equal depth.

Discussion

Of the seven stars considered as possible comparison stars for VV Ori only star 2 (HD 36591), star 5 (HD 36780) and star 7 (HD 36605) appear to be suitable as their pulsation amplitudes are very small. Star 5, however, is considerably redder than VV Ori thus atmospheric extinction would need to be corrected.

Stars 2 (HD 36591), 4 (HD 36882), 5 (HD 36780), 6 (HD 36628) and 7 (HD 36605) are pulsating variables. Period analysis of the TESS light curves would be an interesting project.

Stars 3 (HD 36954) and 8 (HD 36779) are eclipsing binaries with additional pulsational variability. Both would benefit from detailed light curve modelling and pulsation analysis of TESS data. Spectroscopic analysis would be extremely useful to determine radial velocity curves and spectral types of the component stars. More eclipse times of minimum would help refine the orbital periods; however, they would be difficult targets for amateur photometrists due to the relatively long periods and shallow eclipses. Unfortunately, TESS is not currently scheduled to observe this region of the sky again.

Duerbeck (1975) used star 8 (HD 36779) as primary comparison, star 2 (HD 36591) as one check star and HD 36646 as a second check star in a photoelectric photometry study of VV Ori. Chambliss and Leung (1982) used the same stars but star 2 was the primary comparison in their analysis. Terrell, Munari and Siviero (2007) used star 8 as the comparison star in their CCD photometry of VV Ori, but do not mention which check stars were used. The use of star 8 as primary comparison is not necessarily a problem, so long as observations were not made around the time of its eclipses. Chambliss and Leung (1982) noted that no variation in brightness was observed between any of their three reference stars.

Conclusions

All seven stars investigated show pulsations, with two of them also being eclipsing binaries. Star 2 (HD 36591) would be the preferred comparison star as it is similar in brightness and colour to VV Orionis, and star 7 (HD 36605) the preferred check star.

If available, it is recommended that TESS light curves of all comparison and check stars used in your variable star photometry be examined to assess their suitability.

Acknowledgements

This research made use of the AAVSO VSX database and the SIMBAD and VIZIER databases, operated at CDS, Strasbourg, France and of NASA Astrophysics Data System Bibliographic Services. This paper includes data collected by the TESS mission, which are publicly available from the Mikulski Archive for Space Telescopes (MAST). This research made use of AAVSO's VStar software.

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Chambliss, C.R. and Leung, K-C., 1982 The Astrophysical Journal Supplement Series, 49:531-544
Duerbeck, H.W., 1975, Astron. Astrophys., Suppl. Ser., 22, 19
Terrell, D., Munari, U., & Siviero, A., 2007, MNRAS, 374, 530

Determining radial velocities of the eclipsing binary components in BF Velorum: update – *David Moriarty*

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Since writing the article on BF Velorum for the previous newsletter, I realised I had used the wavelength values for the V band in the modelling with Binary Maker 3. In fact I should have used values for 7865 Å, the centre of the infrared band of the TESS light curve that I modelled. The revised model of the light curve is shown in Fig.1. A hot spot with a temperature factor of 1.1 at the centre of the equatorial region on the secondary star facing the primary component gave a good fit to the TESS light curve (Fig.1). As can be seen in the spectra shown in the previous Newsletter, especially at phase 0, intense chromospheric activity on the secondary component is evident.

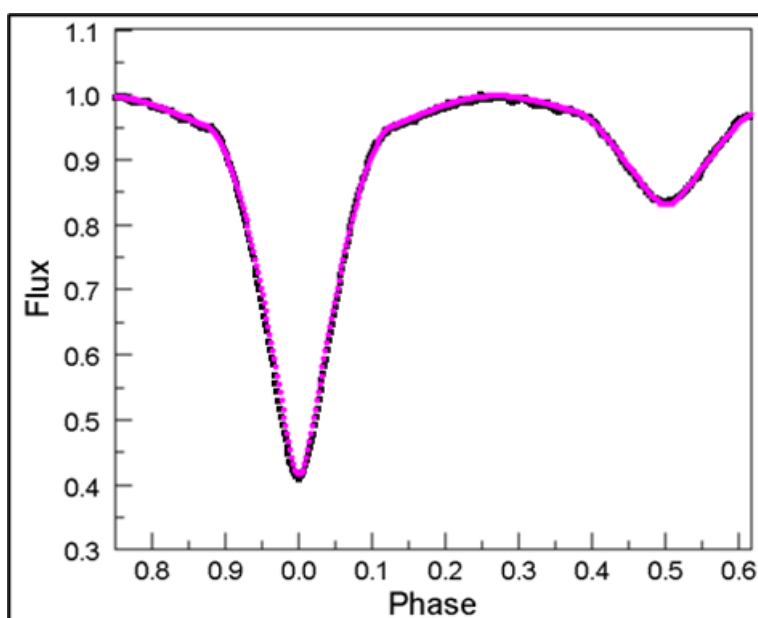


Figure 1. The Binary Maker 3 model (magenta line) of the TESS light curves (black circles) of BF Vel.

The binary model drawn to scale with the Sun is shown in Fig. 2. As can be seen, the binary components are separated by only one solar radius. In contrast to the previous model, the best fit was given by setting the fillout factor for the secondary star to zero, and thus filling its inner critical equipotential or ‘Roche’ lobe, as suggested by Manimanis et al. (2009).

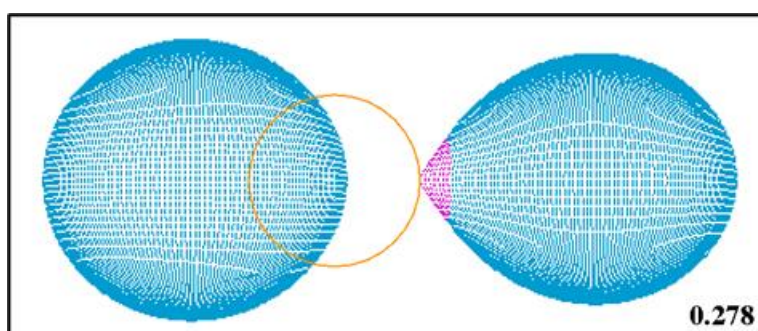


Figure 2. Model of BF Vel drawn to scale with the Sun (orange outline).

The principal modelling parameters and resulting absolute parameters derived with Binary Maker 3 are shown in Table 1.

TABLE 1. Modelled data and absolute parameters for the BF Vel system.

System		
Mass ratio	0.55	
Inclination	89°	
Third light	28%	
Velocity	4 km s ⁻¹	
Period (d)	0.7040281	
Semi-major axis (R _☉)	4.7	
Component parameters		
	Primary	Secondary
T _{eff} (K)	8250	4880
Velocity (km s ⁻¹)	120	217
Mass (M _☉)	1.8	1.0

References

Manimanis V.N., Vamvatira-Nakou C. and Niarchos P.G. Ap&SS 2009, 323, 115.

Publication watch

Mark Blackford and Ed Budding co-authored a recent paper on V410 Puppis.

Erdem, Ahmet ; Sürgit, Derya ; Özkardeş, Burcu ; Hadrava, Petr ; Rhodes, Michael D. ; Love, Tom ; Blackford, Mark G. ; Banks, Timothy S. ; Budding, Edwin, *V410 Puppis: A useful laboratory for early stellar evolution*, Monthly Notices of the Royal Astronomical Society, Volume 515, Issue 4, pp.6151-6163, arXiv:2207.13768

Abstract

New spectrometric (HERCULES) and ground-based multicolour photometric data on the multiple star V410 Puppis are combined with satellite photometry (HIPPARCOS and TESS), as well as historic astrometric observations. Absolute parameters for V410 Pup Aab are derived: $MAa = 3.15 \pm 0.10$, $MAB = 1.83 \pm 0.08 (M_{\odot})$; $RAa = 2.12 \pm 0.10$, $RAB = 1.52 \pm 0.08 (R_{\odot})$; $a = 6.57 \pm 0.04 R_{\odot}$; $TAa = 12500 \pm 1000$, $TAb = 9070 \pm 800 (K)$, and photometric distance $350 \pm 10 (pc)$. We report the discovery of a low-amplitude SPB variation in the light curve and also indications of an accretion structure around V410 Pup B as well as emission cores in V410 Pup C. We argue that V410 Pup is probably a young formation connected with the Vela 2 OB Association. The combined evidence allows an age in the range 7-25 Myr from comparisons with standard stellar evolution modelling.

Stan Walker, Mark Blackford, and Dave Blane, co-authored *two recent papers on QZ Carinae*.

Harmanec, P. ; Zasche, P. ; Brož, M. ; Catalan-Hurtado, R. ; Barlow, B. N. ; Frondorf, W. ; Wolf, M. ; Drechsel, H. ; Chini, R. ; Nasser, A. ; Pigulski, A. ; Labadie-Bartz, J. ; Christie, G. W. ; Walker, W. S. G. ; Blackford, M. ; Blane, D. ; Henden, A. A. ; Bohlson, T. ; Božić, H. ; Jonák, J., *Towards a consistent model of the hot quadruple system HD 93206 = QZ Carinae - I. Observations and their initial analyses*, Astronomy and Astrophysics, 666, A23 (2022), <https://doi.org/10.1051/0004-6361/202142108>

Abstract

The hot nine-component system HD 93206, which contains a gravitationally bounded eclipsing Ac1+Ac2 binary ($P = 5.9987$ d) and a spectroscopic Aa1+Aa2 ($P = 20.734$ d) binary can provide important insights into the origin and evolution of massive stars. Using archival and new spectra, and a rich collection of ground-based and space photometric observations, we carried out a detailed study of this object. We provide a much improved description of both short orbits and a good estimate of the mutual period of both binaries of about 14 500 d (i.e. 40 years). For the first time, we detected weak lines of the fainter component of the 6.0 d eclipsing binary in the optical region of the spectrum, measured their radial velocities, and derived a mass ratio of $M_{Ac2}=M_{Ac1} = 1:29$, which is the opposite of what was estimated from the International Ultraviolet explorer (IUE) spectra. We confirm that the eclipsing subsystem Ac is semidetached and is therefore in a phase of large-scale mass transfer between its components. The Roche-lobe filling and spectroscopically brighter component Ac1 is the less massive of the two and is eclipsed in the secondary minimum. We show that the bulk of the H α emission, so far believed to be associated with the eclipsing system, moves with the primary O9.7 I component Aa1 of the 20.73 d spectroscopic binary. However, the weak emission in the higher Balmer lines seems to be associated with the accretion disc around component Ac2. We demonstrate that accurate masses and other basic physical properties including the distance of this unique system can be obtained but require a more sophisticated modelling. A first step in this direction is presented in the accompanying Paper II (Brož et al.).

Brož, M. ; Harmanec, P. ; Zasche, P. ; Catalan-Hurtado, R. ; Barlow, B. N. ; Frondorf, W. ; Wolf, M. ; Drechsel, H. ; Chini, R. ; Nasser, A. ; Labadie-Bartz, J. ; Christie, G. W. ; Walker, W. S. G. ; Blackford, M. ; Blane, D. ; Henden, A. A. ; Bohlson, T. ; Božić, H. ; Jonák, J., *Towards a consistent model of the hot quadruple system HD 93206 = QZ Carinae: II. N-body model*, *Astronomy and Astrophysics*, 666, A24 (2022), <https://doi.org/10.1051/0004-6361/202243596>

Abstract

Aims. HD93206 is a massive early-type stellar system composed of components resolved by direct imaging (Ab, Ad, B, C, D) and a compact subsystem (Aa1, Aa2, Ac1, Ac2). Its geometry was already determined on the basis of extensive photometric, spectroscopic, and interferometric observations. However, the fundamental absolute parameters are still not known precisely enough.

Methods. We use an advanced N-body model to account for all mutual gravitational perturbations among the four close components, and all observational data types, including astrometry, radial velocities, eclipse timing variations, squared visibilities, closure phases, triple products, normalized spectra, and spectral energy distribution (SED). The model has 38 free parameters, grouped into three sets of orbital elements, component masses, and their basic radiative properties (T , $\log g$, v_{rot}).

Results. We revised the fundamental parameters of QZ Car as follows. For a model with the nominal extinction coefficient $RV \equiv AV = E(B - V) = 3.1$, the best-fit masses are $m_1 = 26.1 M_{\odot}$, $m_2 = 32.3 M_{\odot}$, $m_3 = 70.3 M_{\odot}$, and $m_4 = 8.8 M_{\odot}$, with uncertainties of the order of $2 M_{\odot}$, and the system distance $d = (2800 \pm 100)$ pc. In an alternative model, where we increased the weights of the radial velocity (RV) and transit timing variation (VTT) observations and relaxed the SED constraints, because extinction can be anomalous with $RV \sim 3.4$, the distance is smaller: $d = (2450 \pm 100)$ pc. This corresponds to the distance of the Collinder 228 cluster. Independently, this is confirmed by dereddening the SED, which is only then consistent with the early-type classification (O9.7Ib for Aa1, O8III for Ac1). Future modelling should also account for an accretion disk around the Ac2 component.

Phil Evans was co-author of the following paper.

Psaridi, Angelica ; Bouchy, François ; Lendl, Monika ; et al., *Three new brown dwarfs and a massive hot Jupiter revealed by TESS around early-type stars*, *Astronomy & Astrophysics*, Volume 664, A94, 21 pp., <https://doi.org/10.1051/0004-6361/202243454>

Abstract

Context. The detection and characterization of exoplanets and brown dwarfs around massive AF-type stars is essential to investigate and constrain the impact of stellar mass on planet properties. However, such targets are still poorly explored in radial velocity (RV) surveys because they only feature a small number of stellar lines and those are usually broadened and blended by stellar rotation as well as stellar jitter. As a result, the available information about the formation and evolution of planets and brown dwarfs around hot stars is limited.

Aims. We aim to increase the sample and precisely measure the masses and eccentricities of giant planets and brown dwarfs transiting early-type stars detected by the Transiting Exoplanet Survey Satellite (TESS).

Methods. We followed bright ($V < 12$ mag) stars with $T_{\text{eff}} > 6200$ K that host giant companions ($R > 7 R_{\oplus}$) using ground-based photometric observations as well as high precision radial velocity measurements from the CORALIE, CHIRON, TRES, FEROS, and MINERVA-Australis spectrographs.

Results. In the context of the search for exoplanets and brown dwarfs around early-type stars, we present the discovery of three brown dwarf companions, TOI-629b, TOI-1982b, and TOI-2543b, and one massive planet, TOI-1107b. From the joint analysis of TESS and ground-based photometry in combination with high precision radial velocity measurements, we find the brown dwarfs have masses

between 66 and 68 M_{Jup} , periods between 7.54 and 17.17 days, and radii between 0.95 and 1.11 R_{Jup} . The hot Jupiter TOI-1107b has an orbital period of 4.08 days, a radius of 1.30 R_{Jup} , and a mass of 3.35 M_{Jup} . As a by-product of this program, we identified four low-mass eclipsing components (TOI-288b, TOI-446b, TOI-478b, and TOI-764b).

Conclusions. Both TOI-1107b and TOI-1982b present an anomalously inflated radius with respect to the age of these systems. TOI-629 is among the hottest stars with a known transiting brown dwarf. TOI-629b and TOI-1982b are among the most eccentric brown dwarfs. The massive planet and the three brown dwarfs add to the growing population of well-characterized giant planets and brown dwarfs transiting AF-type stars and they reduce the apparent paucity.

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.VariableStarsSouth.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.

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