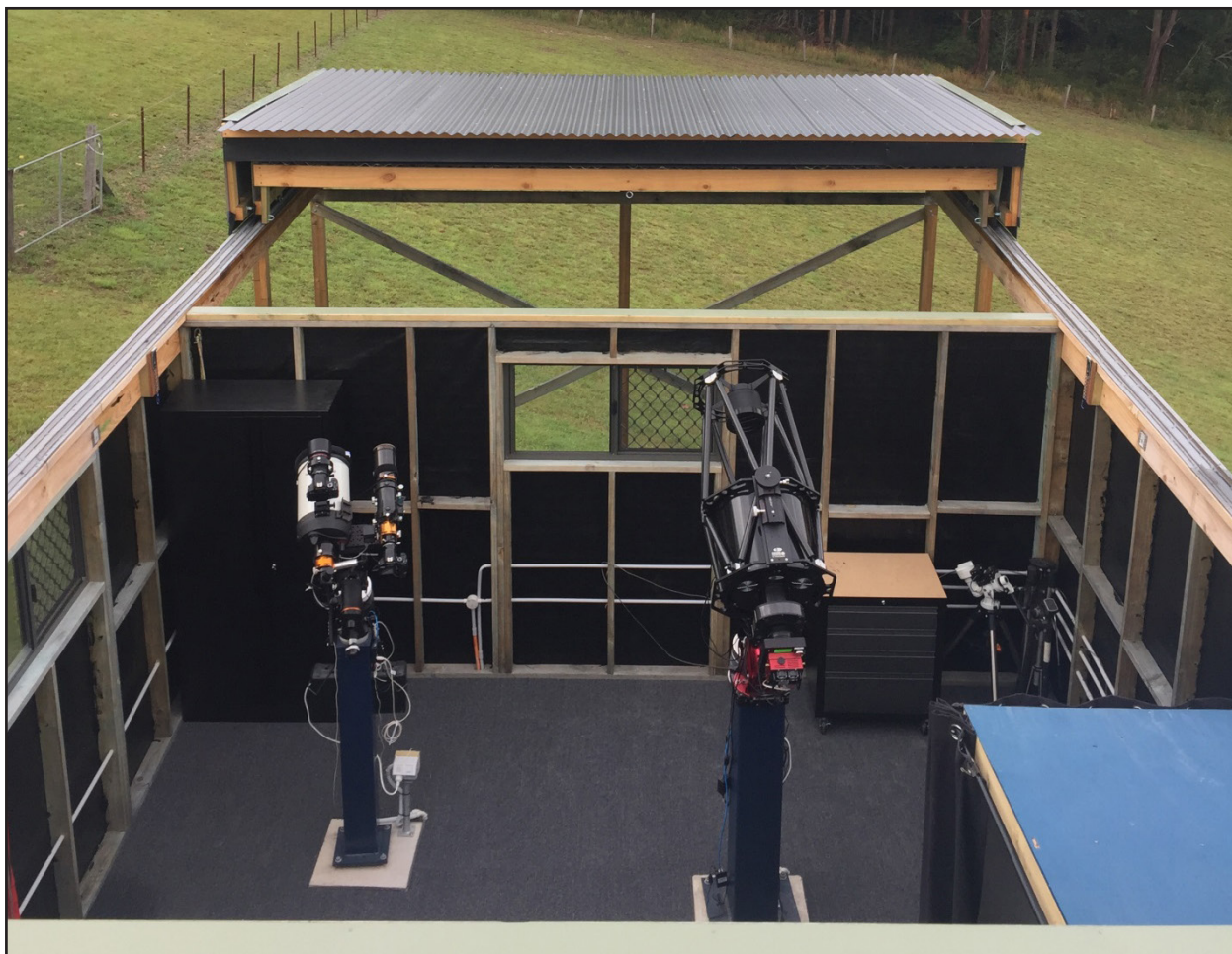




One of the joys of moving to a dark sky country site is that you get to build a new observatory, and our director Mark has been very busy building his (with a little help from friends). Read part 3 of Mark's building saga on page 9.

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Greetings from Congarinni (NSW Mid-North Coast) where it's been a very dry and unusually warm winter. In the 3 months to the end of September the rain gauge registered less than 10mm in total. In this time I've managed 28 nights of observing which must be some sort of record for me. However calibration and measurement of the images has not kept pace so I have a large backlog to work through. It might be sacrilegious to astronomers to say this, but a week or two of rain would help with that, and provide some sorely needed moisture for my property and surrounding farms.



Welcome to the final Newsletter edition for 2017. I trust you'll find much of interest in these pages. Stan may have retired as VSS Director but he is still driving many of our active projects. In this edition he brings us up to date with the QZ Carinae and Z Sagittarii projects. Mati Morel and Carl Knight also contributed articles and I conclude my series outlining the construction and commissioning of my new observatory, a long and sometimes frustrating process.

Stan has been promoting VSS to the various Astronomy clubs in New Zealand in the hope of attracting new variable star observers. I intend following up with a similar campaign in Australia.

The 2018 RASNZ Conference will be held in Christchurch from Friday May 4th to Sunday May 6th next year. Plans are in place to hold the 5th Variable Stars South Symposium following immediately after the conference on the Sunday evening and Monday. Christchurch is easily accessible so we hope to attract a large contingent of our New Zealand and Australian members, as well as from further afield.

Details of the symposium will be in the January 2018 Newsletter. In the meantime please mark those dates in your calendar and seriously consider presenting your work in a talk or poster.

Another significant event next year is the joint BAA-AAVSO meeting in Warwick, UK in July (<https://www.britastro.org/node/10727>) which I will be attending on behalf of VSS. This will be an excellent opportunity to strengthen ties with two of the northern hemisphere's pre-eminent variable star organisation. It would be great to catch up with other VSS members there as well so start planning now. In the meantime, clear skies and good observing. Cheers,

Addendum

Since writing this column the long dry spell has ended emphatically with overcast rainy days for over a week and 130mm falling in just one morning. This proved a little overwhelming for my observatory weatherproofing so a few modifications have been made. Fortunately the telescopes and other gear remained dry. And still I haven't made much progress with the backlog of unprocessed observations.

I had an interesting call from Stephen Hovell recently which called to mind an interesting observing exercise in 1997. Stephen was comparing his measures with Rod Stubbings and Josch Hamsch (made at his Chilean site) and wondered at the large disparity between the various sets of measures

In this particular case - I don't know the exact date - the time difference between Chile, New Zealand and Eastern Australia is 8 hours and 2 hours respectively so that the 10 hour overall difference might well see an apparent error of a magnitude or so. Not real but when it recurs for several nights in a row one begins to wonder. The quiescent magnitude of dwarf novae tends to fluctuate a bit - they're a complex system with mass transfer, a disc and gas stream and constant flickering on a short time scale. But on any given night an observer expects the measures to be reasonably stable except during outbursts.

But the answer is simple - V803 Cen is a dwarf nova comprising a pair of helium white dwarf stars with a very fast outburst cycle of ~23 hours. This is shown in Figure 1 below, the 20 day graph which covers 15 cycles in a little over 14 days. Measures at one site over three or four consecutive days at a similar time will show little change.

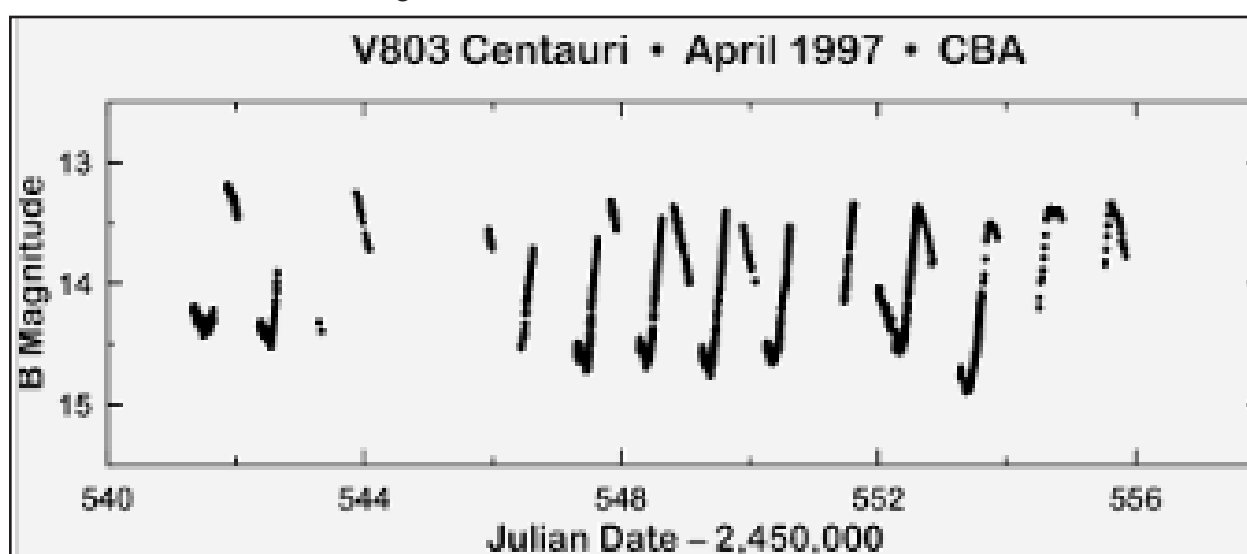
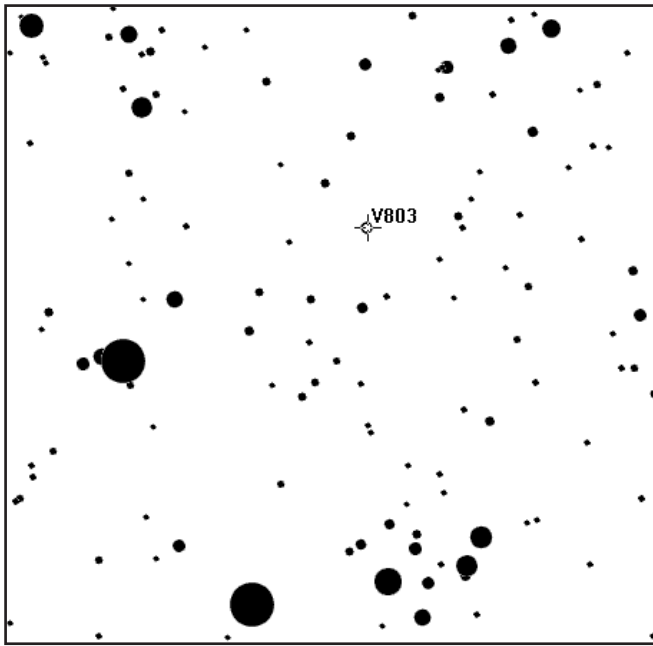


Figure 1. 20 days of observations of V803 showing an approximate 23 day period

The interesting thing is that these observations nearly did not happen. Joseph Patterson who was promoting the Centre for Backyard Astronomy, CBA, at that stage had sent me an SSP6 CCD camera and proposed a brief campaign to observe this star. He observed from South Africa, Jonathan Kemp from Cerro Tololo and I from Waiharara, 45 kilometres south of New Zealand's North Cape. About three days into the campaign I received a note from Joe suggesting that we abandon observations as nothing was happening. This graph illustrates the problem quite clearly.

Take the first cycle. Joe's measures were at minimum and showed a change of about 0.2 to 0.3 magnitudes which he took for the random fluctuations normal to these stars. But I had a nice, steady decline on the same two nights reaching a half-magnitude on the second night. When the differing magnitudes between the two datasets were taken into account it was clear that here we had a star with a period just under a day - but was it a CV or an RR Lyrae star? Shortly Jonathan reached Tololo and began filling the gaps on the rising branches - and such a dramatic object formed the basis of an interesting article in *Sky and Telescope*.

So Stephen's measures were not in error but were of a most unusual and interesting star with an unexpected period. Another interesting aspect is that the mass ratio of the two stars is, from memory, about 50:1 so with such frequent outbursts one wonders how long the system will endure before the tiny mass losing star can no longer keep up its end of the relationship.



A 20 arcminute field of V803 Centauri, 13 23 45, -41 44 23 (2000) from Guide 9. The bright stars at the left are, from the bottom, 7.9, 8.8, 10.7.

V 803 Cen usually cycles between 13.2 and 14.5 but also has superoutbursts at frequent intervals where it reaches magnitude 12.5 and also shows superhumps with a period of ~1618 seconds. Its orbital period is 1612 seconds, or 26.867 minutes

It is a very complex object and seems to break many of the 'rules' for dwarf nova behaviour. An interesting paper is V803 Centauri: a Helium Rich Dwarf Nova, PASP 112: 625-631, May 2000, which provides a more detailed analysis

RY Tuc : A study of the region – *Mati Morel*

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Abstract

A study of the region of RY Tuc in an attempt to identify this star fails to meet current criteria. Old and new observations have been combined but, by modern standards, the identification is mainly circumstantial or suggestive. An actual discovery photograph would be required, to make it final.

Introduction

RY Tuc first appeared as an anonymous object in a list of 25 SMC objects reported by Innes and Wood (1922). 22 of their discoveries were matched with known Harvard variable (HV) stars, so their identities seemed secure. See Figure 1, a facsimile of their table, from UOC55. The discoveries were made by comparing two Cape Observatory plates, by blink microscope. The telescope used was the 24-inch McClean refractor at Cape. Details on the plates are as follows.

- Plate 763 1905 Nov. 24, exp. 2h30m
- Plate 763a 1921 Nov. 26, exp. 3h04m

Curiously, Innes included two nebulous objects: - the first entry, a “red star or neb.,” turns out to be an H II region, later catalogued by Henize (1956) as N52A and N52B. The last entry is NGC 416.

UOC 55

One unidentified variable is located at (1875) 0h56m.9 -73°02'. See Figure 1. It had no HV number and in due course was designated RY Tuc, 13 - (16p. A simple line entry gives no indication of the context. Due to the differing exposures, the magnitude reach of the two plates also differs. In the estimation of Innes, plate 763 reaches 16p, while 763a reaches 17p, in four instances. The extra reach is significant in the SMC. At about 16p the star density in the SMC starts to explode, and the longer exposure can pull in objects which were invisible on a shorter exposure. The high star density in the SMC caused difficulties for determining precise positions, in the early part of the 20th century.

VARIABLE STARS, ETC.									
1875.		1905, Nov. 24.		1921, Nov. 26.		Harvard.		Remarks.	
R.A.	So. Dec.	L.	W.	L.	W.	No.	Range.		
h. m.	° '								
0 50.1	73 21	Red star or neb.	Ft. neb.						
0 51.0	73 22	15	15	13	14	1640	14.3 ... 15.2		
0 52.8	73 22	15	16	13	14	1750	15.1 ... 15.8		
0 53.5	73 20	15	16	13	14	1743	15.0 ... 15.9		
0 54.2	73 34	14	15	12	14	1773	14.5 ... 15.6		
0 54.8	73 32	15	16	13	14	1789	14.2 ... 15.3		
0 54.8	73 12	11	12½	12½	14	1762	14.8 ... 15.8		Is close to an 11th.
0 55.4	73 30	14	16	12	14	1820	14.7 ... 15.6		
0 55.9	73 19	16	15	17	trace	1829	14.0 ... 15.0		
RY Tuc — 0 56.9	73 2	inv.	trace	13 red	14 red	...	...		
0 56.9	73 32	16	15½	inv.	inv.	1842	14.5 ... 15.3		
0 57.7	72 46	12	12	14	13½	~~1887~~	14.8 ... 15.2		HV 1877
0 58.2	73 28	15	16	inv.	inv.	1830	14.6 ... 15.2		
0 59.4	73 27	14	13	15	15	1922	14.9 ... 15.8		Or 1920 same range.
0 59.4	72 32	14	14	16	16	1929	14.0 ... 14.6		
0 59.6	73 26	15	14	17 (?)	trace	1926	15.5 ... 16.1		
0 59.7	73 0	13 grey	15	16	inv.	1972	14.3 ... 15.3		Near a 15th.
1 0.2	73 3	15½	14	17	16	1962	14.0 ... 14.8		Between two of the 16th mag.
1 0.4	73 0	12	12	14	13½	1974	13.8 ... 15.6		
1 1.6	72 31	13	15	16	inv.	2002	15.9 ... 16.8		
1 3.0	72 58	12	13½	16	15½	2056	14.2 ... 15.3		
TV Tuc — 1 3.4	73 6	13	14½	15	16	~~2041~~	14.0 ... 15.0		2' N. of 73° 64.
1 3.5	73 11	13	13	14	14½	2040	13.6 ... 14.6		
1 3.6	72 34	15½	14½	17	trace	2046	14.5 ... 15.3		Remarkable.
1 4.0	73 1	Grey cluster	Ft. globular cluster						

The identifications with Harvard are somewhat uncertain. *IS HV 11205*

Figure 1. A copy of Innes and Woods' table of 25 variable stars, from UOC55.

Accuracy of coordinates

At a casual glance, one might assume that the 1875 positions given by Innes would, though approximate, be reasonably close to the mark. This turns out to be not the case at all. In comparing all of his positions, precessed forward, with the corresponding positions in the GCVS, I find many discordances, many quite troubling. Here are some examples.

- HV 1750 = RR Tuc. Innes RA off by 61s.
- HV 1773 = RT Tuc. Innes RA off by 26s.
- HV 1820 = RW Tuc. Innes RA off by 35s
- HV 1830 = ST Tuc. Innes RA off by 112s !
- HV 1962 = SY Tuc. Innes Dec. off by 13'
- HV 2056 = TU Tuc. Innes RA off by 50s

and so forth.

The poor accuracy renders UOC55 positions very unreliable, inevitably including RY Tuc.

Location of RY Tuc

The best clue to this star is the observation on plate 763a, a "red star 13-14p", but invisible on the other plate, of shorter exposure. Innes' coordinates land close to a field star, $V=15.417$ $B-V=0.127$, APASS data, at (J2000) 01:00:59.383 -72:21:49.16 UCAC4. This is not a red star, nor does it show any variability on available UK Schmidt plates. There is no other obvious red field star, locally. The nearest candidate is a member of the star cluster Kron 42 = OGLE 124, about 1.8' due W (see Figure 2). This cluster was not recognized in Innes' day. Three bright members are in WEBDA, plus UCAC4 PM data (RA, Dec.).

- #1. (J2000) 01:00:35.00 -72:21:59.9 $V=14.23$ $B-V=+1.57$ $B=15.80$ PM +129.3mas/y, -66.7mas/y
- #2. (J2000) 01:00:33.20 -72:22:10.2 $V=13.99$ $B-V=-0.06$ $B=13.93$ PM -2.94mas/y, -3.12mas/y
- #3. (J2000) 01:00:34.26 -72:21:55.6 $V=14.43$ $B-V=-0.14$ $B=14.29$ PM +25mas/y, +68mas/y

The proper motion (PM) of Star 2 is so vanishingly small that even after 100 years movement is barely

detectable, which is to be expected at the distance of the SMC. Star 3 is somewhat greater in PM, but both are blue stars, at a rather similar distance, in the SMC. Otero (priv. comm) noted that Star 1 has a PM which is vastly greater than 2 or 3, and is possibly a foreground red dwarf. The PM mentioned is indeed large relative to other K42 stars, but is really very modest compared with **nearby** galactic stars, whose PM is 10 to 100 times greater. Star 1 can hardly be a nearby red dwarf, though it may well be a more distant galactic red giant, fortuitously aligned with the SMC cluster K42.

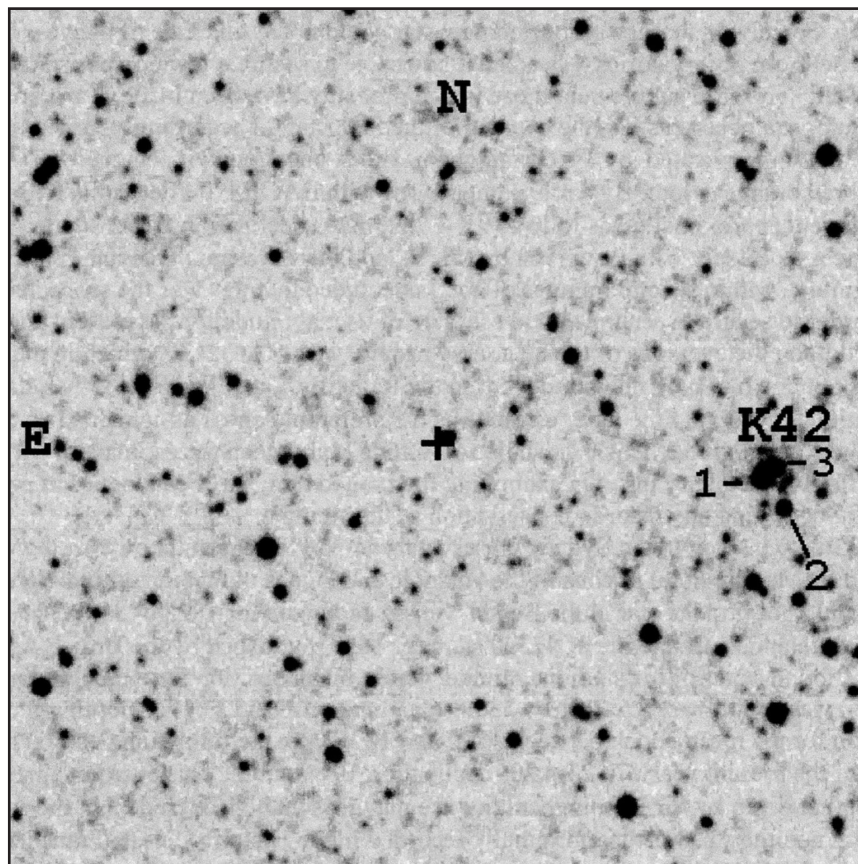


Figure 2. The field of RY Tuc and SMC cluster K42. The nominal position of RY Tuc is shown by a cross. Stars 1, 2 and 3 in cluster K42 are identified. Adaptation of DSS IR image.

The magnitudes reported by Innes and Wood (13-14p) are possibly a blended magnitude.

It is possible that Innes picked up Star 1 on the longer exposure plate as a grey=red image. At 15.8B it would have barely registered on the shorter exposure plate, which is consistent with its lower magnitude limit. We can dismiss the position published by Innes as another instance of a poor position.

Conclusion

After evaluation of historical and contemporary material, Star 1 in SMC cluster K42 is a candidate for RY Tuc, but confirmation via a precise position is lacking. The evidence is circumstantial.

Acknowledgements

This research has made use of the WEBDA database, operated at the Department of Theoretical Physics and Astrophysics of the Masaryk University. I also acknowledge the use of the *AAVSO Photometric All-Sky Survey (APASS)*, funded by the Robert Martin Ayers Sciences Fund.

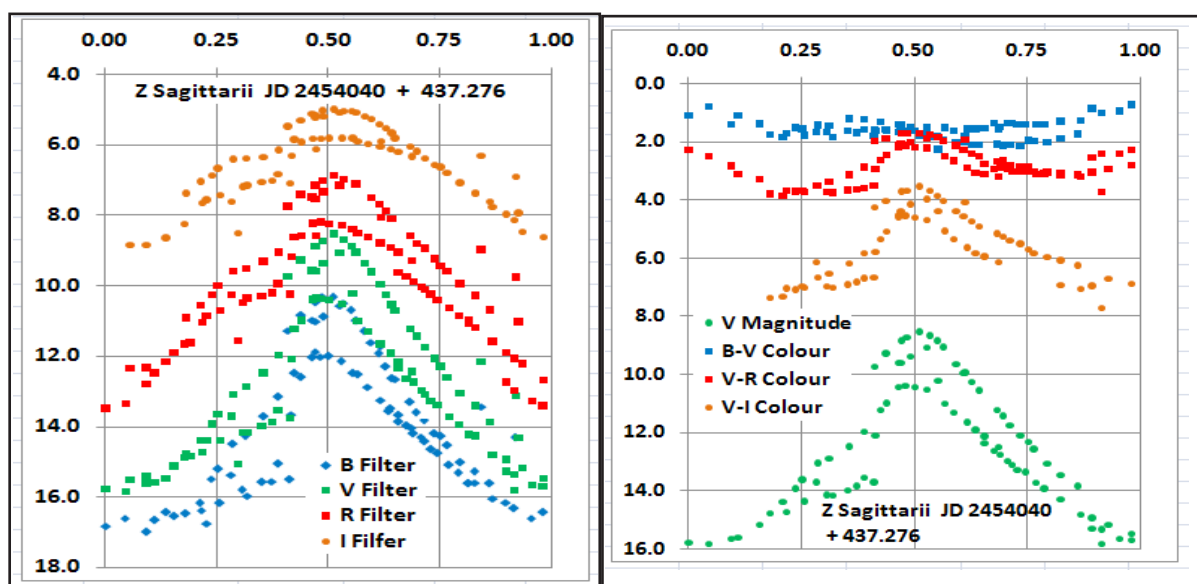
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Introduction

In 2005 Giorgio di Scala observed a number of Mira stars in BVRI for a number of cycles. I have been interested in those showing humps on the light curve as these may well be similar to BH Crucis which evolved from a dual maximum Mira to a Mira with a hump on the rising light curve. Are these other stars similar but perhaps more or less evolved?

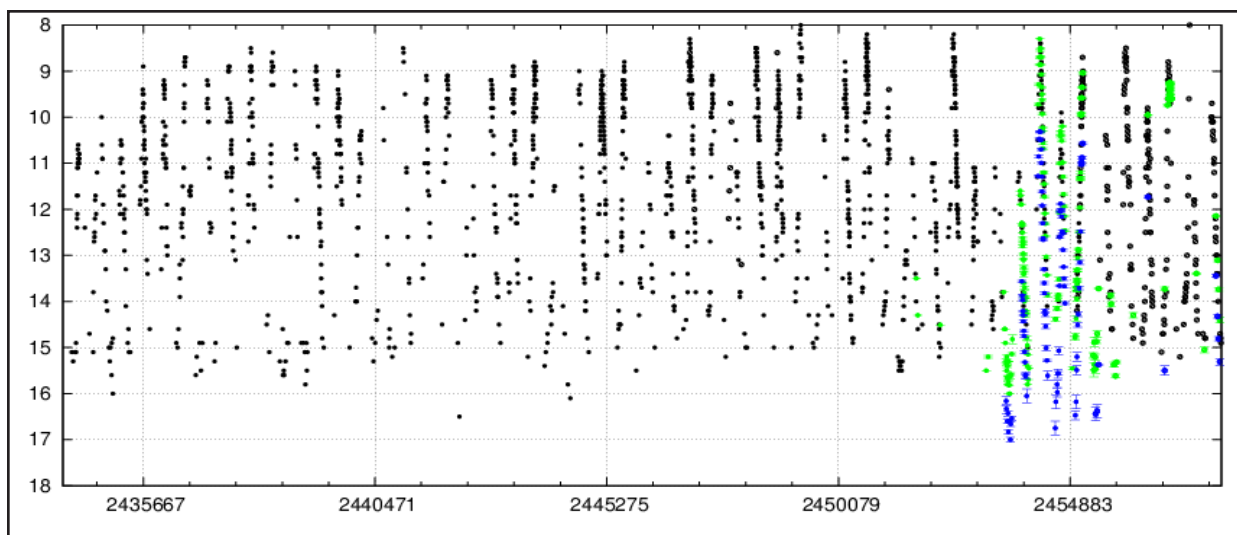
Let's look at the colour curves of Z Sagittarii to begin. At left we see a phased light curve as measured in each filter, at the right is a graph of V, B-V, V-R and V-I. This latter illustration shows two interesting features. The B-V colour curve is inverted, being faintest near maximum. This probably indicates that the system is composite with a cool red star dominating when the system is brightest, but with a hotter and bluer star contributing to the measured light at minimum. The other unusual thing is that both B-V and V-I show reversed slopes from phase 0.85 to 1.00. Why?



The historical background

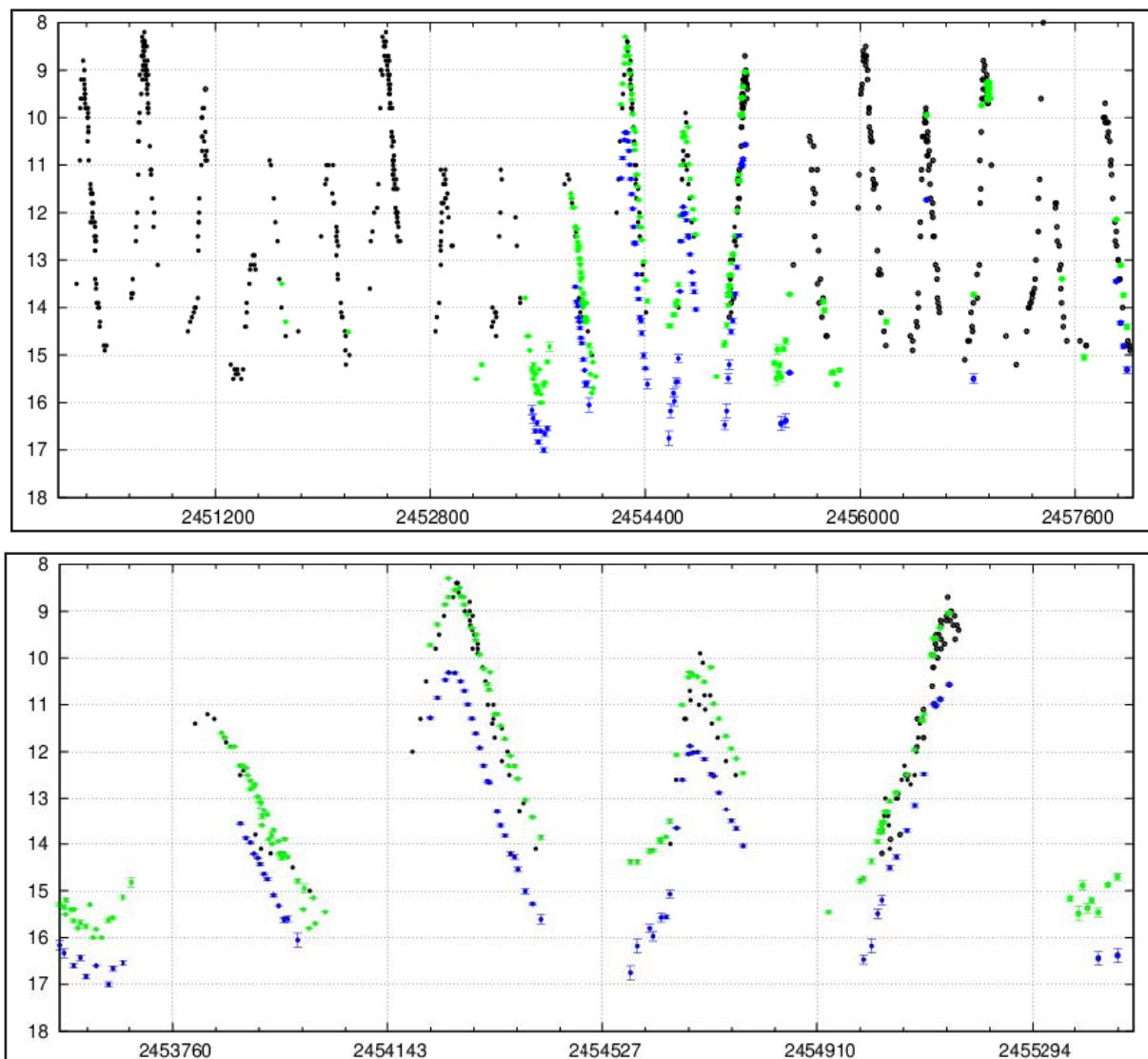
Z Sagittarii has been reasonably well observed since 1950. Prior to that the measures were scattered and largely photographic. Unfortunately, being at a declination of -21 it was outside the normal observing area of the RASNZ VSS but was low in the sky for European observers.

Measures from 1952 onward are shown below.



The light curve seems fairly regular—perhaps the odd low maximum in the 1950s but more erratic behaviour since 2000. In these plots based on International Database measures green is V, blue is B and black points are visual measures.

The last 8000 days since 1996 are shown in the next illustration to the same vertical scale. The minima should be more rounded than usual if there is a companion but being rather faint these are not well observed. If the companion is very blue, as seems probable, it might be a white dwarf star. Evolutionary models probably rule out a main sequence companion. There are indications in the di Scala data that at least one minimum is wider than expected. This can be seen in the next illustration covering only the interval of his measures.



Conclusions and suggestions

Examination of the last graph above shows that due to the humps the rising and falling branches are not separated by the same interval. As well, the maximum varied from ~ 8.2 to ~ 11.1 . This would explain the inconsistencies in the B-V and V-R light curves near minimum.

Is there a companion? An examination of Guide 9 reveals nothing down to $V = 17$ but anything with a separation of less than 5-10 arcseconds would be difficult to detect. Which introduces another possibility—can someone obtain some U-B measures? This is a neglected area due to two things—the common but erroneous belief that measuring red stars at shorter wavelengths is not sensible and that CCDs are not sensitive enough in the U filter to be of any use. Binaries are quite common and probably 10% to 15% of Miras are binary. The prototype star, omicron Ceti, is one such. But unless the companion has evolved more and is now a white dwarf it will be fainter and difficult to detect except by the B-V and U-B colour curves. But are these in some way related to the hump effect—one area for investigation?

As for the sensitivity there are several contributing factors. True, the sensitivity of many CCDs at U wavelengths is low but Sony and one or two KAF detectors have a U response in the region of 30% of the R filter. The more noticeable feature is that the U filter has a narrow passband, about 20% of R. So this makes for a difference of ~16x or 3 magnitudes. But, considering that in the circumstances of stars such as Z Sagittarii one U-B measure is probably worth a few hundred R or I measures there is a strong case to make the U measures to see whether binarity is present. A good project and since this star is overhead in the evening and around $V = 14.5$ at present ideally placed for such measures.

Congarinni observatory – part 3 – *Mark Blackford*

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It's taken 9 months but finally my observatory project has just about concluded. In the two earlier installments in this series I described the site selection and initial construction work. Here I'll wrap up the story and give some examples of early photometry results from the completed observatory.

The building is 5m x 5m in size which allows space for two piers for permanently mounted telescopes, a computer room in the north-west corner, some storage cabinets, and enough clear floor space for a 10" Dobsonian for visual observing. The door is a little wider than standard so a larger dob could be a possibility in the future.

I decided to construct the slide-off roof in two sections to make it easier to move onto the gantry when preparing for an observing session. The treated pine roof frames were first assembled in my garage to ensure they fit together properly and rolled smoothly on the tracks (described later). I then disassembled the southern roof frame and reassembled it on the observatory. Working on my own this proved a slow but manageable task, requiring bracing poles and clamps to hold things in place while I screwed the frame together again.

For the northern roof frame section I enlisted my mate Danny to help carry it fully assembled from the garage and lift it onto the observatory. The frame was not particularly heavy; the two of us had no trouble maneuvering it into position.

The observatory wall frames were wrapped in plastic insulation which is aluminized on one side and blue on the other. As Figure 2 in the previous article in this series shows, I installed the insulation with the aluminized side facing into the observatory. This is how all the DIY websites said to do it. In retrospect I should have had the blue side facing inward because I'll have to paint the inside of the observatory to minimize reflected light. Carpet tiles were laid to eliminate reflected light from the bare concrete floor.

The same insulation was attached to the top of the roof frames, this time with the blue side down, followed by Colorbond corrugated iron sheets. The sides of the roof sections are constructed from Colorbond flashing. Weatherproofing was achieved with Neoprene rubber strips along all four sides. However, there was one small leak at the join between two sections of the roof track. This was solved by judicious application of silastic water proofing.

The top panel of Figure 1 overleaf shows the roof in the closed position. The two-part roof allows for just the southern section to be opened when observing targets south of the celestial equator, as shown in the middle panel. The northern half of the observatory, including the computer "room", remains covered providing a wind break for the telescopes and reducing dew. When fully opened (bottom panel) the entire sky is available down to an elevation of about 20 degrees, except to the east and south east where tall trees on a neighboring property restrict viewing below 30 degrees.

Having the roof in two parts allowed for a shorter gantry south of the observatory where the ground slopes away fairly steeply (left of Figure 1). A one-piece roof would have required an extra set of unreasonably long poles to support longer horizontal tracks.

A local engineering firm was engaged to make the tracks on which the roof sections roll. These are composed of two lengths of 45mm angle iron spot welded to 100mm wide by 6mm thick steel base plates, see Figure 2 left panel. A total of 17m of track was needed, 8.5m for each side. I had them made in 3m



Figure 1. Observatory with roof closed (top), partially open (middle) and fully opened (bottom). To the right of the observatory is a Granny flat (sans Grannies) and double garage.

and 2.5m lengths to keep each section to a manageable weight for two people to manoeuvre into position on top of the east and west walls. The tracks were aligned then screwed into the treated pine top plate of the wall frames through predrilled holes on the track base plates.



Figure 2 Left. Roof tracks and casters. **Right.** One of six hasp and staples for securing the roof when closed.

Heavy duty groove casters are screwed to the bottom of the roof frames and ride smoothly on the 45mm angle iron tracks. I used two casters on each side of each roof section, but will add a third for better weight distribution.

When closed the roof sections are secured in place using six hasps and staples (Figure 2 right panel). These have been tested on a few occasions by strong and gusty winds and I'm happy to report that the roof remained in place. For added piece of mind I can also use ratchet tie-down straps when the roof is either opened or closed.

Figure 3 shows the observatory layout. The left (east) pier has a Celestron CGEM mount carrying an 8" EdgeHD, mainly used for visual observing, and Orion ED80T CF apochromatic refractor equipped with field flattener, Moonlite motorized focuser and DSLR camera for bright star photometry. A second DSLR with 200mm f2.8 lens is piggybacked on the 8" OTA.

The MX+ mount came with two 20 pound counterweights which was insufficient for the payload so I had two more made by the same engineer who made the roof tracks. These worked out to be less than quarter the cost of buying two from Software Bisque.

A set of drawers on casters, filing cabinet and steel cabinet provide storage for various astro bits and pieces, although a second cabinet would be useful. The computer room (Figure 4) is located in the north-west corner. It's really just a curtained off corner with a plywood roof salvaged from the temporary observatory mentioned in my first article in this series. The curtains effectively block computer monitor lights from interfering with the telescopes and also keep dew off the desk.

An electrician installed power and Ethernet cables in plastic conduits in the observatory frame and under the concrete slab to weatherproof external power points at the base of each pier. One of these is visible next to the left pier in Figure 3. Each pier is on a separate circuit breaker. Additional weatherproof power points are placed around the observatory walls. No lights have been installed yet but I intend putting a couple of white and red lights around the walls eventually.



Figure 3. *Looking south with the roof opened and ready for a night of photometry.*

The right (west) pier has a Paramount MX+ mount carrying a GSO 14" RC equipped with an SBIG STT-3200ME CCD camera and filter wheel with autoguider camera, and Optec Gemini focuser/rotator. This is a purely photometric instrument for fainter targets. Unfortunately the 14" RC is a little too tall when pointing to the south celestial pole to allow the roof to open and close, so it needs to be parked with the OTA in a horizontal orientation.

The mounts, focusers, cameras and filter wheels are operated by MaxIm DL Pro and TheSkyX remotely via a StarTech 4-port USB over CAT5 extender, one for each pier. This has worked flawlessly for the CGEM mount but I've had some issues with the Paramount MX+ that should be fixed by the time you read this.



Figure 4. *Computer room and 10" Dobsonian for visual observing.*

Since the roof and the ED80 telescope were installed in late June I've had a pretty good run of weather, recording 36 DSLR time series of 13 different eclipsing binary targets. The left panel of Figure 5 shows a phased light curve of the EW type eclipsing binary XZ PsA from DSLR images recorded through the ED80 refractor. The phase was calculated using epoch HJD 2452437.798 (12 Jun 2002) and period 0.75357d which were obtained from the AAVSO VSX database. The minimum is displaced from phase 0.5 suggesting the period needs to be refined so further observations are required next season.

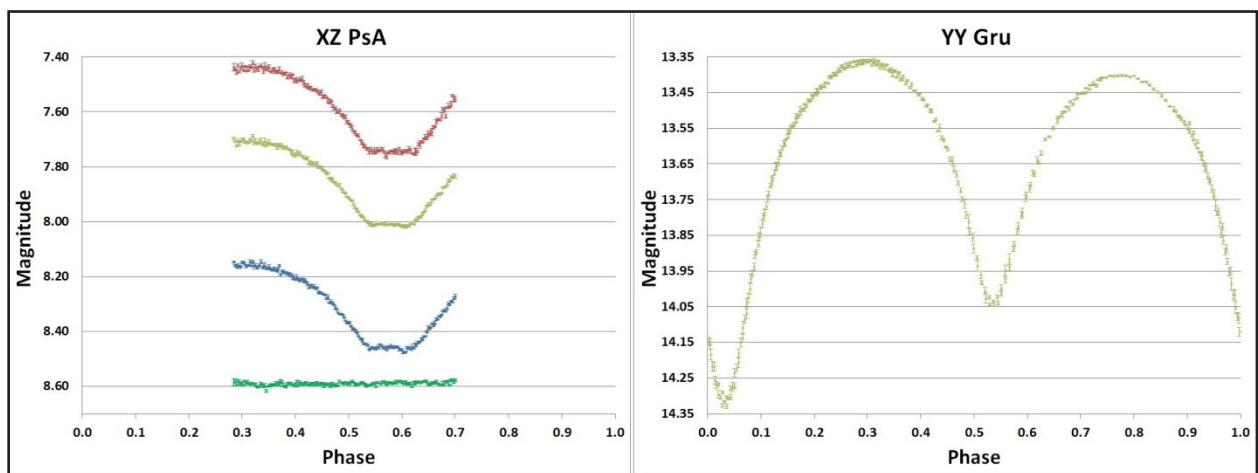


Figure 5. *Phased light curves of XZ PsA (left panel) and YY Gru (right panel).*

Commissioning of the 14" RC is continuing, however three separate time series of YY Gruis have been collected through a clear filter so far. These observations cover the entire light curve as shown in the right panel of Figure 5. Two primary and one secondary eclipse were recorded. The epoch HJD 2451870.809 (22 Nov 2000) and period 0.292649 d from VSX were used to calculate the phase. Again the primary and

secondary minima are displaced from phase 0 and 0.5, respectively. I intend making further observations this season in order to refine the period and epoch.

So the observatory construction phase has been completed and instrument commissioning is well advanced. I look forward to many years of photometry now that I've invested all that time, money and effort. If any VSS members are traveling to or through the NSW mid north coast feel free to drop in and take a look at Congarinni Observatory. I can be contacted at the email address above.

The early ejection sequence of classical novae — *Carl Knight*

Abstract

This year has seen the publication of a paper (Eyres et al. 2017) that examines the light curve of V5589 Sgr obtained on the rise. Remarkable in this high-cadence light curve is the presence of not one, but two pre-maximum halts. This observation appears to confirm aspects of the models of novae light curves developed by Hillman et al. (2014). This paper seeks examine the work of these two papers and discuss the thermonuclear runaway and hydrodynamics leading to the pre-maximum halt(s) up to mass loss.

1 Introduction

Classical novae (CNe) occur in accreting white dwarf (WD) systems where the hydrogen (H) rich envelope of the WD, captured from a companion main sequence star, is able to undergo a thermonuclear runaway (TNR) catalytically producing helium (He) via the Carbon-Nitrogen-Oxygen (CNO) cycle (see Hillman et al. 2014; Eyres et al. 2017).

Payne-Gaposchkin (1957) identified that in the early rise to maximum light of these events there is “sporadically” (Eyres et al. 2017) seen a brief pause or reversal. This is a pre-maximum halt (PMH). This feature has been poorly understood.

One of the most fundamental issues, observationally, is the sheer serendipity required to be observing a CNe progenitor at the point when a TNR occurs and subsequent PMH might be observed (see Eyres et al. 2017).

Of particular interest are the observations discussed by Eyres et al. (2017) where dual PMHs were observed of V5589 Sgr at high cadence ≈ 40 m (Nova Sgr 2012). The authors point out that prior detections have suffered from a lack of resolution as “[d]ue to the rate of ascent, the pre-maximum optical light-curve has been only rarely observed, and at cadences of 1–2 data points per day”.

Hillman et al. (2014) developed theoretical light curves of CNe for a range of WD masses, core temperatures and accretion rates guided by the constraints determined previously by Prialnik (1995), Prialnik & Kovetz (1995) and Yaron et al. (2005): Hillman et al write:

“It became clear (Prialnik 1995) that a simulation of a nova on a WD of given composition (e.g. [carbon] C and [oxygen] O in equal mass fractions) depended on three key parameters: the WD mass M_{WD} , its (isothermal) core temperature T_c , and the accretion rate $\dot{M}$. Grids of nova simulations for wide ranges of these three parameters were calculated (Prialnik & Kovetz 1995), culminating with a determination of the limits of these ranges, outside of which novae could not occur (Yaron et al. 2005).”

STEREO B V5589 Sgr observations by Eyres et al (2017) provide some level of confirmation of the model light curves developed by Hillman et al. (2014) for a CNe progenitor with WD mass $1.0 M_{\odot}$, central temperature 5×10^7 K and mass accretion rate $10^{-10} M_{\odot} \text{ yr}^{-1}$.

2 Hillman et al. (2014) modelling of novae light curves

2.1 Modelling WD mass (M_{WD}), core temperature (T_c) and accretion rate ($\dot{M}$)

Hillman et al. (2014 §4) state the parameter range explored in their models (hereafter “Hillman models” or “models”): “the WD mass (M_{WD} : $0.65, 1.0, 1.25$ and $1.4 M_{\odot}$), the core temperature (T_c : $10^7, 3 \times 10^7$ and 5×10^7 K) and the accretion rate ($\dot{M}_{WD}$: $10^{-7}, 10^{-8}, 10^{-9}, 10^{-10}, 10^{-11}$ and $10^{-12} M_{\odot} \text{ yr}^{-1}$).

The models take into account hydrodynamics, opacity, nuclear reaction networks, convection, mixing, diffusion of elements, the contribution of accretion and mass loss by opaque supersonic wind. The mass loss point in the models is determined by the model ejecta attaining escape velocity (Hillman, 2017)

The synthetic light curves derived from the models are X-ray, near ultraviolet (NUV) and visible (V).

2.2 Thermonuclear runaway primer

To undergo a CNO TNR, a CO rich WD must accumulate a H rich envelope.

The progenitor must meet the temperature conditions necessary to produce a TNR. If too hot then the WD will have weak electron degeneracy and weak convective mixing between the outer region of the core and the accreted gas envelope. Such progenitors are believed to undergo weak TNR that yield no mass ejection. At the other end of the spectrum, very cold WDs have deep convective mixing into the core that significantly delays hydrogen ignition in the envelope – especially if the accretion rate is low (Schwartzman et al. 1994). In the ideal progenitor WD Schwartzman et al. note:

“When hydrogen-rich material accumulates on top of the WD and hydrogen diffuses into this convective zone, it becomes rapidly mixed throughout and then continues to diffuse downwards from its bottom. This zone acts as a pump that drives hydrogen into the hot, but still degenerate, CO-rich core, where conditions are optimal for explosive ignition. In such cases a TNR develops much sooner than in cooler WDs.” (Schwartzman et al. 1994 §3)

A proper pressure at the core-envelope interface of around 10^{20} dyn cm⁻² must be reached (Schwartzman et al 1994) with strong electron degeneracy pressure. The temperature required for the CNO TNR is in the order of 2.0×10^8 K. When these conditions are met, the CNO TNR can occur.

For most CNe the TNR lasts for hours, but Hillman et al (2014) discuss models of $0.65 M_{\odot}$ WD (eg T_c 3×10^7 K, $10^{-11} M_{\odot}$ yr⁻¹ in one example) that yield a class of progenitor for whom the TNR may last days at much lower temperatures (eg 1.2×10^8 K) than most CNe. This class of progenitors are predicted to produce near ultra-violet (NUV) flashes and there is observational evidence of such phenomena (Pietsch et al. 2007).

Some cool, slow accreting, medium mass WD models produce X-ray flashes in addition to NUV flashes. Having higher mass and smaller radii than the $0.65 M_{\odot}$ discussed above, they are able to achieve higher effective temperatures during TNR and subsequently flash in shorter wavelengths.

Finally we come to the models that yield PMH phenomena. These models consider only a subset of WD masses of $1 M_{\odot}$ though the phenomena is not unique to such a mass (Hillman, 2017).

These models also exhibit a NUV flash but this is due to temperatures remaining high even during the envelope expansion phase rather than a sustained slow burn as per the models of $0.65 M_{\odot}$. (Hillman et al. 2014)

2.3 Pre-maximum halt phenomena and their hydrodynamics

A subset of the models produced PMH phenomena. More remarkably, some produced double PMHs. At that time double PMHs had not been observed and the final acceptance of PMH as a bonefide phenomenon is relatively recent as seen in the conclusion of Hounsell et al (2010) who say:

“This work has enabled us to follow in unprecedented detail the rise to maximum of all four of the novae surveyed. In turn, it has provided significant, detailed, and undeniable evidence for the existence of the previously controversial pre-maximum halt, with accurate times of occurrence, duration, and magnitude below peak given.”

The PMH phenomena was found by Hillman models and “...in the different electromagnetic bands; some show the halt in all three bands and others in only one or two.” As might be expected, when T_{eff} rises, so does the luminosity, when T_{eff} declines, the luminosity follows suit. A PMH is a temporary drop in luminosity as T_{eff} declines.

The PMH phenomena occur as the envelope expands but prior to mass loss. At this stage the envelope is very opaque so the dominant energy transport mechanism is convection. As the envelope expands, this

convection becomes less efficient at energy transport and the rise in flux stalls or slightly reverses as a result. Trapped heat ensures that the envelope is continuing to expand and the envelope thins to allow radiative heat loss. When this occurs, the stalled flux increase resumes its rise (Hillman et al. 2014).

The onset of the second PMH in the models is more difficult to understand. It is unclear which of the following holds true:

1. The predominant heat loss mechanism of the envelope returns to convective, perhaps when sufficient heat has escaped radiatively leading to a reduction in temperature, and the basic explanation above repeats.
2. Both mechanisms (convection and radiative transport) are in operation (ie no return to convection dominating) and the convection present suffers a second stall before expansion thinning the envelope allows further heat loss radiatively.

Posing these options to Yael Hillman, she responded “When working on the model grid, I baffled endlessly with this question myself... and although (a) sounds simpler and more complete, (b) is probably closer to reality.” (Hillman, 2017b)

The exact nature of the hydrodynamics between the halts then needs further analysis.

Hillman et al. (2014) find that “[s]ome models produce a double halt, while the second halt is usually shorter, with a smaller amplitude and does not always show up in all three bands.” This is due to the modulation being more pronounced in shorter wavelengths and the amplitude being undetectable in longer wavelengths in some cases hence not showing up in all three bands (Hillman, 2017b).

2.4 Relationship of pre-maximum halt phenomena to nova evolution

Hounsell et al. (2010) performed analysis of three novae with PMH phenomena:

- V1280 Sco. 2007 February 4.86 UT.
- V598 Pup. 2007 October 9.0 UT.
- KT Eri. 2009 November 25.536 UT.

Lacking more observations of the phenomena, they were unable to forge a link between other characteristics of the novae evolution and their PMHs.

Similarly Hillman models don’t link PMH to further nova evolution.

2.5 Mass loss and oscillations

Fundamentally, for mass loss to occur, part of the WD envelope must achieve sufficient energy to no longer be gravitationally bound to the WD. Additionally having been given a large scale disruption, the gravitationally bound portion of the WD envelope must resettle into a state of hydrostatic equilibrium.

Hillman models of the envelope, expansion and mass loss assume a simple spherical configuration:

“In my simulations, the oscillations occur in models with low mass WDs accreting at slow rates. The timescales are long for these models and allow more time for conditions to develop. The “sloshing around” [the phrase the author used in the question to Hillman] is a result of the envelope adjusting and readjusting to changes due to expansion. When the timescale is long, the changes are slower, thus allowing the envelope to continuously re-balance itself.” (Hillman, 2017c)

In the simplest terms, the readjustment of the gravitationally bound material in the WD envelope imprints on the luminosity and ejecta yielding the observed oscillations.

3 V5589 Sgr

3.1 Discovery and observation

“V5589 Sgr (Nova Sgr 2012, PNV J17452791–2305213, coordinates J2000 17 45 28.03 –23 05 22.7) was discovered on 2012 April 21.0112 UT (Sokolovsky et al 2012) at $V \sim 9.6$, rising to a reported maximum of $V = 8.8$ (Korotkiy et al. 2012) by 2012

April 21.654 UT (CBAT 2015). Pre-discovery images detected the outburst on 2012 April 20.8403 UT down to $V = 10.2$ (CBAT 2015)” (Eyres et al. 2017)

The Optical Gravitational Lensing Experiment (OGLE) has data for V5589 Sgr at quiescence from 2010 onwards. Eyres et al (2017) say that the system has a period of 1.59230 days and appears to be a WD and an evolved sub-giant, noting:

“The last pre-eruption image was taken on 2012 April 20.3728 UT at $I = 16.90$ ”

They were able to produce a light curve with a cadence of 40m from stacked 40s exposures when the nova crossed the pixels of the STEREO HI-1B spacecraft CCD between 18 April 2012 and 7 May 2012.

3.2 Classification of V5589 Sgr

STEREO data is consistent with AAVSO B, V and visual estimates, the AAVSO data being lower cadence and the visual estimates being accurate to 0.1 magnitude at best.

Peak light, by convention referred to as Day 0, is the point from which a CNe speed class might be determined as ‘slow’ or fast and so forth. The speed of the nova is related to the energetics of the event.

Fast novae tend to have higher mass progenitors, lower mass envelopes and both better mixing of and availability of CNO to drive the TNR. The ejecta from lower mass envelopes also thin and decline in luminosity more quickly (Shara et al. 1980).

Using the STEREO data, the peak light was determined to have occurred at $JD\ 2456038.8224 \pm 0.0139$ (Eyres et al. 2017). Luminosity decline and recovery from oscillations in the light curve made the determination of the point at which V5589 Sgr declined by 2 magnitudes allowing its speed class to be determined, somewhat difficult:

“Determining the time to decline by two magnitudes, t_2 , and hence the speed class, is somewhat more uncertain. The brightness at peak is 7.94 ± 0.09 , and the brightness drops below 9.94 for the first time after $JD\ 2456040.9057 \pm 0.0139$ but recovers 2 h later. The last time it is brighter than this is the point at $JD\ 2456042.3224$.” (Eyres et al. 2017)

Eyres et al argue that the difficulty is likely due to the cadence of observation making much more detail in the light curve apparent, thus muddying, what for many other novae, is a clear point at which the nova has dropped the requisite number of magnitudes for its speed class to be determined. Furthermore, that whilst such decline and recovery features are found in slower novae, these features are also present in fast novae but simply missed due to insufficient cadence in the observation of faster novae.

The final determination made by Eyres et al. (is that V5589 Sgr is a very fast nova taking somewhere between 2.1 and 3.9 days to decline 2 magnitudes from maximum light.

Spectroscopy revealed that the ejecta were expanding at between 5600 km s^{-1} and 6500 km s^{-1} . The absolute magnitude and ejecta velocity as might be expected appear to also be related to the novae speed. The faster the nova speed class the brighter the peak luminosity and the higher the ejecta velocity (Eyres et al. 2017).

3.3 Observation of double pre-maximum halts

Prior to mass loss as its envelope expanded, V5589 Sgr. exhibited two PMHs:

“...in the rise phase of deviations from a monotonic increase that are consistent with PMHs seen in other classical novae. For V5589 Sgr we have identified two short deviations – peaking at $JD\ 2456037.8502 \pm 0.0139$ and $JD\ 2456037.9891 \pm 0.0139$ – with this phenomenon.” (Eyres et al. 2017)

The detected PMHs seen by Eyres et al are brief and close to the detectability limits of the 40 m cadence of their observations. Effectively the rise takes place over a single datum and declines over three. Never-the-less still detectable.

Their light curve of V5589 Sgr is reproduced in figure 1. The double PMH are marked.

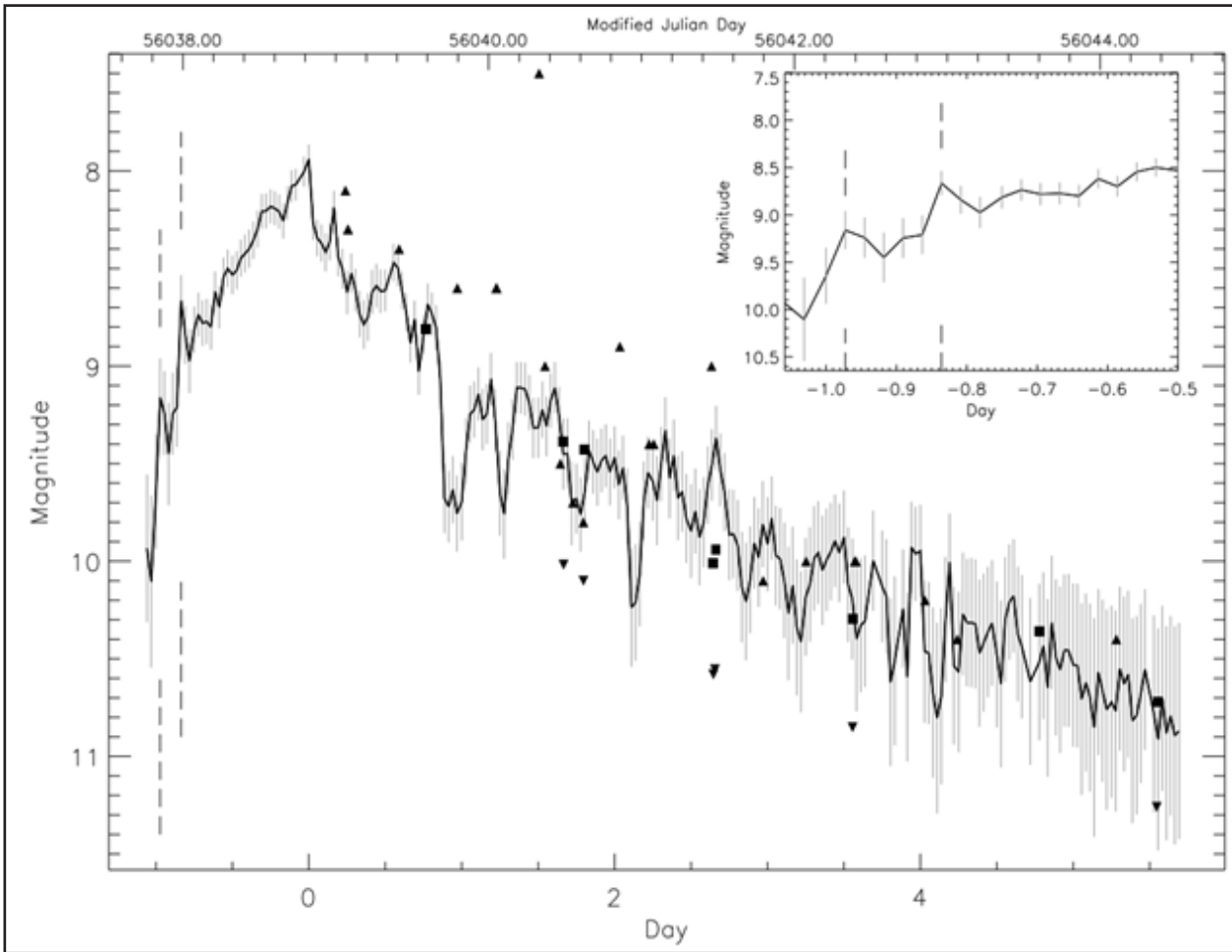


Figure 1. STEREO HI-1B data with error bars, plus AAVSO visual estimates (triangles), V (squares) and B (inverted triangles) included for comparison; offset by 1 mag upwards for clarity. STEREO is approximately R-band, for which data are available in AAVSO only after JD 2456051 (MJD 56051.5), about 6 d after the end of this data run. Vertical dashed lines mark the PMHs described in the text. The inset zooms in on the ~14 hour period around the PMHs. From Eyres et al. 2017.

Having established the position and time of the PMHs on the light curve Eyres et al established a best fit by aligning the second PMH of models and the second PMH of the observed light curve. This yields a best match to a model with $M_{\text{WD}} = 1.25M_{\odot}$, $T_c = 3 \times 10^7$ K and $\dot{M}_{\text{WD}} = 10^{-9} M_{\odot} \text{ yr}^{-1}$.

This result is suggestive that the processes leading to PMH phenomena are understood.

3.4 Mass loss and the observed PMHs

Figure 2 shows differences in the evolution of the light curves between the models and the observations of V5589 Sgr, though it should also be noted there is a difference in resolution between the two. Hillman notes:

“The model showed a remarkable resemblance to the PMHs whereas other parts of the novae cycle did not show as much of a resemblance (the time scales of decline were different). This may be due to some tweaking still needed in our understanding of the way a star evolves, or/and, of what we are observing.” (Hillman, 2017)

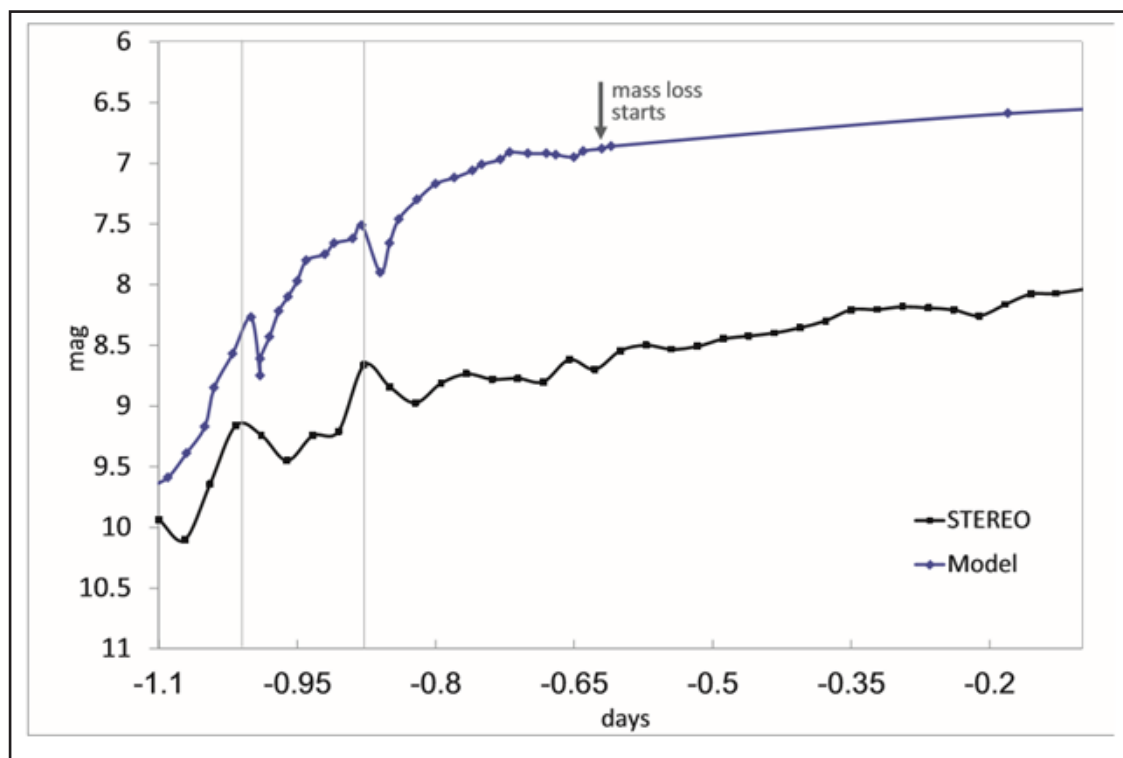


Figure 2. Comparison of data (lower line) and model (upper line) for the parameters giving the closest match to the pre-maximum behaviour (WD mass $1.0 M_{\odot}$, central temperature 5×10^7 K and mass accretion rate $10^{-10} M_{\odot} \text{ yr}^{-1}$). The time axis is relative to day 0 at JD 2456038.8224. From Eyres et al.

The point of mass loss is indicated for the model. This is the point at which material no longer bound to the WD first reaches escape velocity and in the models is not taken into account beyond that point (Hillman, 2017)

The mass loss point has not been determined for V5589 Sgr, but can be reasonably constrained to after the first PMH and before maximum light. (Eyres et al. 2017)

3.5 Analysis of fluctuations in the decline phase

It can be seen from figure 1 that in the decline phase of V5589 Sgr, there are noticeable fluctuations in the light curve. Examining only from maximum light onward, Eyres et al performed FFT analysis looking for any periodicity, especially the fundamental and harmonics of the orbital period of V5589 Sgr (1.59230 days). Their conclusion was that the modulation of the light curve is not explained by eclipse or orbital phenomena.

4 Closing remarks

PMH phenomena now have a solid theoretical basis as well as solid irrefutable observation.

The author was surprised to learn that there had been any doubt of their existence – such is the power of assumption – and to learn that the issue was at all debated in the literature (see Hounsell et al. 2010).

Observation of the double PMH phenomena reinforces confidence in the Hillman models. The double PMH of Eyres et al. (2017) is the first conclusive observation of the phenomena. Hillman confirmed to the author that the models were part of her work toward her PhD and whilst her response was somewhat coy to the author's enquiry about the exciting confirmation of her theoretical work, never-the-less the result is an exciting and an important advance in its own right of the understanding of an important, once debated, phenomena.

Hillman models also show multiple outburst phenomena. There was speculation that V1369 Cen's 2013 nova might have undergone multiple outbursts (Hendon 2014 and 2015).

The author intends to re-visit V1369 Cen in light of the Hillman models that exhibit multiple outbursts.

The fact that Eyres et al. (2017) conclude and reasonably prove, that the fluctuations present in the decline of V5589 Sgr are not eclipse or orbital phenomena leaves us with an open question: What then is the cause of the fluctuations?

Any observer of novae in the decline phase will have seen for themselves (numerous examples such as V1369 Cen exist) many short time scale fluctuations in the light curve of novae. Collision of ejecta with prior stellar wind is typically found well after the fluctuations detected (day 0 to day 6 in Figure 1). Williams & Mason (2009) see evidence for ejecta/prior stellar wind collision in the change of spectra. Broadly, the shift from absorption spectra to forbidden emission line spectra at between 2-6 weeks from eruption. It would seem then that the fluctuations observed by Eyres et al are too early for the phenomena observed by Williams & Mason (2009).

In conclusion, more work to be done by both observers and theoreticians.

5 Thanks

Yael Hillman is a post-doc at the American Museum of Natural History (AMNH) New York visiting the Weizmann Institute of Science, Israel. She has very kindly taken the time to answer the author's questions regarding the CNe light curve models in her work (Hillman et al. 2014), the detection of double pre-maximum halts in the 2012 eruption of V5589 Sgr. (Eyres et al 2017) and to check the overall accuracy of this article.

Errors are entirely those of the author.

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An exercise in multi-longitude and multi-detector photometry

Introduction

It all began in 1968 when two very new visual observers, Brian Marino and Stan Walker, decided that one of the two main comparison stars for eta Carinae, HD 93206, was variable. But it had to await 23 March, 1971, when our custom built photometer became fully operational, for us to begin measures which, after 46 years, are still incomplete.

HD 93206 is a quadruple system of massive stars arranged in two pairs: an eclipsing secondary pair with a period very close to 6d (QZ Car) and a non-eclipsing primary pair with a period of about 21d. These pairs orbit a common centre of gravity in about 50yr. Measured times of eclipses occur early or late depending on where the two pairs are in their long period orbit, this is called the Light Time Effect (LTE).

Leung et al. derived a mean light curve (MLC) based on the original 58 UBV measures made at the Auckland Observatory. Fitting this MLC to a set of observations allows us to estimate the times of mid eclipse, Figures 1 and 2.

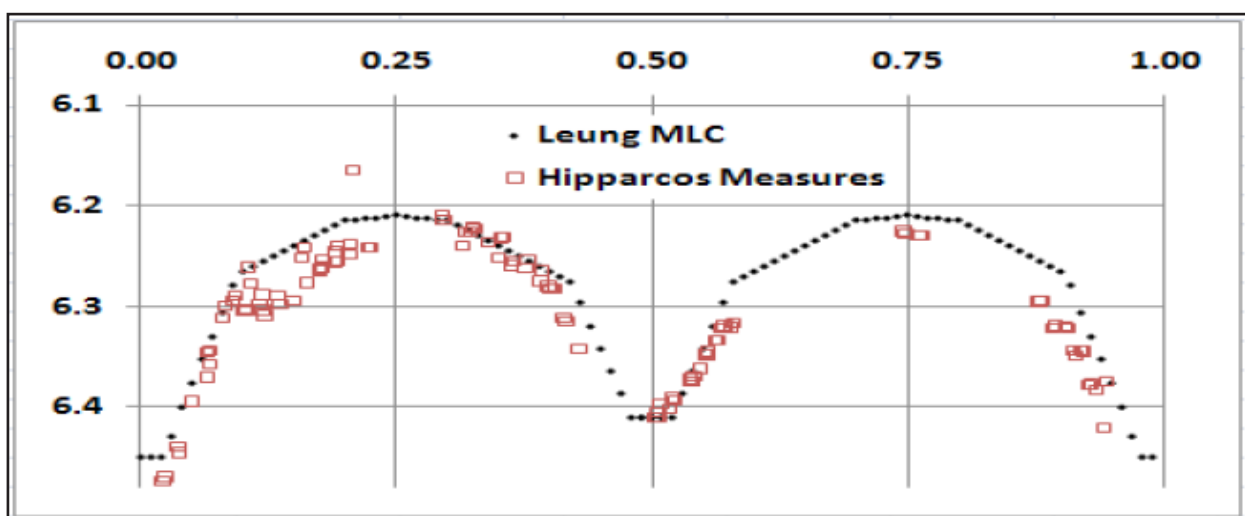


Figure 1. Measures made by the Hipparcos satellite in 1980-82 are fitted to the mean light curve from 1971-72. There is quite clearly a zero point problem in that the Hipparcos measures appear ~ 0.030 fainter. They are quite noisy at times and do not cover the second maximum well. These measures have been corrected for a light time effect of -0.1044 days. More about this later.

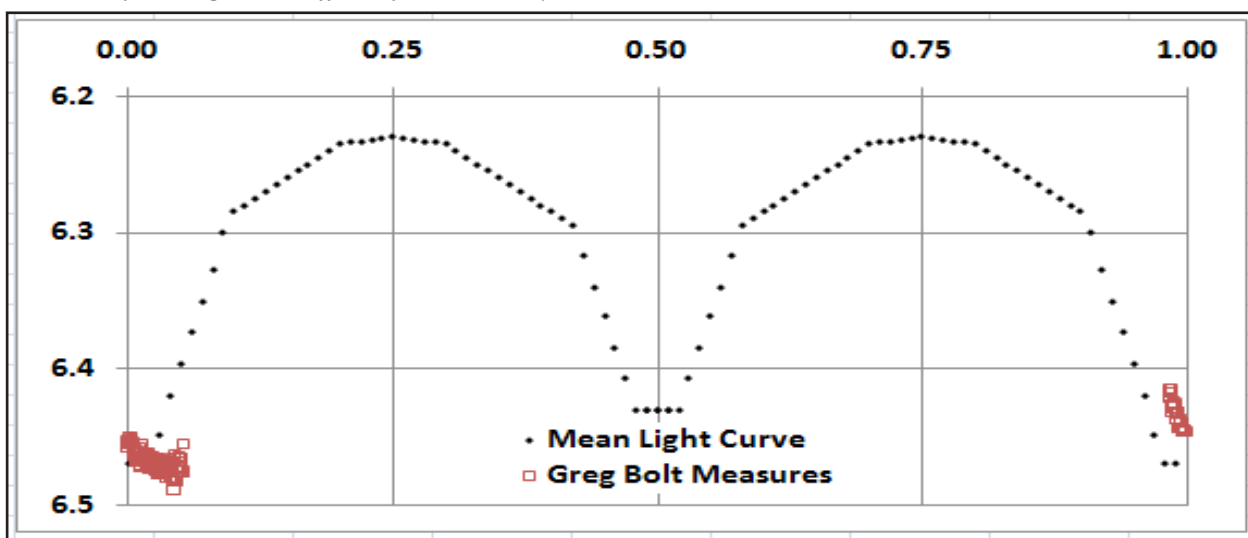


Figure 2. Measures made on 10 March, 2017, by Greg Bolt. A preliminary analysis of these show that the measured eclipse is ~ 0.1400 days late.

Determining the light time effects

The phase of each observation was calculated using the standard epoch (JD 2441033.03) and period (5.99857d) and the LTE determined by fitting the MLC by a least squares method. An Observed minus Calculated (O-C) diagram constructed from all available observations is shown in Figure 3. The best estimate of the orbital period of the eclipsing pair, 5.99857 days, was used in all fits. But until the resulting curve in the O-C diagram returns to the original slope neither the period of the eclipsing pair nor the orbital period of the whole system can be determined accurately.

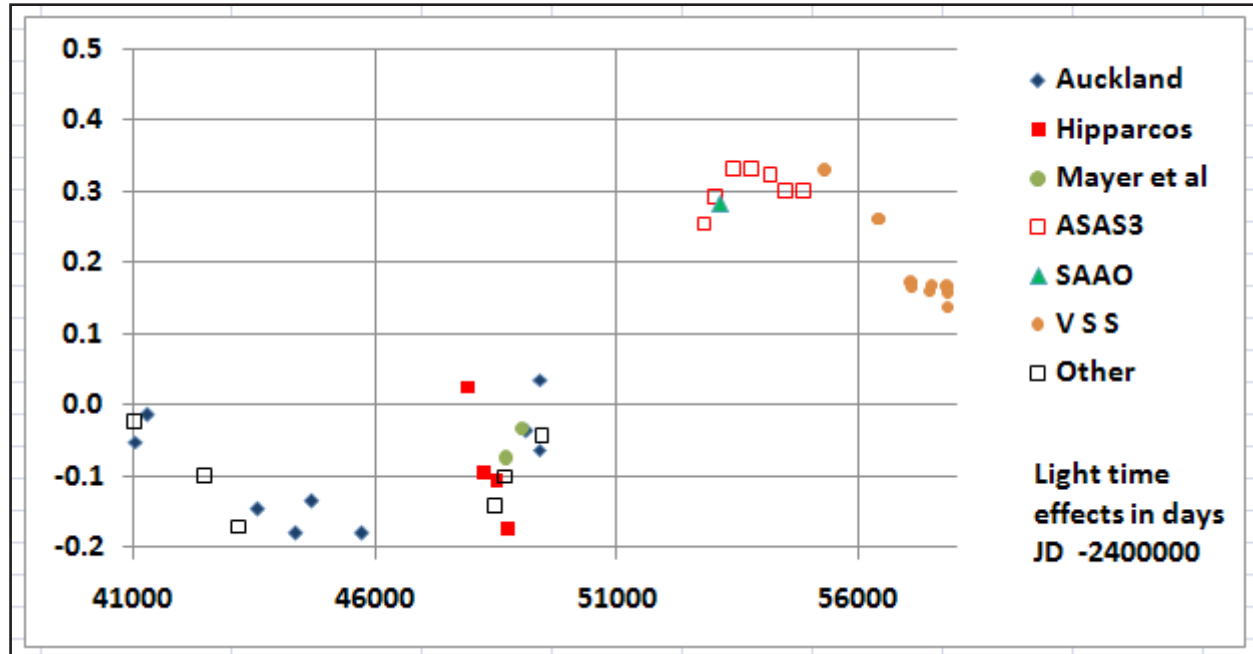


Figure 3. Plot of the various light time effects from 1971 to 2017. During this interval detectors have changed from photomultiplier tubes to CCDs and DSLR cameras which complicates the analysis, as does the variety of values used for comparison stars.

The accuracy of this method depends upon all observers using the same comparison stars and applying the correct transformations. In practice this is not always the case and it may be necessary to use a zero point correction to raise or lower the magnitude of the data to achieve a good fit. This is simple if the actual eclipse is measured as it was by Greg Bolt in Figure 2. But this is not always possible. In reality, if the magnitudes are correct, the most accurate LTE values are obtained by fitting the measures to the ingress or egress curves. But measurement accuracy then becomes critical. Because this is the fainter pair of stars the eclipse amplitude is quite low at ~ 0.23 for the primary, ~ 0.20 for the secondary. Thus it's difficult to determine the actual times of the beginning and end of totality as the change in magnitude is small.

What is the purpose of all this?

QZ Carinae is not just another eclipsing binary system. It is so luminous at ~ 8000 light years that it would be marginally visibly to the naked eye in dark skies if it was not seen against of the background of the eta Carina nebula. QZ itself illuminates much of the southern part of that nebula.

The stars themselves are impressive: Based on the original photoelectric measures and some spectroscopy Leung's group determined the following parameters.

Star	Spec	Temp	Radius	Mass	MV	Star	Spec	Temp	Radius	Mass	MV
Pri 1	O9.7Iab	32,000	22.5	~ 40	-6.4	Sec 1	B0Ib	30,000	16.1	16.7	-6.2
Pri 2	B2V			~ 9	-2.3~	Sec 2	O9V	32,463	8.9	28.0	-5.0

The inclination of the secondary pair in QZ Carinae is given by Leung et al. at 85.9° with $\sim 60^\circ$ for the non-eclipsing primary pair. Morrison & Conti showed the primary pair make up a spectroscopic binary with an orbital period of 20.72 days. More recently we have published an up to date analysis in Monthly Notices of the RAS increasing the overall mass of the system from 93.7 to 112 solar masses—the abstract

follows:

New high-resolution spectroscopy and BVR photometry together with literature data on the complex massive quaternary star QZ Car are collected and analysed. Absolute parameters are found as follows. System A: $M_1 = 43 (\pm 3)$, $M_2 = 19 (+3 -7)$, $R_1 = 28 (\pm 2)$, $R_2 = 6 (\pm 2)$, (☉); $T_1 \sim 28\,000$, $T_2 \sim 33\,000$ K; System B: $M_1 = 30 (\pm 3)$, $M_2 = 20 (\pm 3)$, $R_1 = 10 (\pm 0.5)$, $R_2 = 20 (\pm 1)$, (☉); $T_1 \sim 36\,000$, $T_2 \sim 30\,000$ K (model dependent temperatures). The wide system AB: Period = $49.5 (\pm 1)$ yr, Epochs, conjunction = 1984.8 (± 1), periastron = 2005.3 (± 3) yr, mean separation = $65 (\pm 3)$, (au); orbital inclination = $85 (+5 -15)$ deg, photometric distance $\sim 2700 (\pm 300)$ pc, age = $4 (\pm 1)$ Myr. Other new contributions concern: (a) analysis of the timing of minima differences (O – C)s for the eclipsing binary (System B); (b) the width of the eclipses, pointing to relatively large effects of radiation pressure; (c) inferences from the rotational widths of lines for both Systems A and B; and (d) implications for theoretical models of early-type stars. While feeling greater confidence on the quaternary's general parametrization, observational complications arising from strong wind interactions or other, unclear, causes still inhibit precision and call for continued multiwavelength observations. Our high-inclination value for the AB system helps to explain failures to resolve the wide binary in the previous years. The derived young age independently confirms membership of QZ Car to the open cluster Collinder 228.

So QZ Carinae is one of the most massive systems in our galaxy and certainly one of the most interesting.

Light time effects

What is a light time effect (LTE) and what does it tell us? We all use one in transforming JD to HJD. In the case of a binary system the stars will be at differing distances from the observer as they travel around their orbit. With QZ Carinae there is a good marker for one pair of stars - the time of mid-eclipse and whether it is occurring early or late. So given the LTE amplitude of this orbit we can translate ~ 13 hours into ~ 95 AU or a radius of ~ 47.5 AU. This is the orbit as we see it. A correction for the inclination is almost certainly necessary in the final analysis.

The shape of the orbit is also important. This one probably indicates that periastron occurred about 2005 where the distance between the two slopes is least, with apastron about 25-30 years earlier. Given that the curve is not sinusoidal it also indicates an elliptical orbit. When the two descending or ascending slopes become identical this will indicate the overall period of the system. Since the 5.99857d orbital period of the eclipsing pair that is being used may not be quite correct any error will show as a vertical offset in the O-C diagram. Correction of the O-C diagram will then provide accurate orbital times for all system components - the two pairs of stars and the system as a whole. Hence the need for very accurate epoch times and the present project. This vertical offset occurs because the QZ Carinae system as a whole is almost certainly approaching or receding from our solar system - in all, a nice collection of things to resolve.

What can we deduce from the available measures?

These have been rounded to make calculation easier. As well, the most uncertain value, the period of the system, has been taken as 50 years which matches the 2017 measures rather more closely. But this value is probably ± 5 -10%.

Using an orbital period of 50 years and a combined mass of 100 solar masses and working in AU, solar masses and years we use the formula $R^3 = (M+M)P^2$ to derive a mean orbit radius of 63 AU. Clearly it is inclined to our line of sight.

The circumference of the orbit is then $2\pi \times 63 \times 149.5879 \times 10^6$ which provides 59212.93×10^6 km

The orbital velocity is this circumference divided by seconds in 50 years or $59212.93 \times 10^6 / ((31.5576 \times 10^6) \times 50)$ giving 37.527 km/sec. This can be checked by using Velocity Earth $\times$ AU / Years, or $29.7859 \times 63 / 50 = 37.530$ km/sec

Assuming that the orbit is circular (see Figure 4) and that we are observing from its plane (this assumption is incorrect as the orbit is eccentric and the models suggest we are not in this plane) we can derive a theoretical LTE correction using $\text{Velocity} \times \text{seconds in year} / \text{speed of light} = \text{LTE in seconds}$. This equates to 3950.6 seconds per year or 0.04572 days per year. An easier value to work with might be 0.1253 per 1000 JDs. But eccentricity increases velocities near periastron and decreases them near apastron. Then there is little variation in the LTE when the system is travelling parallel to the solar system. Our angle to the plane of the system and the major axis also have a strong effect. Figure 3 shows an LTE amplitude of ~ 0.55 days which translates to 95 AU. But the theoretical amplitude of the orbit is ~ 126 AU. So our line of sight is considerably inclined to the orbit.

The various models of binary systems take all of these things into account but it's always better to understand just what they're taking into account to get the answers.

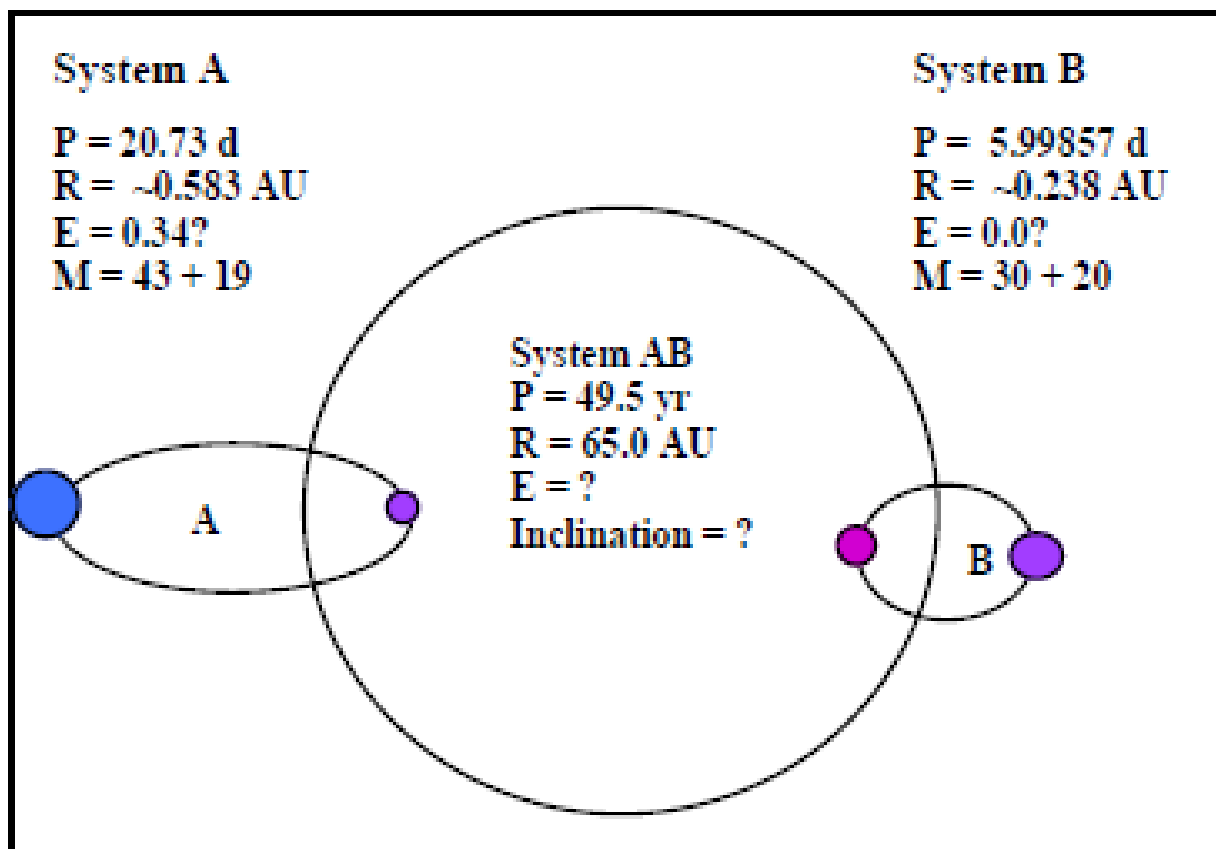


Figure 4. A layout of the system, not to scale, showing some of the important aspects.

The O-C measures

These showed little change from 53000 to 56000, or 2004 to 2011, indicating that the orbital motion was parallel to our own, but now the eclipsing pair is approaching us. The LTE has decreased from 0.2611 days in 2013 to 0.1373 in 2017. This, however, is the interval most affected by the use of different comparisons which we are now working to resolve. Prior to this ASAS was in operation but with the system varying between $V = 6.2$ and 6.5 there were varying degrees of saturation which made determination of epochs inaccurate.

The 2017 project has been quite satisfactory in determining the current epoch. But it is clear that the diversity of comparison stars has affected most of the epochs since 2000 and we are presently reworking these. In some cases this will need working with the original images, in others merely correcting datasets to change them to the recently determined correct values for comparisons. This argues for everyone using the same comparisons which has not happened in the past.

In Figure 5 are shown a group of measures during the observing season just completed. Whilst they may look noisy remember that the scale is 0.005 magnitudes or 5 millimagms per millimetre. So these are very good measures. Even the scale of the total light curve at the upper right is only 7.5 millimagms per mm. But the system is very active with stellar winds, probably some ejected material and the elliptical light variations of the primary pair.

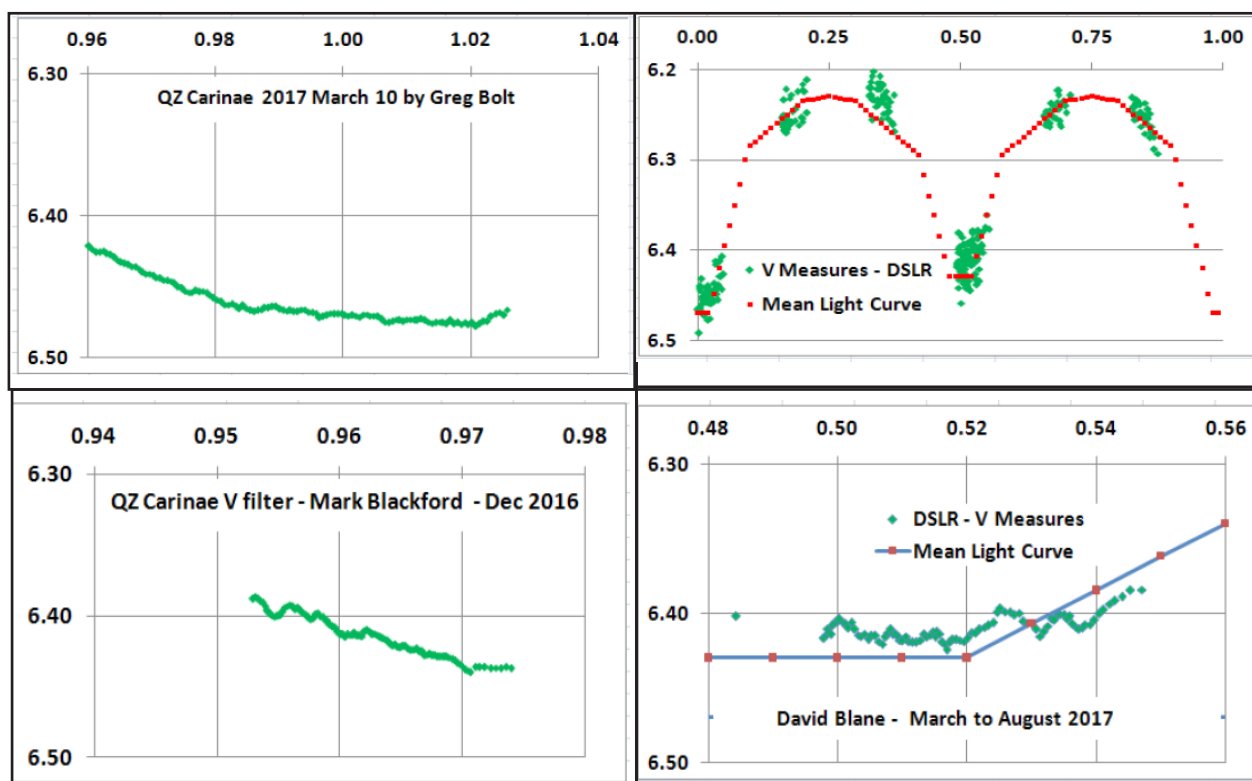


Figure 5. This shows four of the datasets collected during 2017. The phases are based on the ephemeris $JD\ 2441033.084 + 5.99857$ with a LTE of -0.1500 days or -0.025 phase applied. In the lower right graph the theoretical mean light curve is shown as a blue line between 1% points.

Other possibilities

Still on the photometric side one of the original goals of the project was to see if a signature of the brighter non-eclipsing pair was detectable in the photometric data. If it exists it would be easiest to identify when the star was not in eclipse. So the measures near maximum are still valuable in this context. A confusing factor is the small sections of the light curve visible from one site in any one year. Another is the period relationship of 3.46:1.0 or 6.92:2 which means the measures tend to lie in clumps as seen in the upper right panel of Figure 4.

Spectroscopy

The authors of this article are both photometrists and leave spectroscopy to those who know what they're doing in that field. Ed Budding and Roger Butland have made good use of the Hercules equipment at Mt John and more recently David Moriarty has been using the ANU's 2.3 metre telescope on this system. Terry Bohlsen also made a few spectral measures in 2015 and plans further measures with more sensitive equipment beginning in January.

Obviously one of the primary goals is to determine temperatures, masses, etc., for the stars in the system. But radial velocities of the respective components are critical and David is obtaining some extremely interesting results here. Look forward to some preliminary comments about all of this in the January newsletter. Figure 4 shows a representation of the system - not to scale - and this illustrates the complexity of sorting out and measuring the variety of velocities.

An update of these aspects will be included in the January newsletter.

Making the measures consistent by standardising the comparisons

All of the non-CCD measures appear to have used the same reduction methods but the same cannot be said for the CCD data, most of which has been collected by Variable Stars South observers. The problem arises with the comparison stars and values adopted. No fault of the observers but many have followed the AAVSO procedure of finding a published value of appropriate comparisons and using these. Most come from Guide 9 or similar where Hipparcos values have been transformed using the Bessell relationships which were not intended to be used in such a manner.

Mark Blackford measured the E4 and E5 regions on 24 April using a small refractor stopped down to 50mm, after that some selected stars in the QZ Carinae area were measured. Two sets of comparisons have been determined, one close to QZ for the narrow field CCDs, another more widely spread for DSLR cameras to select stars where contamination by close companions is not a problem. Results of this are shown in the table below. The project as mentioned in an earlier newsletter will carry on into 2018. Please use only the measured values of the comparisons as listed below.

Star	Identity	R A	Dec	V	B-V	V-R	V-I
AUK A	HD 93131	10h44m31.840s	-60°12'23.54"	6.448	-0.011	0.119	0.234
AUK C	HD 93695	10h48m24.633s	-59°57'52.44"	6.427	-0.121	-0.048	-0.092
CCD 1	HD 93191	10h44m27.532s	-59°53'05.41"	8.537	-0.004	0.000	-0.072
CCD 2	HD 305523	10h45m09.241s	-60°02'37.99"	8.543	0.185	0.167	0.382
CCD 3	HD 93222	10h45m15.964s	-60°10'48.79"	8.119	0.094	0.120	0.266
CCD 4	HD 93028	10h43m54.777s	-60°17'23.43"	8.375	-0.019	0.039	0.065
DSLRL 2	HD 93403	10h46m24.388s	-59°29'48.64"	7.265	0.234	0.198	0.435
DSLRL 5	HD 92741	10h41m51.592s	-60°03'43.10"	7.241	-0.008	0.014	0.031
DSLRL 6	HD 93843	10h49m18.064s	-60°18'47.49"	7.311	-0.021	0.043	0.098
DSLRL 7	HD 93683	10h48m18.800s	-60°42'25.00"	7.889	0.128	0.161	0.373

Table 1. Measured *V* magnitudes and colour indices of selected stars. For CCD observers CCD 3 and CCD 4 are the recommended comparison and check stars, respectively.

We welcome extra participants who we advise to consult the outline of the project which will be available on the reconfigured web-site in November as a description of the ‘QZ Carinae project’.

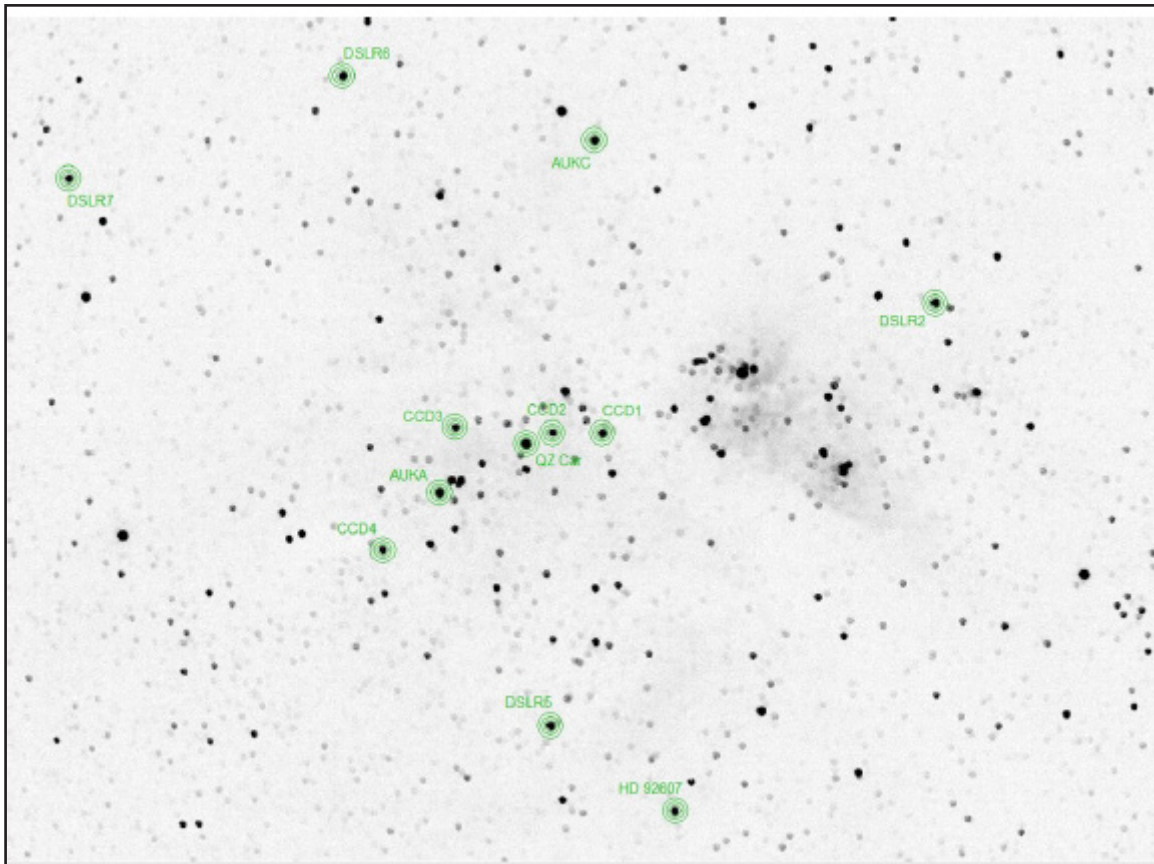


Figure 6. Finder chart for stars listed in Table 1.

References

- Leung, K.-C., Moffat, A. F. J., & Seggewiss, W. 1979, ApJ, 231, 742
Morrison, N. D., & Conti, P. S. 1980, ApJ, 239, 212

John Hearnshaw recently contacted me inviting contributions from VSS members to the JAAVSO. Below is an extract from John's email:

"I am on the editorial board of JAAVSO, and the AAVSO director, Stella Kafka, and editorial board chair of JAAVSO, John Percy, are seeking ways to expand the Journal and make it more international. The great majority of papers at present come from N America.

I am sure you are all very aware of JAAVSO, but perhaps not all members of VSS know about it, or perhaps they don't realize that JAAVSO would welcome their papers. Papers published are refereed, so it has a high level of credibility and the papers are widely respected in the international community. But apparently not many southern observers of variable stars are publishing there.

JAAVSO is referenced in ADS but generally only abstracts are visible on-line in ADS. You can read full articles on-line by downloading the pdf from the JAAVSO website <https://www.aavso.org/apps/jaavso/>

Anyway, the purpose of this email is simply to transmit the invitation from Stella Kafka and John Percy for VSS members to consider publishing their results in JAAVSO."

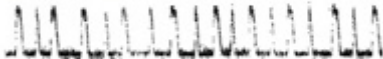
The JAAVSO is an excellent publication for scholarly papers on all aspects of variable star astronomy, including instrumentation, observation reports and data analysis. The website mentioned above has links to articles in the current and previous JAAVSO issues, as well as information for authors, editorial policies, etc. I am sure the editorial board would be happy to provide advice to prospective authors.



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Absolute parameters of young stars: QZ Carinae

W. S. G. Walker, M. Blackford, R. Butland and E. Budding. 2017 MNRAS.470.2007W

Abstract

New high-resolution spectroscopy and BVR photometry together with literature data on the complex massive quaternary star QZ Car are collected and analysed. Absolute parameters are found as follows. System A: $M_1 = 43 (\pm 3)$, $M_2 = 19 (+3 -7)$, $R_1 = 28 (\pm 2)$, $R_2 = 6 (\pm 2)$, (☉); $T_1 \sim 28\,000$, $T_2 \sim 33\,000$ K; System B: $M_1 = 30 (\pm 3)$, $M_2 = 20 (\pm 3)$, $R_1 = 10 (\pm 0.5)$, $R_2 = 20 (\pm 1)$, (☉); $T_1 \sim 36\,000$, $T_2 \sim 30\,000$ K (model dependent temperatures). The wide system AB: Period = $49.5 (\pm 1)$ yr, Epochs, conjunction = 1984.8 (± 1), periastron = 2005.3 (± 3) yr, mean separation = $65 (\pm 3)$, (au); orbital inclination = $85 (+5 -15)$ deg, photometric distance $\sim 2700 (\pm 300)$ pc, age = $4 (\pm 1)$ Myr. Other new contributions concern: (a) analysis of the timing of minima differences (O – C)s for the eclipsing binary (System B); (b) the width of the eclipses, pointing to relatively large effects of radiation pressure; (c) inferences from the rotational widths of lines for both Systems A and B; and (d) implications for theoretical models of early-type stars. While feeling greater confidence on the quaternary's general parametrization, observational complications arising from strong wind interactions or other, unclear, causes still inhibit precision and call for continued multiwavelength observations. Our high-inclination value for the AB system helps to explain failures to resolve the wide binary in the previous years. The derived young age independently confirms membership of QZ Car to the open cluster Collinder 228

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.

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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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