



Hristo Pavlov explains his video method for eclipsing binaries at VSSS4.

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From the director – *Stan Walker*

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Congratulations to Mark Blackford, David O'Driscoll and other helpers who organised Symposium Four of Variable Stars South - also to everyone who presented papers at an extremely interesting conference - and we all enjoyed NACAA which was more general in its presentations.

This issue of the newsletter is a little late as with the conference at Easter most of us had little time to spare for anything other than preparing for that. As to the symposium, various papers appear elsewhere. This was a very successful meeting and I and others were impressed by the variety of presentations and the standard of activities which they described. Apart from the eleven papers and five poster papers a further eleven papers were presented at the main NACAA conference. A pleasing aspect was a more active visual observers' presence with two spoken papers and a poster paper at VSSS4 and another spoken paper at NACAA. CCD and DSLR photometry papers were, as usual, varied and interesting.

The whole event was enjoyable – amongst the best conferences I've ever attended. A good venue, good organisation and a wide range of papers – excellent in both content and presentation. I hope to see many of these in formal print shortly. It may take several months but ultimately these will all appear in a group on the website.

It was announced that the next NACAA conference will be in Ballarat in 2018 and, whilst I will have retired as director by then and it will not be my decision, it might be a useful venue for VSSS5. Tom Richards has suggested that we are now strong enough to look at the concept of specialised conferences at 3-4 year intervals with more professional participation and this idea must be pursued. So things are a bit flexible but think about it.

Returning to the standard of papers we must ensure that these reach as large an audience as possible. Much of the work that is being done is worthy of publication in the mainstream professional journals but this needs theoretical input and discussion which is best provided by professional associates - an area to be explored and developed.

At the time of writing this I haven't seen the newsletter contributions but there are a number of items from members outside the regular group - a very pleasing development.

David O'Driscoll and I discussed a number of aspects of the web site whilst in Sydney. Prior to that we had added an 'urgent notices' area – largely aimed at particular observational projects but covering other items as well. One of the items raised at the concluding discussion in VSSS4 related to communication amongst members: either by way of the website or through the underused Google group. So we will add another area to encourage cooperation. An example of need is T Muscae, a semi-regular star which is being analysed by Aline Homes who would like some B and V measures to give her a clearer understanding of what type of star it is and why it's doing what it does. All of this means more work for David but his efforts are valuable and appreciated.

Expanding this concept we need a better interchange between members – what they're doing and any areas which may be of interest to others, or where others can help with a different kind of measure. The visual observers are the best placed to see if stars are behaving unusually. One star of interest is L² Puppis which Andrew Pearce has been following – the pulsations of this star died out almost completely in mid-2015 and are still at a low level. This star has been in the news lately and I see that Terry Bohlsen has made some UBV measures which are extremely interesting – but which I had to look at the International Database (AID) to find. Neil Butterworth is there with DSLR measures and the visual observers' input is strong.

Still in the visual field but including others such as Neil Butterworth and the old Auckland Photoelectric Observers Group - one of the poster papers presented at the conferences involved the ongoing Cepheid project. After discussing the detailed measures and the results with David O'Driscoll we will be treating

this as a prototype to display the results of our work in an easily accessible manner on the website. This is not new as Tom, Margaret and David have been doing this in the EB eclipse timing field (ToMs) but the data are not clearly accessible. So a separate 'Research' area is required. We are not interested in the detailed measures as they are in the AID but the results: epochs of maximum, O-C diagrams and tables, error estimates and other pertinent information which is useful to anyone else working in this field. Even links to published papers.

Prior to this we have used a 'project based' approach. This will still be retained in the present manner – and will continue to attract new participants - but we wish to see the results displayed or available in a more accessible form in this part of the site. The publication of papers is preferable but the material on which the figures are based is an important historical record and useful to others in the field.

Returning to visual aspects there are a couple of articles in this newsletter relating to particular stars - the Cepheid U Carinae and a dual maximum Mira, TT Centauri, where visual and photoelectric measures, even a spectrum in the latter case, are used to show the value of combining different types of measures and encouraging members to discuss what they're doing and hope to achieve. It would be good to develop a group of photoelectric observers to complement the visual measures - something like the old 'targets of opportunity' concept which now mainly looks at transient events - but in a more organised manner so that we don't get the feast/famine distributions which we see with some popular stars.

And finally - V777 Sagittarii will emerge from eclipse in early to mid-May. Details are on the website under '**urgent notices**'. It's a late evening/early morning object but please try to make a few measures in B and V. It's a struggle for DSLR but possible, though easy for CCDs. And it will resolve the orbital period.

Validation of variables discovered by McNaught – *Mati Morel*

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Summary

A list of 22 possible variables originally discovered by Rob McNaught in late 1980s have been re-examined using modern databases such as ASAS-3. Most of them are confirmed variables, and this note puts them on the record, together with ASAS-3 light curves.

Observations

Rob McNaught conducted his own part-time photographic search for variables in the period 1985-1987 from Siding Spring Observatory, using telephoto lens and film camera. The number of observations for each discovery was usually limited to three or four, but occasionally as many as eight. This was usually not enough to construct a meaningful lightcurve, but Rob could often confirm the variability by examination of UK Schmidt fields (R and IR plates), especially effective for red stars.

Discoveries

Around 1990 Rob sent me a batch of his hand-drawn sketches. The scales and amount of detail can vary greatly from one star to the next, some based on his original films, and others are copied from Schmidt plates. Nevertheless at that time it was hardly possible to extend his observations, or to classify his discoveries. The resources are now available via such tools as VSX, and ASAS (All-Sky Automated Survey).

I have re-examined all of his charts and identified his stars beyond doubt. ASAS-3 lightcurves are included here for all of his red variables. 15 stars are long period, one is of EA type, and one is a nova. Four stars proved to be constant (and do not appear in VSX). One star, no 16, has been omitted, even though labelled *V342 Ara* by Rob. His star is at (J2000) 16:36:20.45 -55:23:58.4, $r = 15.46$, due N of X Ara. This is not V342 Ara, and it may be the result of confusion with X Ara.

Discussion

Rob's magnitude estimates are not photometric, and very rough, and are not reproduced here. The

complete list of his discoveries is shown here as Table 1. Many are original discoveries, made long before ASAS came on line in about 2000, and a few are re-discoveries. Some have now received final GCVS designations, but 9 still have only their ASAS-3 names. In Table 1 I give the full range in V, from their ASAS-3 lightcurves. The *status* column explicitly confirms the variability (or not). *Type* is my own estimation, from the lightcurve. *Period* is in most cases taken from VSX.

Lightcurves are provided, from ASAS-3, for all red variables, as **Fig. 1 (a) to (o)**.

Sequences

Only three of the long-period variables in the list have full V sequences, from the AAVSO. They are : NSV 17686, QW Lup and V838 Ara.

References

McNaught, R. 1990. Private communication

Morel, M. And Camilleri, P. 1993. Inf. Bull. Var. Stars 3923

Pojmanski, G. 2002, Acta Astronomica, 52, 397. *The All Sky Automated Survey. Catalog of Stars*. <http://www.astrouw.edu.pl/asas/>
VSX database. <https://aavso.org/vsx/>

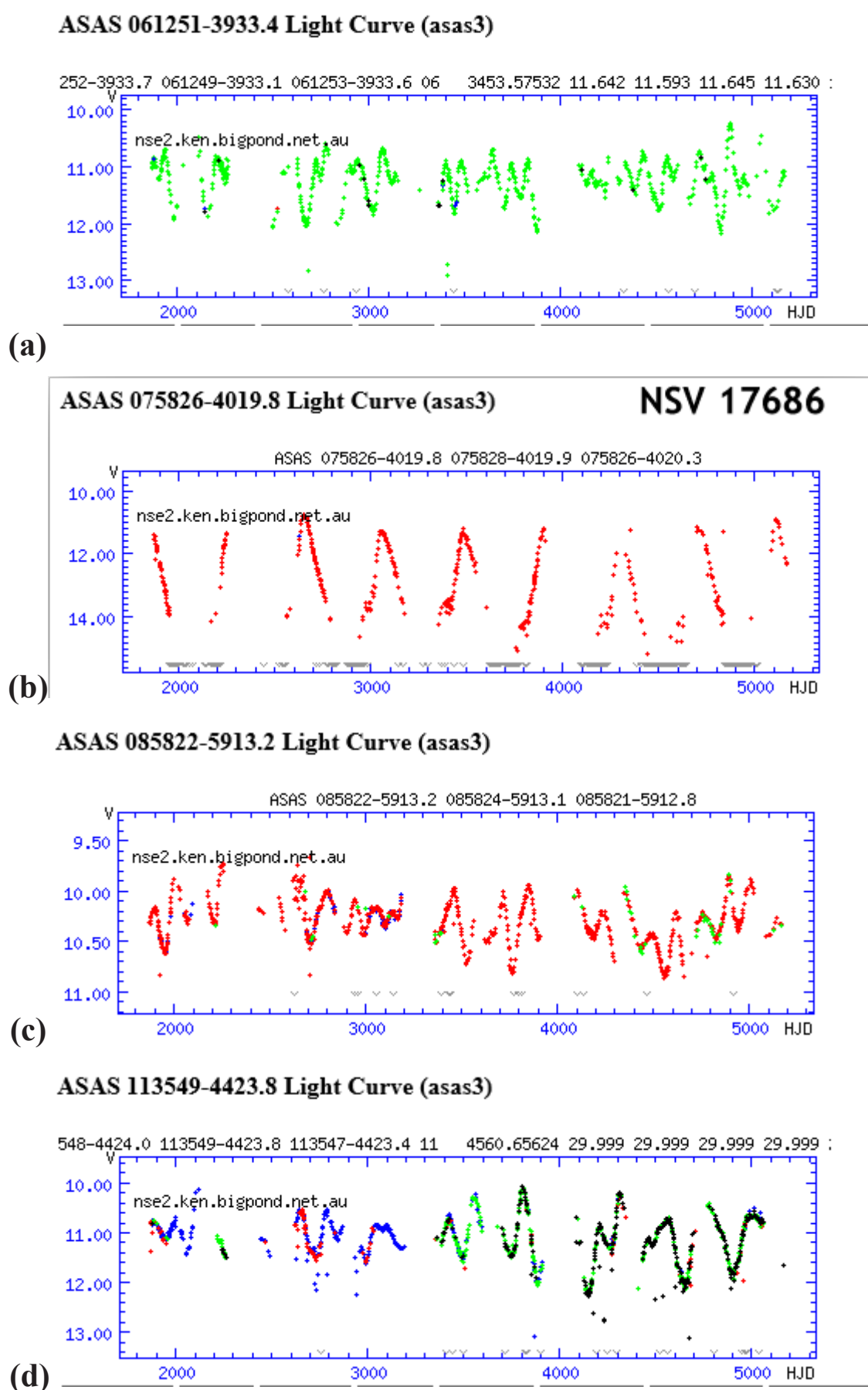
Table 1. VARIABLES DISCOVERED OR RECOVERED BY R MCNAUGHT 1985-1987.

Variable				Range. (V)						
#	Name	(2000)		Max	Min	Status	Type	Per.d	ASAS	LC
1	ASAS J061251-3933.4	06:12:51.18	-39:33:25.7	10.3	12.0	VAR	SR	170.5		a
2		06:19:05.2	+15:26:57	11.5		CST				
3	NSV 17686	07:58:25.87	-40:19:48.6	10.7	(15.0	VAR	M	410		b
4		08:07:04.1	-68:49:32	12.3		CST				
5	ASAS J085822-5913.2	08:58:22.31	-59:13:11.5	9.5	10.7	VAR	SR	129.3		c
6	ASAS J113549-4423.8	11:35:49.20	-44:23:47.1	10.0	12.2	VAR	SR	449		d
7	ASAS J114921-5221.9	11:49:20.41	-52:21:54.1	9.8	11.4	VAR	SR	855		e
8	ASAS J124758-4510.4	12:47:57.93	-45:10:23.6	8.5	9.8	VAR	SR	194.3		f
9	ASAS J142410-6344.4	14:24:10.22	-63:44:20.1	9.2	11.8	VAR	M	421.8		g
10		14:46:24.6	-53:41:15	13.4		CST				
11	QW Lup = NSV 6825	14:51:07.55	-54:46:18.8	10.0	(15.9	VAR	M	387		h
12	OQ Lup = NSV 6842	14:53:45.01	-54:38:14.6	12.62	14.4:	VAR	EA	1.83777		
13		15:31:26.78	-70:17:33.6	10.93		CST				
14	ASAS J161949-4553.4	16:19:48.74	-45:53:22.3	9.9	11.4	VAR	SR	215.0		i
15	V1161 Sco	16:32:45.93	-39:45:48.7	10.1	(15.4	VAR	M	433		j
17	V838 Ara	16:39:20.25	-54:04:35	10.3	17.0	VAR	M	254		k
18	ASAS J172353-4616.6	17:23:53.56	-46:16:36.5	8.7	10.2	VAR	SR	286		l
19	TT Ara	18:03:55.77	-47:13:59.3	9.3	14.4	VAR	M	353		m
20	ASAS J184925-4503.8	18:49:24.80	-45:03:42.4	10.0	14.0	VAR	M	357.3		n
21	V4579 Sgr (1986)	18:03:37.90	-28:00:08.9	11	16.5B	VAR	NB			
22	V1640 Aql	19:20:35.03	-03:57:50.8	10.9	(13.5	VAR	M	210		o

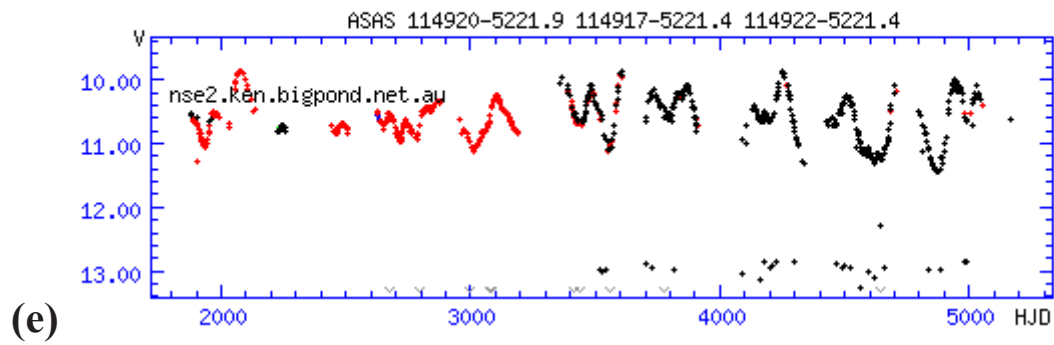
NOTES:

- 3 Also found by P. Camilleri (1993)
- 7 Also found by V. Tabur.
- 8 HD 111204 (Mb). 9.33v, +1.30 (Tycho-2).
- 10 IR excess.
- 11 IR excess.
- 15 Carbon star?
- 17 Also found by P. Camilleri (1993)
- 18 HD 157144 (M6 III). 9.26V, +1.48 (Tycho-2).
- 21 Recorded on short-exposure V plates for GSC. 04 Aug 87 m=12.75; 15 Sep 87 m=12.47

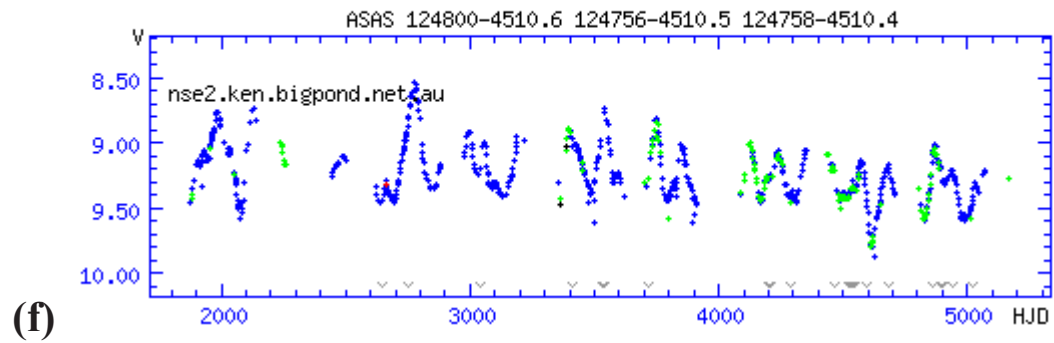
Figure 1. Light curves (a - d) of McNaught red variables from ASAS-3



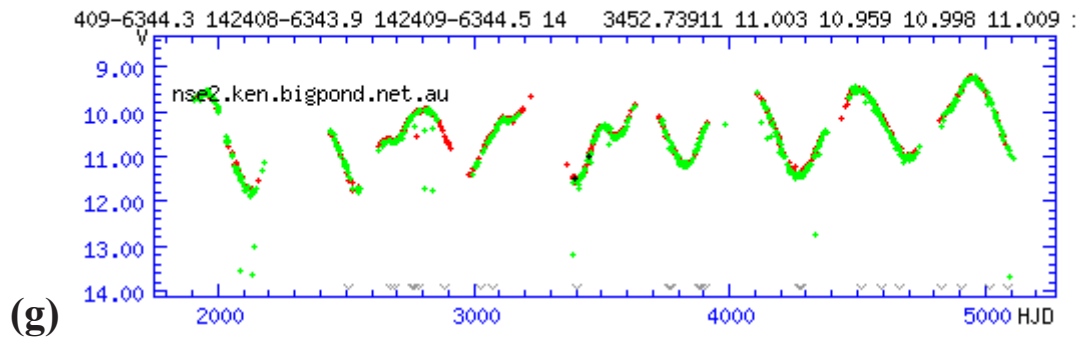
ASAS 114920-5221.9 Light Curve (asas3)



ASAS 124758-4510.4 Light Curve (asas3)

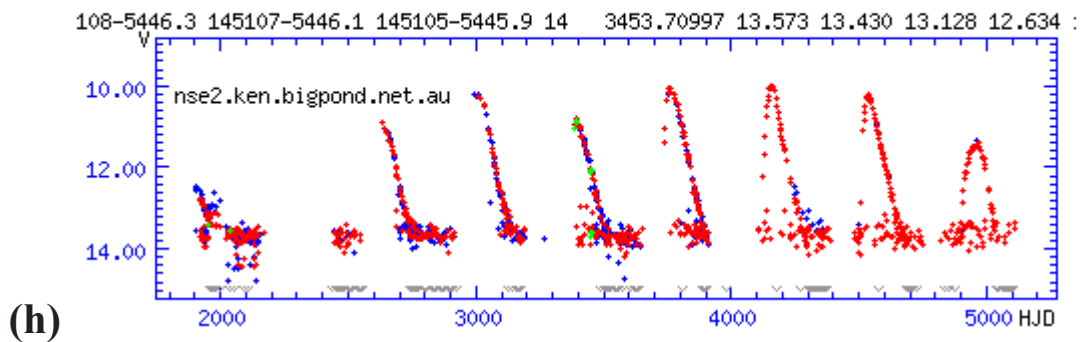


ASAS 142410-6344.3 Light Curve (asas3)

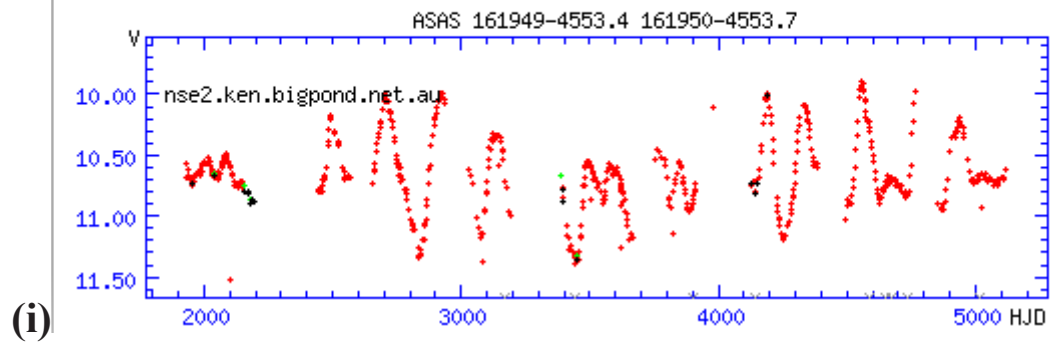


ASAS 145108-5446.3 Light Curve (asas3)

QW Lup

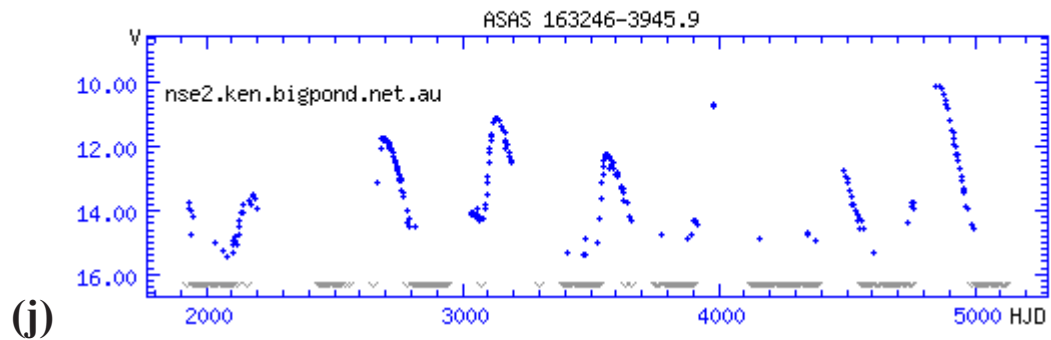


ASAS 161949-4553.4 Light Curve (asas3)



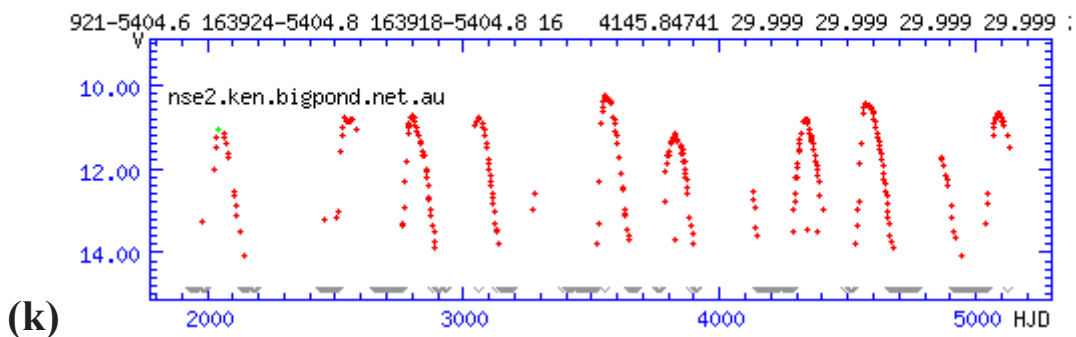
ASAS 163246-3945.8 Light Curve (asas3)

V1161 Sco

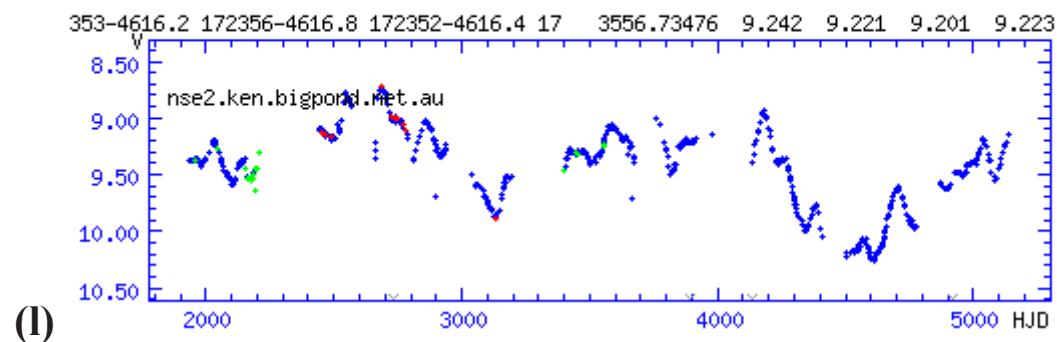


ASAS 163921-5404.6 Light Curve (asas3)

V838 Ara

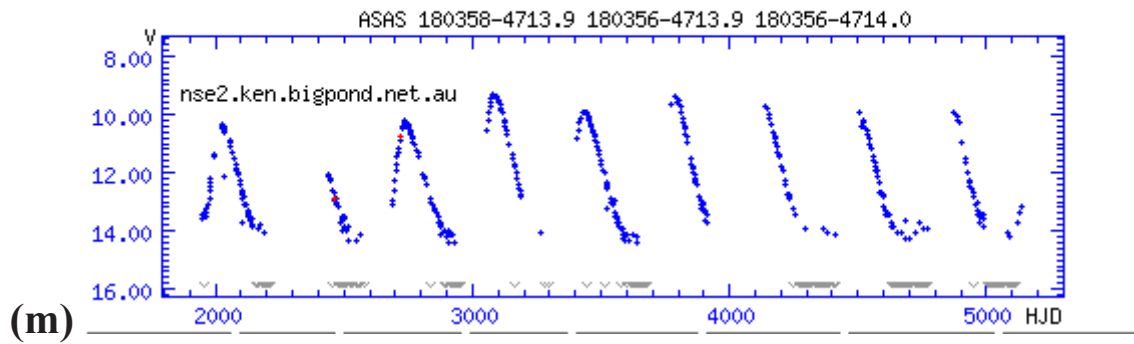


ASAS 172354-4616.6 Light Curve (asas3)

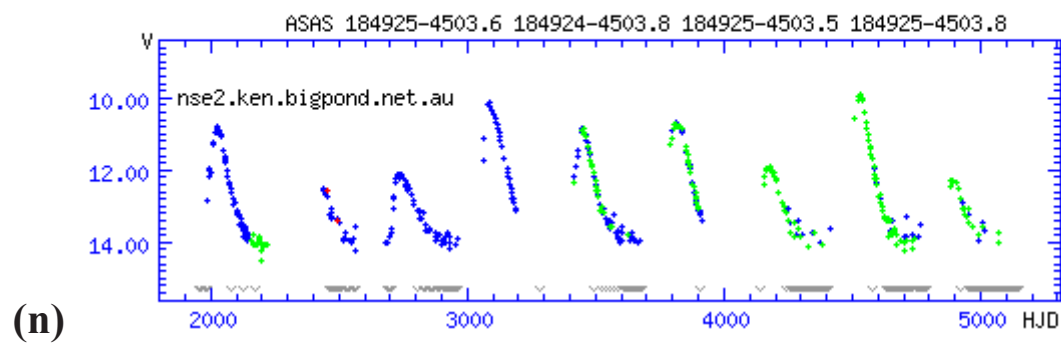


ASAS 180356-4713.9 Light Curve (asas3)

TT Ara

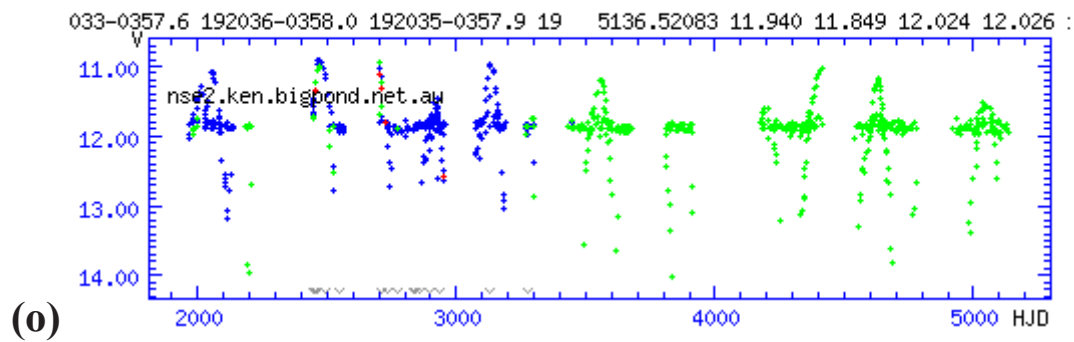


ASAS 184925-4503.7 Light Curve (asas3)



ASAS 192035-0357.8 Light Curve (asas3)

V1640 Aql



Variable Stars South report to the Royal Astronomical Society of New Zealand, Variable Star Section

Active membership continued to increase in 2015 with more than a dozen additions, some of whom made presentations at conferences or published refereed papers.

Members also attended conferences; eight were at the Mt John Anniversary symposium with fifteen or more at the associated RASNZ annual conference. A poster paper was presented at the former, two spoken papers and three posters were presented at the latter. As well, our editor, Phil Evans, attended a meeting in Hawaii of current and past Swinburne University masters students where he introduced VSS to a number of attendees. Andrew Pearce, an enthusiastic visual observer, presented a poster paper at the Spring Meeting of the AAVSO.

The new director of the American Association of Variable Star Observers, Stella Kafka, with some financial assistance from this section and the RASNZ, attended both the Mt John meetings and also spoke to the Auckland and Wellington societies. This allowed a useful interchange of views between our management committee and Stella which has continued with an on-line meeting in October with another to take place shortly.

Our director, Tom Richards, retired at the end of December, 2014, and Stan Walker took his place. A slight change of structure was introduced with the setting up of a group, known as the management committee for convenience, as the scope of our activities is becoming too large for any one person to lead effectively. At present this group comprises the director, plus Tom Richards, Mark Blackford, David Moriarty, David O'Driscoll, webmaster, Phil Evans, editor and Bob Evans, treasurer and membership secretary.

Tom's efforts since 2009 - and unofficially before that - have seen the rebirth of serious amateur variable star astronomy in Australia and New Zealand and a fitting tribute to his enthusiasm and inspiration was the award by our parent body of honorary membership of the Royal Astronomical Society of New Zealand at the 2015 annual general meeting.

An interesting innovation was set up by Carl Knight of Manawatu who helped a local year 11 student, Tessa Hiscox of Freyberg High School, in a practical project involving CCD measures of the Cepheid, UU Muscae, for her participation in the August 2015 science fair in Palmerston North. This resulted in a distinction prize for Tessa but the more lasting and practical result has been a series of meetings with school science teachers in the area and a general discussion about what cooperation is practical and realistic.

Also in the outreach area Alan Plummer continues to write a monthly article for Sky & Telescope, Australia, Alan Baldwin contributes items for the RASNZ newsletter, Stan Walker has written articles for Southern Stars and the Auckland Society's Journal and our website, maintained by David O'Driscoll, is very popular with many visitors.

Phil Evans edited four Newsletters during the year and these are available to anyone on our website at: <http://www.variablestarssouth.org/>. These cover a wide range of stellar topics and are well supported - even those going back years are still frequently accessed. David has also arranged that most presentations at the VSS symposia and other conferences are also available.

Visual observing continues to be strong

Andrew Pearce's following summary is typical:

Intensive visual coverage of about 400 LPVs between declinations 10S and 60S with the aim of detecting long term changes in period and the investigation of anomalous features such as humps on the ascending branches of the light curve and double maxima, etc.

Monitoring of RCB stars in the same declination range. I'm able to follow any fades down to about mag 15.5. During 2015, V854 Cen was especially active and a few others that had been below visual threshold for many years, brightened (V CrA, UW Cen, etc.).

Visual measures of all southern Milky Way novae. Highlights included V5668 Sgr which rose to 4th magnitude. V1369 Cen continues to be followed visually during its very slow decline.

Observations of bright southern Cepheids and semi-regular stars (brighter than 10th mag). Most interesting star in 2015 was L² Pup which displayed essentially a constant brightness near minimum (or a very narrow range of less than 0.5 mag) since July 2015.

Good coverage of southern eclipsing binary BL Tel

Other active visual observers include Peter Williams, Alan Plummer, Paul Camillieri, Rod Stubbings, Bob Evans and Stephen Hovell.

Peter Williams contributes the following summary of one long-term project.

BL Telescopii 2015 eclipse observations summary from Peter Williams:

Members of the VSS have successfully observed the 2015 eclipse of the Algol type eclipsing binary, this being the 12th eclipse monitored in this ongoing program. Although primarily a programme for visual observers, this and the previous eclipse have also been well monitored by observers using DSLR/CCD equipment and it is interesting to note that such electronic equipment was not generally available to amateurs at the onset of this long term programme.

This visual light curve indicates mid eclipse occurred on 2015 Aug 28.9UT (GJD 2457262.4), an interval of 778.4 days since the 2013 eclipse. The total duration of the 2015 eclipse was 75 days, slightly longer than average and the longest eclipse duration so far observed. A minimum brightness of magnitude 9.2 was observed.

Based on these visual results, the next eclipse of BL Tel will be centred near 2017 Oct 13 when this field will be well placed in the western evening sky at the end of twilight.

It is interesting to note the BL Tel programme has recorded 12 eclipses spanning an interval of 11671 days, some 32 years, and is amongst the longest continually running programmes to observe a specific star thus far coordinated through the VSS and is a tribute to the dedication of all observers.

Alan Plummer: V694 Monocerotis project

V694 Mon is a well observed bright Z Andromedae star that has been in my visual observing programme since late 2005. Over that time my observations of V694 Mon have been patchy. The farther north a target lies, the less interest I tend to have, plus, I noticed early on that my observations were noisy, which I found discouraging. (I now know 'noisy' is the nature of this beast's lightcurve.) Then take into account the warmer months not being good for observing from my location, a couple of years of *totally* bad observing conditions, and it's lucky I have a light curve at all. However, I have been able to keep it up through 2015, to see a spike in the light curve in early 2016.

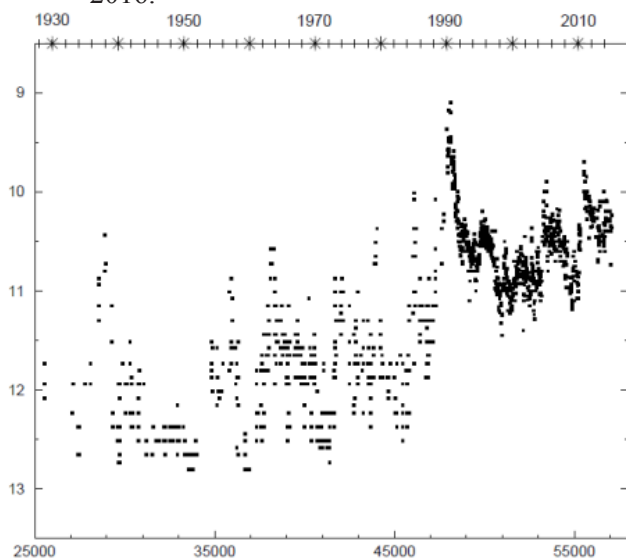


Figure 1. From Leibowitz and Formiggini (2015) shows data from 1928 until 2015. Archival survey observations are used until 1990 and, in response to that obvious brightening, amateurs (mostly Albert Jones) started observing the star. The data are clearly improved with the object being placed on the RASNZ VSS observing programme. The graph shows the ongoing value of visual observations. Z And stars are binary systems, and a subtype of cataclysmic variable stars. Leibowitz and Formiggini found V694 Mon has a 5.3 year period, somewhat evident in the light curve, reflecting possibly a pulsation period of a red giant, the (eccentric) orbital period of the binary system, or the precession of an accretion disc around a white dwarf.

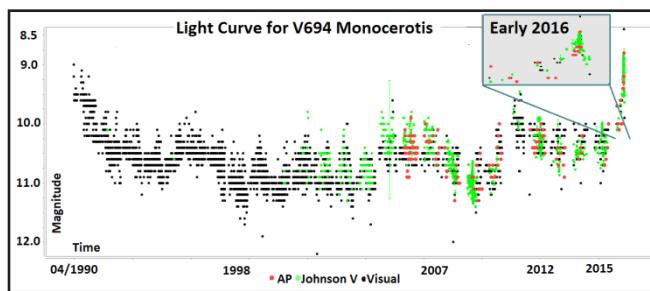


Figure 2. Shows the raw International Database data from 1990 until now plotted with VStar. This data—comprising VSS measures—can clearly be seen in Figure 1. A look at the recent data shows VSS members David Boyd, Eric Blown, and myself contributing. (Apologies to anybody missed out.) My observations are in orange, Johnson V are green, and other visual observers are black. It can be seen that the current outburst

of V694 Mon has been brighter than ever measured before. There is not space here to go into the physical nature of this exciting star; I encourage you to do so yourself. And observe it, of course.

2015 DSLR activity from Mark Blackford

The EB and EW binaries project received DSLR observations from the following:

Mark Blackford: NT Aps, RR Cen, BO Ind, MW Pav, V0386 Pav, EE Aqr

Neil Butterworth: V0878 Ara, eps CrA, DE Mic, UX Ret, V0883 Sco, V0954 Sco

Col Bembrick and Jonathan Powles have conducted light curve modelling using 2015 and earlier observations collected under this project. Their results will be presented at the Variable Stars South Symposium No. 4 on Good Friday, 2016.

M. Blackford also collected DSLR observations of:

QZ Car (QZ Car project led by Stan Walker and Ed Budding)

HX Vel, V0454 Car (Burcu Ozkardes)

Eta Mus, V0831 Cen, del Pic (Ed Budding)

BL Tel (Peter Williams)

KX Vel (Pavel Mayer)

David Benn has been doing DSLR photometry of R Car and BL Tel mostly, since Jan 2015 after taking Mark Blackford's DSLR course for AAVSO. Also some untransformed DSLR photometry (Tri-color Green) of novae.

Neil Butterworth is also active in the DSLR field. He comments:

Further to Mark's report, I also observed the following Cepheids:-

ST Pup, RS Pup, RZ Vel, SW Vel, RY Vel, XZ Car, WZ Car and U Car.

Also Mira or LPV stars: BH Cru, T Cen, R Cen, V744 Cen, NU Pav, V819 Ara, V3877 Sgr, V383 Nor, EY Cir and DP Ara

Roy Axelsen reports:

During 2015, I was able to get time series DSLR photometry on the following delta Scuti stars: V393 Car, V1338 Cen, V1430 Sco, V1307 Sco and AD CMi.

Eclipsing Binaries

The eclipsing binaries field has seen some changes. Initially it was divided into two sections - Algols, which have rather regular light curves and a rather complex group comprising beta Lyrae stars, W Ursae Majoris stars and others where the light curves show almost continuous variations. This left out some of the more interesting objects, eclipsing stars where one component is a pulsating variable and ignored completely the cataclysmic variables which are all interacting binaries.

The observations and analysis of binary systems is complex with a wide range of people and techniques involved. No longer do the VSS targets fit in neat little packages with easy solutions.

This has resulted in structural changes in projects, which the comments below from David Moriarty

illustrate. “As reported in the last newsletter, the EA project has been closed as such, and absorbed into a wider Eclipsing Binary project with the EW-EB project. The EA project was originally designed to search for circumbinary planets via eclipse timings; however, that requires a long time frame and many observers. Several VSS members contributed in the first few years, but all have now withdrawn. The last active observers were Margaret Streamer and David Moriarty. In the interim Tom Richards and Mark Blackford will co-ordinate the eclipsing binary projects, but the sheer complexity of these will probably lead to some interesting and valuable discussions at VSSS4”.

Changes within the eclipsing binaries programme — David Moriarty comments:

In 2015, my observations and research have been mostly on contact and near contact binaries and a few of the original EA set. The following were observed in B, V & I pass bands: V775 Cen, YZ Cha, AF Cru, TW Cru, BC Gru, RV Gru, RX Gru, V Gru, V626 Sco and AW Vel.

Margaret Streamer and I have resigned as leaders of the EA Project. The reasons are set out in extracts from an email to Stan: *“In my case, I find contact and near contact binaries very interesting and have been reading and studying papers on contact binary formation and evolution in order to write up my work with TW Cru over the past 5 years and more recently with BC Gru, RV Gru and V Gru. I am working now on papers on BC and RV Gru (the latter with Tom), as well as preparing for the work with UQ on the spectral project, for which V775 Cen and ST Cen are the principal targets. The latter are probably near contact, or close to being near-contact, binaries. In future, I would like to expand observations and modelling of near contact and contact binaries as well as semi-detached binaries, i.e. studies appropriate to the EW-EB project.*

Margaret has now enrolled at ANU in a 4 year part time M.Phil. degree, which will include course work and research that will concentrate on her interests with some of the oscillating eclipsing binaries.”

I will be supervising an Honours student at the University of Queensland to obtain high resolution spectra of several eclipsing binary targets from which spectral types and radial velocities can be determined and thence combined with my photometric data to develop accurate models of the binaries. Sarah Sweet (a postdoctoral astronomer at the ANU Research School of astronomy and Astrophysics) and Michael Drinkwater (Professor of Astrophysics at UQ) are collaborating on the project. We will use the ANU 2.3 metre telescope at Siding Spring Observatory in April, 2016.

A paper with the work of the EA Project group was published in 2015:

M. Streamer, J Byron, D. J. W. Moriarty, T. Richards, W. Allen, R. Axelsen, C. Bembrick, M. Blackford, T. Bohlsen, D. Herald, R. Idaczyk, S. Kerr, R. McIntosh, Y.Ogmen, J.Powles, P. Starr, G.Stockham. *Revised Light Elements of 78 Southern Eclipsing Binary Systems*. JAAVSO 43: 67-73, 2015

Tom Richards reports on the Eclipsing Binaries project - CCD results

In the past year three observers have recorded 65 minima in the project database (Phil Evans, Rarotonga (15 minima); Robert Jenkins, Adelaide (2 minima); and Tom Richards, Kangaroo Ground (48 minima). Target systems were MR Aps (4 minima plus light elements), V676 Cen (17 minima plus light elements), YY Gru (4 minima), NSV 1000 Hya (8 minima plus light elements), DI Mic (5 minima plus light elements), GZ Pup (5 minima plus light elements), CP Scl (8 minima plus light elements), AD Phe (7 minima plus light elements), BU Vel (6 minima plus light elements) and W Vol (1 minimum). A paper on these results is under construction.

Publications by members of the CCD group:

Moriarty, DJW, *Period Analysis, Photometry, and Astrophysical Models of the Eclipsing Binary TW Crucis*, JAAVSO 43, 2015.

Southern binaries programme: An overview from Ed Budding

A programme of studies of (relatively neglected) southern eclipsing binary systems has been underway in recent years, involving spectrographic observations at the Mt John University Observatory, as well as important new photometric contributions coming from members of the VSS.

While it is relatively well-known that the '*eclipse method*' can yield absolute parameters of stars, such as luminosities, masses, radii and distances, it is less well-recognized that top quality local instrumental development, such as the Hercules facility at Mt John, is now pushing results to a new high level of precision. When such data are combined with the remarkable and proven capability of VSS photometry, including new multicolour DSLR data, at least for stars brighter than $V = 8$, resulting parameters are used to test the latest developments of theory. For example with the incorporation of wind-driven mass loss, more advanced models of convection or tests of composition.

The special access (due to location) to the great <stellar nurseries> of the southern hemisphere, such as the Sco-Cen OB Association (the nearest such formation in the Galaxy), gives added significance to this collaborative research. Recent papers from the Southern Binaries programme in leading journals establish the exemplary quality of the findings. We are demonstrating the ability to check and clarify contemporary areas of study in stellar astrophysics, from the formation of stars through their evolution and ultimate fate.

This is a list that I recently prepared on radial velocity measures made (but not yet published) using the Hercules spectrograph at Mt John.

delta Cap

QZ, V454, V462 and V486 Car

V655 and V766 Cen -- partial coverage.

V851 and V863 Cen -- good coverage

HZ, UW, LZ, MS, and tau CMa.

eta Mus (ongoing , follow-up work)

delta and VV Ori -- a lot of data;

delta Pic,

pi, PU and V410 Pup

HX, NX, V356 Vel

But completion of the (difficult) QZ Car project is a bit of a priority at present.

Beginners & outreach from Alan Baldwin, beginners programme coordinator

During the year sets of charts have been sent to a few enquirers who have made contact either by way of the web-site or by referral.

With the visit of Dr Stella Kafka, director of AAVSO to New Zealand in May, publicity on variable star observing was given at meetings of the Auckland and Wellington Astronomical Societies and at the RASNZ Conference at Tekapo. In addition presentations were made at the Swinburne Conference in Hawaii by Phil Evans and at the Foxton StellarFest in the Lower north Island region by Alan Baldwin.

There has been considerable discussion in the background on ideas for projects for people new to astronomy to introduce them to observing and so generate skills which can be built on with more sophisticated projects. This year this has led to a focus on projects for secondary school age students; these could particularly be conducted through Science Fair projects. In Palmerston North we had an example with Tessa Hiscox monitoring UU Mus for a Science Fair project, who was mentored by Carl Knight and Stella Kafka. Some guidelines for this activity were given by Carl Knight in an article in the December 2015 issue of Southern Stars (Vol 54, No 4, pg. 10. Some more sharing of ideas of suitable projects for this space would be welcome.

It is helpful to have the mentoring role distributed and it seems logical to have the mentor, if the match is reasonably close, to live in the same region. Some of this has happened in this past year

and I appreciate the help of VSS members who have assisted in this way and we hope it will bear fruit in due course. I hope other members will be willing to help if approached.

Pulsating variables - a summary from Stan Walker

Most of 2015 was devoted to setting up a Cepheid monitoring programme aimed at stars brighter than $V = 10$ with periods in excess of 10 days and amplitudes greater than one magnitude. These stars are easy to observe visually with acceptable accuracy. These have been observed for decades by some observers but using classical visual techniques which are not entirely suited to Cepheids or other small amplitude pulsators. Considerable improvement in accuracy can be obtained by using comparison sequences better suited to such stars and this is being developed. A presentation about the type 2 Cepheid, ST Puppis, was made at Tekapo and later published in JAAVSO. Neil Butterworth, DSLR BV, and Andrew Pearce, visual, continue to follow this unusual and challenging object. Butterworth has followed 7 other Cepheids. Pearce and Williams are observing others visually.

Some attention was given to colour changes in certain Mira stars showing abnormal light curves but it is a slow process and requires patience. Eight of Butterworth's stars are Miras and LPVs.

Delta Scuti stars are monitored by Roy Axelsen, and Margaret Streamer is working on these objects in binary systems. Even the BL Telescopii project involves pulsation as it is a good example of a complex system with a hot star, the companion to which is a semi-regular pulsating star.

Semi-Regular Star Analysis – Aline Homes

Preliminary analyses for three bright semi-regulars, T Muscae, T Centauri and L² Puppis have been completed so far and results have been summarised in a poster presented at the RASNZ Conference in Tekapo. Most of the variation of T Mus can be accounted for by the interaction of two cycles, a primary cycle of 375.5 days and a longer secondary cycle of approximately 1001 days. There is still some variation to be accounted for. The amplitude of variation for this star has more or less doubled in the past few years, mainly due to deeper minima. Only visual data are available and colour data for T Mus are urgently needed.

Where colour data are available, maxima and minima in V have been found to lag behind those in other wavebands by 20-25 days. This is particularly marked in T Centauri. Dust emission events have been detected in both T Mus and L² Pup and these appear to have caused perturbations in the behaviour of the star, as well as dimming. The dimming of L² Pup has been particularly marked and persistent, but analysis of available observations on this star is ongoing. Pressure of other work and the need to find and train a new analyst have meant that not much progress has been made since the Tekapo conference, but work should begin again shortly.

Exoplanets from Phil Evans

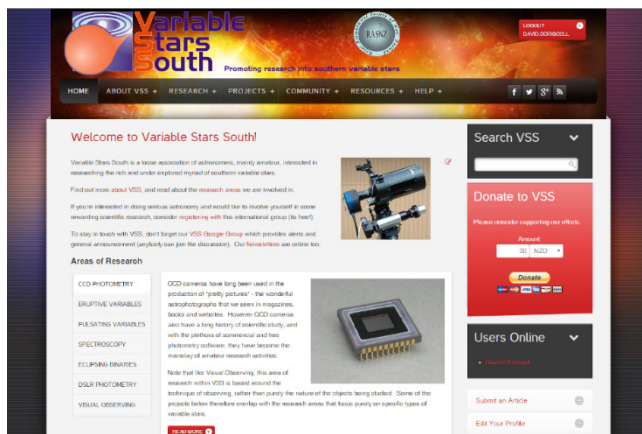
Phil Evans continues to pursue exoplanet transits and during 2015 published observations of ten transits on the Exoplanet Transit Database maintained by the Czech Astronomical Society. They were of WASP 28b, 31b, 50b, 57b, 64b (2 transits), 75b, 97b and HATS-1b & 5b. He co-authored a paper on WASP-41b along with professional astronomer Martin Vanko and Perth amateur T G Tan.

Vanko, M., Evans, P., Tan T G. (2015). "*The refined physical properties of the transiting exoplanetary system WASP-41.*" *Astronomische Nachrichten* 336: 145.

The VSS Website

VSS has managed a website as its primary method of communication since its inception.

This website supports over 120 registered members of the community as well as external unregistered guests. Over 1000 pages of content and more than 1050 individual files are served by the site to members and visitors.



Countries	Pages	Hits	Bandwidth
United States us	3,271	13,088	490.22 MB
China cn	2,148	2,784	389.55 MB
Ukraine ua	1,679	1,737	91.06 MB
France fr	1,198	2,384	152.39 MB
Ireland ie	1,051	8,264	210.81 MB
Austria at	840	840	107.50 MB
Australia au	564	5,179	235.75 MB
Germany de	439	1,000	165.78 MB
Russian Federation ru	373	526	25.96 MB
Canada ca	301	527	42.15 MB
Unknown zz	218	822	41.84 MB
New Zealand nz	203	2,119	86.06 MB
Great Britain gb	146	1,157	57.82 MB
Netherlands nl	125	183	15.12 MB
Brazil br	116	208	31.17 MB

The site serves approximately 1500 unique visitors every month who access an average of 13,000 pages, representing over 2Gb of data. Site visitors come from all over the world, although some of these represent attacks on the site which need to be defended against! Significant effort has been expended trying to ensure that the site remains secure and available. VSS also has an active discussion forum hosted by Google Groups that allows the VSS management and members to ask questions and share information.

Webhosting and software costs are the only significant costs incurred, and have been managed through the use of free software where possible. 2015 saw the site transferred to a new hosting provider who could provide a more stable environment for the site.

Stan Walker

Director RASNZ VSS

Our fourth symposium on variable stars was held in Sydney over the Easter weekend in conjunction with the 27th NACAA - the National Australian Convention of Amateur Astronomers. About 150 amateur and professional astronomers were registered for NACAA, about 40 of those attended the VSS seminar.

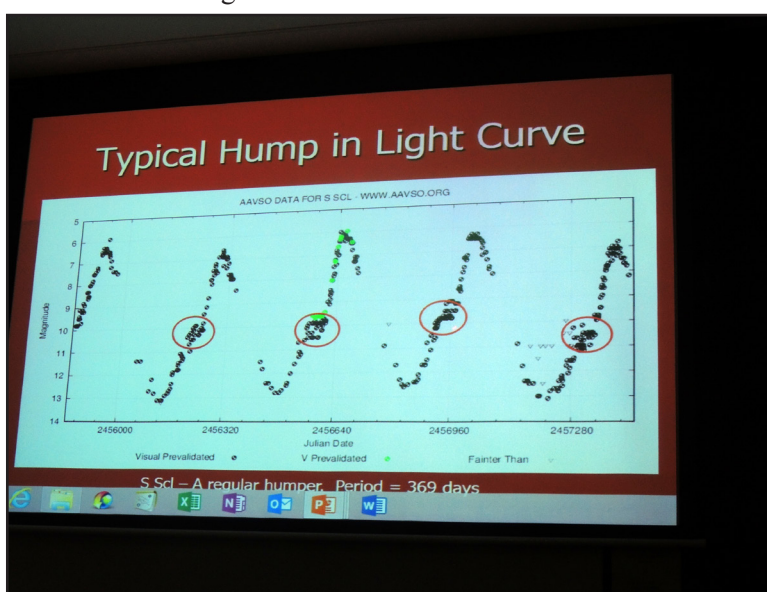
For many of those seminar delegates the weekend began with an informal get-together on the Thursday evening at the Duck Inn, a restaurant near to the hotels where many were staying. Although I was unable to attend I have been assured by those who did that it was a very convivial evening.

The seminar proper began on Friday morning at a lecture theatre in the new Faculty of Law building at the University of Sydney. After a brief welcome by Mark Blackford and an introduction by Stan Walker, our present director, the main programme began with **Margaret Streamer** discussing the EA binaries project which she and David Moriarty jointly directed. In her presentation she highlighted the successes of the project and the publications that arose from it, but pointed out that there was still a long way to go with at least 73 targets in her list still to be observed in different filters. She also noted that V0339 Ara

had some major differences in out of eclipse magnitudes between observers.

Andrew Pearce then discussed his and others' visual observations of long-period variables (LPVs). He talked about the simple equipment used and showed how visual observation demonstrated that LPVs are far from predictable with examples of humps on ascending branches of LPV light curves.

Jeff Byron's presentation concerned methods of generating light elements for eclipsing binaries and in particular highlighted the need for weighted regression and correct interpretation and use of uncertainties. He demonstrated a quantitative procedure for combining



A slide from Andrew's talk showing humps on the ascending branch of the light curve the long-period variable S Scl.



The setting for VSSS4 in the Faculty of Laws building

historical ASAS data into the light element calculations and introduced his own software 'Jackknife' for producing times of minimum with more realistic error estimates than commercially available software. An expanded version of Jeff's presentation is published on page 26 of this newsletter.

After morning tea **David Moriarty** gave two presentations on his work modelling eclipsing binaries. David first discussed how the catalogue data for some southern clipers are not correct, illustrating this with his observations of V0626 Sco and V0775 Cen. He showed how the temperature of the secondary in



David Moriarty's two presentations concerned modelling of certain eclipsing binary systems.

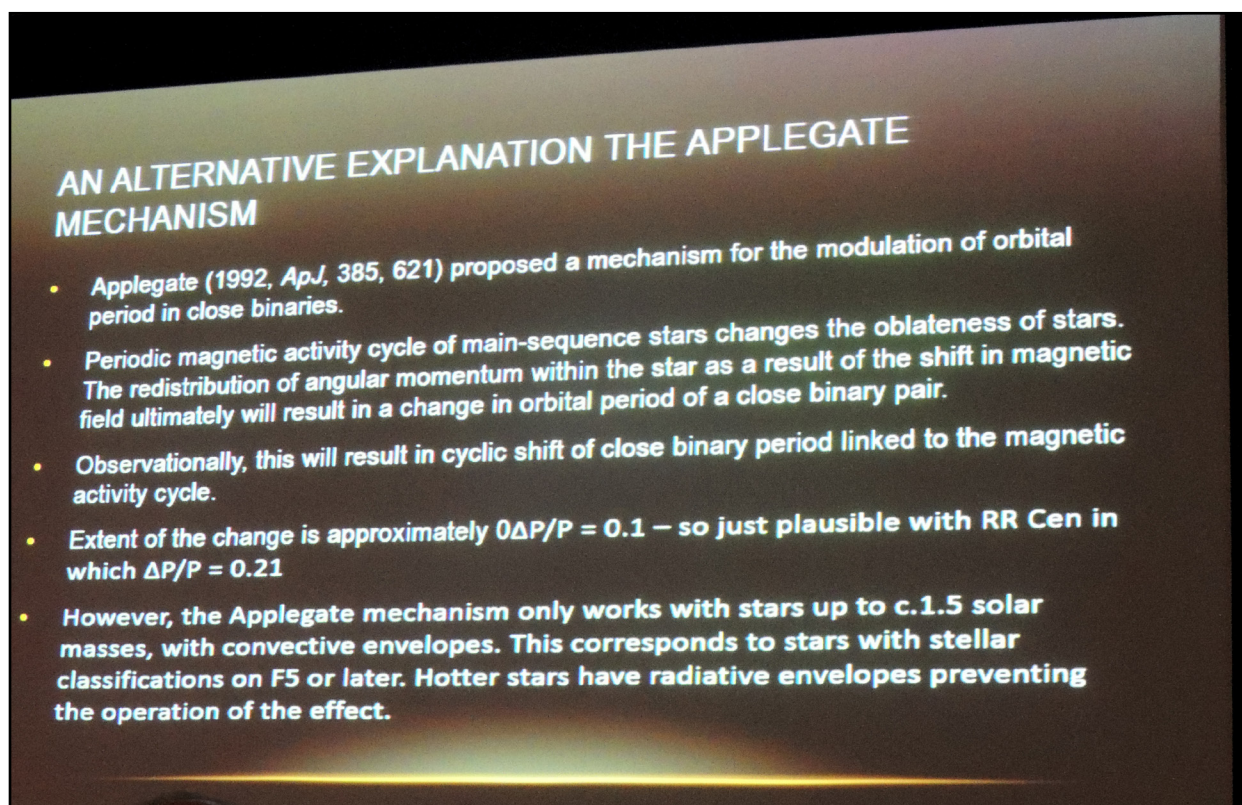
V0626 Sco is much lower than catalogue data and that V0775 Cen is not the detached binary that catalogues say but is more likely in a near contact state.

His second presentation covered similar work modelling the over-contact binary BC Gruis. He speculated that the variation in orbital period that has occurred since its discovery may be due to mass exchange or the possible presence of a third component recently revealed through spectroscopy at the ESO.

David presented a revised astrophysical model of the BC Gruis system.

binary. Previous explanations for the increased period and sinusoidal variability of the period relied upon mass transfer or the presence of a third body in the system. Using historical data and observations by himself and Mark Blackford, Jonathon concluded that the period increase was part of a 90 year oscillation. He suggest that this variation may be better understood as being caused by the Applegate mechanism – changes in oblateness of the system due to magnetic activity of the outer layers of the system.

The last presentation before lunch was by **Jonathon Powles** who offered an alternative explanation of the changing period of RR Cen, an EW contact



Jonathon Powles offered the Applegate mechanism as an alternative explanation of cyclic period changes in RR Cen - a contact EW eclipsing binary system.

Morning and afternoon teas and lunch were held in the Taste Baguette Cafe, upstairs from the lecture theatre providing the time for informal discussion among members and the opportunity to meet and get to know one another.

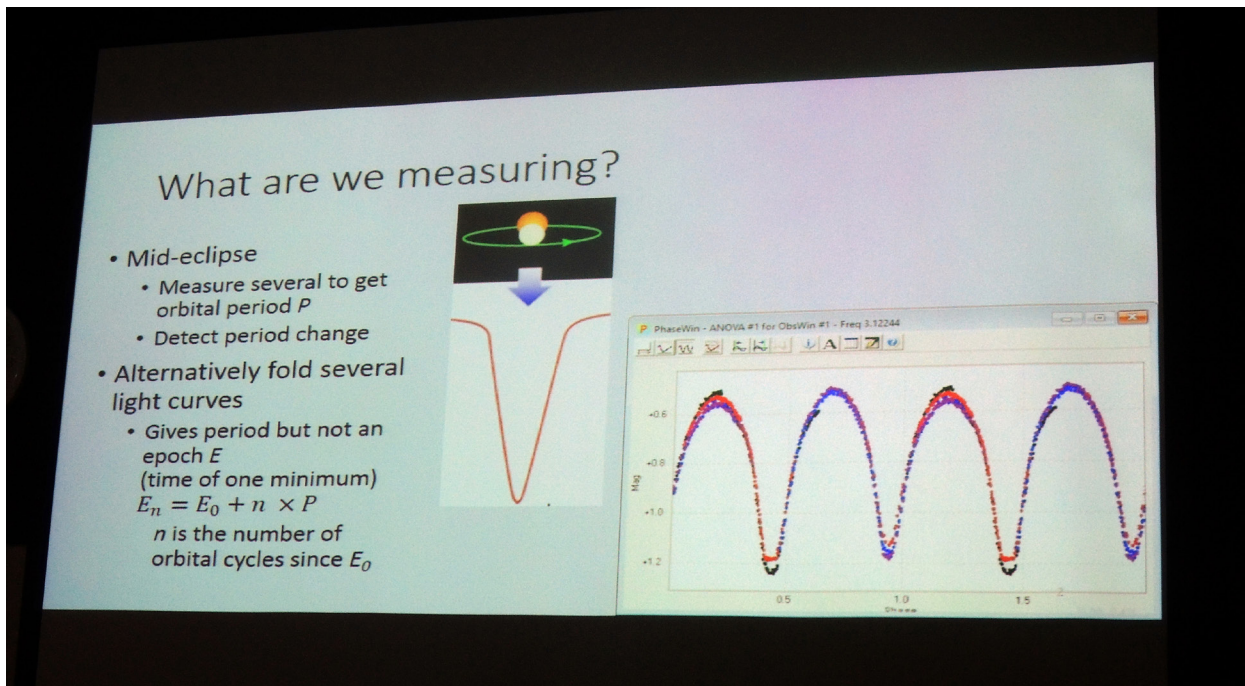


Peter Lake and Tom Richards.



Bernard Heathcote, Col Bembrick and Margaret Streamer.

The afternoon session was kicked off by **Tom Richards** who ‘plumbed the depths’ of eclipsing binary minima, comparing methods of determining the time of minimum. He explained how the standard KvW (Kee and van Worden) was problematic in that it expected full symmetry of the descending and ascending portions of the minimum curve. He recommended that observers use Bob Nelson’s six methods software and obtain an average time for the minimum.



Tom Richards explained how to measure the period of an eclipsing binary.

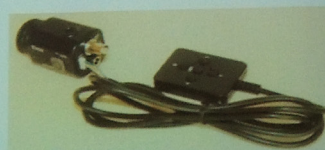
Tom’s talk illustrated an aspect of CCD observations - in general they have poor time resolution - that the next speaker may well have overcome with a novel method of observing eclipsing binaries. **Hristo Pavlov** showed his method of using a video camera to measure the light output of an EB.

Because video cameras use high frame rates (compared to CCD cameras) they offer much finer time resolution making the business of finding the time of minimum that much more accurate.

Hristo has developed his own suite of software to control video cameras and for the reduction of astronomical data from them. It is available from his website www.hristopavlov.net and is free of charge.

How is Video Different?

- More noise
- Order of magnitude more data points
- Video is 8 bit
- Video may be non linear
- Not good for calibrated photometry
- Accuracy of 0.02 mags rather than 0.001 mags
- Timing unaffected
- Good for timing light curves



Video observations for variable stars has its pros and cons as Hristo pointed out.

Its good time resolution aside there are problems with its use for eclipsing binary work. It can only be used for bright stars, is inherently noisier, lacks depth in being only 8-bit as opposed to the 14 or 16 bit depth of CCD cameras, it may be non-linear and can only provide a precision of 0.02 magnitudes.

Murray Forbes then provided us with a snapshot of his PhD thesis when he described an improved method for determining extinction in various filters. Murray's presentation can be found on page 34 of this newsletter.

Also published in this newsletter is **Ed Budding's** presentation on the quadruple system QZ Car. Ed's presentation begins on page 20 and includes recent DSLR observations by **Mark Blackford** and historical data collected by **Stan Walker**.

Mark also made a short presentation on his use of DSLR cameras for variable star observations.

Finally **Peter Williams** treated us to his recollections of 45 years of visual observation of variable stars. Over that time he has had a number of memorable moments including the early detection of declines in R Corona Borealis stars and being the first person to detect the naked eye nova Nova Vel 1999. Peter was also was the first to detect comet 1998 P1 (comet Williams).

General discussion followed led by **Stan Walker** who asked for ways in which we could improve our organisation. Comments from the floor included:

- the need for collaboration between visual and electronic observers
- having CCD observers and equipment ready for alert work
- an email group for alert work
- greater education at star parties
- website needed to be updated more frequently
- make use of the "Ice In Space" website for publicity
- demonstrations at star parties with portable equipment
- building up our own data library not necessarily in AAVSO format.

Abstract

The four main components of QZ Car form a pair of close binaries that share a wide orbit with a period of about 50 years. Observing this system is not really as simple as ‘two binaries for the price of one’, however, as these massive young stars are involved in complex processes of interaction. A comprehensive picture of the system has been worked on for some time. A review of the various aspects of this effort brings out, in the one target, many of the more general issues in close binary research.

1. Context

I should first say thanks to all those involved in organizing this wonderful meeting and also to all here who came to listen. The talk’s title concerns QZ Carinae – but I’ll also be trying to reach out a bit to the wider programme beyond this individual system.

The basics of binary star research are probably well known to most of you. Figure 1 shows a postage stamp produced by the Czech Republic featuring the late Prof. Zdenek Kopal, my old teacher in Manchester – way back. Note also the famous ‘Roche lobes’ in this picture. Kopal was the author of a well-known reference book on close binary systems, and if you want to go more into technical details that could be a starting point. A couple of years ago an international meeting was held in Bohemia to celebrate the centenary of Kopal’s birth there, and I presented a paper noting the significant contributions of VSS-members through collaborative programmes including observations of close binary stars like those discussed in this article. The role of DSLR photometry is of special interest here, I believe.



Figure 1. *Official postage stamp featuring binary astrophysics*

A couple of simple facts are worth pointing out: 1. The analysis of binary star data can tell us a lot about stellar properties in general. Many binaries studied in this way are well-known, but a large proportion of the still relatively unknown group are in the sky’s southern hemisphere. 2. Relatively simple equipment can produce information of great scientific interest, when properly applied. I am sure that others are giving more details about this kind of work at this meeting; I just wanted to mention this -- and support it. But a lot of the pieces in the jig-saw puzzle of absolute sizes, masses, luminosities, and so on, of stars can be put together when we combine photometry – such as that in DSLR light curves – with spectrographic information. In order to get the spectrographic information in this programme we have been making use of the 1m telescope at Mt John University Observatory and its high resolution Hercules spectrograph (Idaczyk et al., 2013).

Table 1 comes from notes in my workbook during last December’s visit to Mt John. This is not a complete list of targets, but it should give a few ideas. You may recognize some stars you are interested in on this list. The red ones require more observations. The black ones now have reasonably full radial velocity curves, and we should be writing up and publishing our information on such examples.

Recent SBP targets (Dec 2015)

Star	rv coverage situation
Cap d	Some more points desirable
Car QZ	Now not bad. A few more points may still be desirable for better rvs.
v454	Fairly good.
v462	Fairly good.
v486	Fairly good.
v655	Target of opportunity – small number of points
eta	An ongoing project, to check on long-term behaviour
Cen v716	None yet
v788	" "
v851	Small number so far
v863	Now probably enough for good rv curve
Cir del	None yet
CMa HZ	Good rv coverage
UW	" "
tau	" "
LZ	More rv coverage needed
MS	" " "
MX	" " "
Mus eta	ongoing long-term project to check on γ -velocity
GT	2 only
Ori del	Good rv coverage
VV	" " "
π^5	New target: few rvs only
Pup PU	Now fairly good coverage.
NO	" " " "
v410	" " " "
Sgr ups	maybe collect a few more (on cloudier nights...?)
Vel HX	Now fairly good coverage.
NX	" " " "
v356	" " " "

Table 1. *Observing shortlist taken from Dec 2015 workbook. Examples in red prioritized here.*

2. QZ Carinae: why an enigma?

For a start, QZ Car is not simply a binary, but a pair of binary stars: a quaternary, that can be regarded as an hierarchical wide binary composed of two closer pairs. Fig 2 gives an idea about this, though some of the numbers can be argued about. The smaller of the two systems – System B – is an eclipsing binary, so, as mentioned, can be of considerable assistance in providing facts. However, field maps of the target region show that the system is located in a kind of great and blotchy fog. QZ Car, in fact, is immersed in that large star-forming region well-known as the Great Carina Nebula, quite close, on the sky, to eta Carina itself, and also at the centre of a nice-to-see star little cluster known as Collinder 228. This is a very heterogeneous part of the Galaxy.

We do not doubt the O-type stellar classifications for QZ Car, so we can at once suspect that we are dealing with very massive, hot stars that source powerful and interacting stellar winds. That was indeed the subject of Parkin et al's paper of a few years ago, from where the sketch in Fig 2 comes. Parkin et al found QZ Car to be an inherently strong X-ray source.

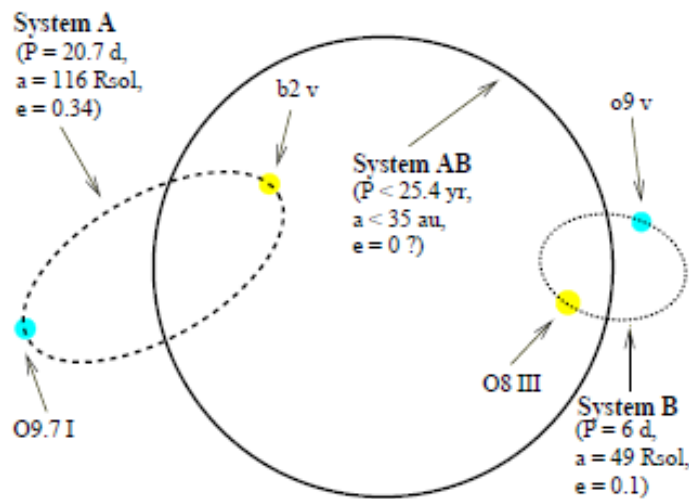


Figure 2. *Schematic representation of the QZ Carinae quaternary system*

In recent years attention has been called to the brightening up of stars in eccentric binaries at times when they come close together. This is due to the enhancement of the proximity effects with closeness of the approach. By proximity effects I mean the tidal extension of the bodies and the so-called reflection of light due to the mutual illumination and heating. The more eccentric is the binary the stronger will be this effect, but the shorter the pulse-like rise of brightness. From the shape of the light curve, this has been called the ‘*heartbeat effect*’. We wondered if this might occur in the more massive A component of QZ Car, which has a fairly eccentric orbit – and it may too – but our calculations suggest that this effect is small compared to other light curve complications.

One of the special problems about QZ Car is that the eclipsing binary’s period is very close to 6 whole days. This means that every six nights the same bit of the light curve returns. It implies that a long time is required to build up the picture – although, the situation may not be all that bad. I calculate that it takes about 120 days for a given phase window to drift on to where the next one had originally been. In other words, getting the light curve may be a whole season’s job, so something of a challenge. But not impossible. That problem did not apply to the HIPPARCOS satellite – but in that case there was something else. The HIPPARCOS light curves, shown in Fig 3, are pieced together from 3 years of intermittent monitoring. In that time, the wide orbit of the two binaries would have traversed about 20 degrees of its own cycle. It means that the HIPPARCOS light curve, depending a bit on where it was in this long cycle, could be a bit blurred, due to the so-called light time effect. That effect is basically the one noticed by Roemer, who first measured the speed of light from the timing of Jupiter’s satellite eclipses. As it is, simple fitting of a model to the HIPPARCOS data shows that the scatter of points about the mean light curve is significantly greater than would normally apply – up to several hundredths of a magnitude, as you can see – rather than the more typical 1 hundredth.

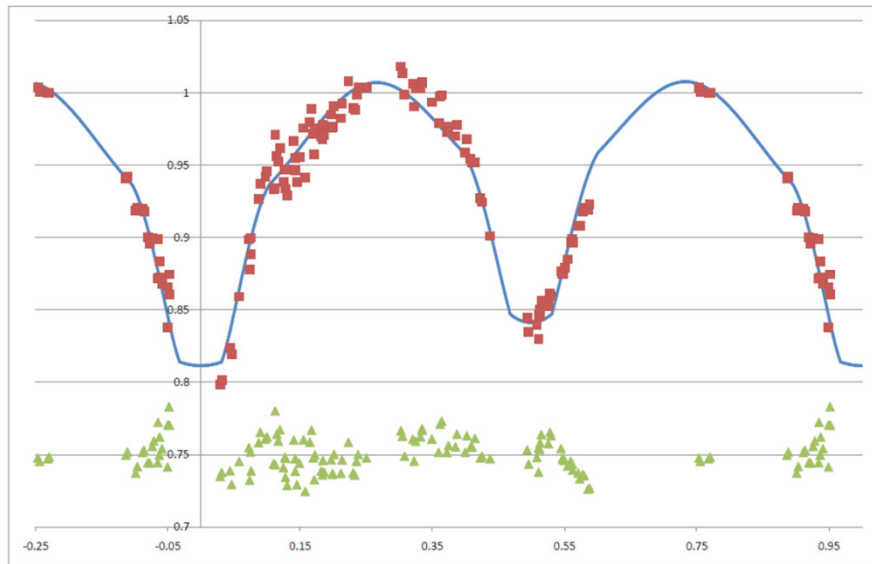


Figure 3. *HIPPARCOS light curve of QZ Car showing fitting and residuals.*

3. Bringing in the spectroscopy

Let's take a look at the spectroscopy (Fig 4). This diagram was prepared by our friend from Wellington, Roger Butland, who also reduced the raw data. It is easily seen that there are two main contributions, but it's not obvious that the deeper one is from the supergiant in Binary A and the shallower one from the giant in Binary B. We were able to confirm this from these data.

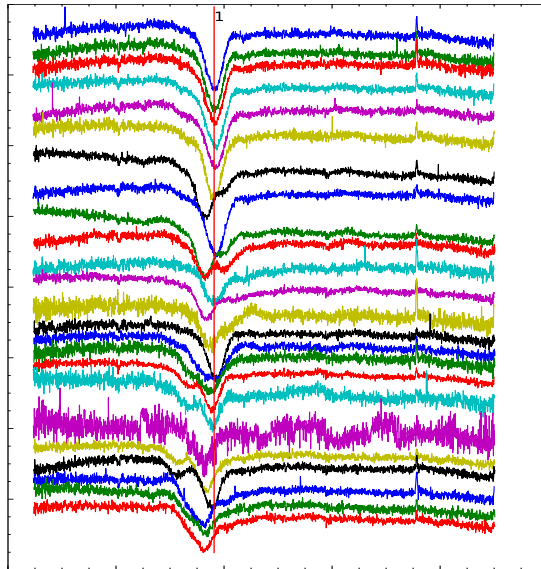


Figure 4. *Succession of reduced spectra of QZ Car from observations made in 2012-14. Just one spectral order of ~50 available ones is shown, but it is the one showing the prominent He I absorption feature at 6678Å. From measurements of the Doppler shifts of this kind of line we can build up a knowledge of the orbital motions.*

One interesting thing is that the width of the B component lines should enable us to confirm the photometric model. I think it does – but not exactly the same parameters as those given in the classic reference paper for QZ Car of Leung et al (1979).

Leung et al built their picture starting from the original light curve of Stan Walker and Brian Marino (1972) which they showed in their paper. But there is very little to go on in determining the eclipse widths in Leung et al's model, which are definitely narrower than the ones we just saw from HIPPARCOS and also that from Mark Blackford (Fig 5). We can notice in Fig 5 that characteristic pattern of the 6 clumps of points – coming from the repetitive 6-day cycle of the observational situation. Mark's data reveal that the scatter about the mean light curve shows systematic effects – it is not just a point-to-point scatter. We tried to relate this to a possible heartbeat effect of Component A, but the residuals did not fit our model very well.

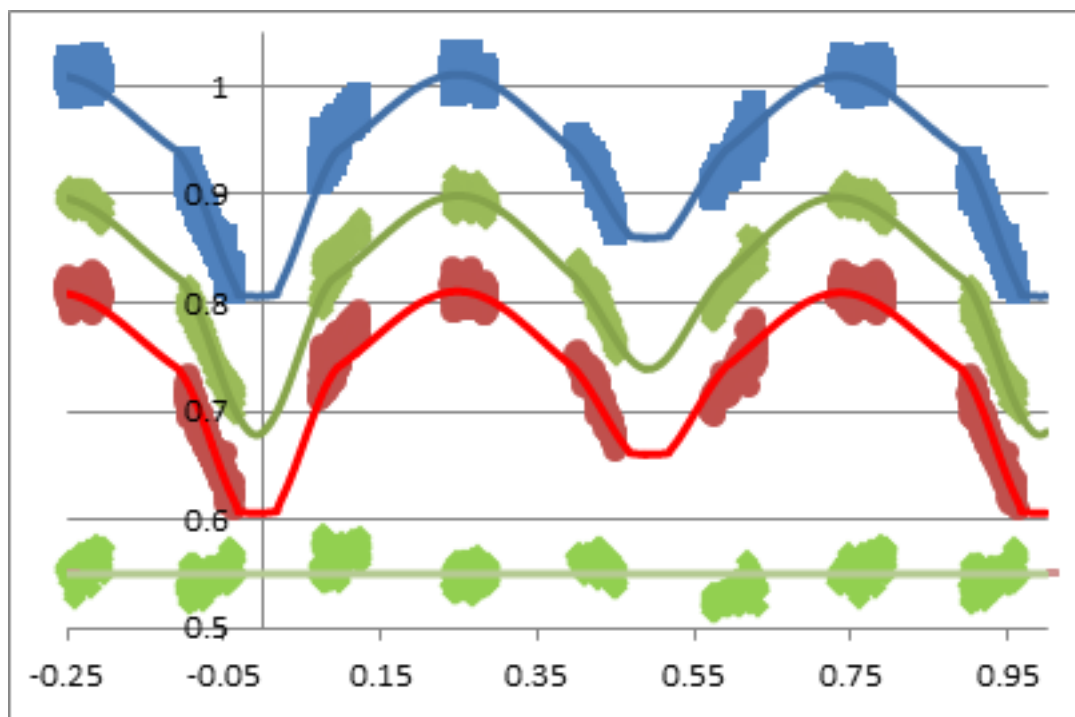


Figure 5. Mark Blackford's BVR light curves of QZ Car, fitted with optimal Radau models. The V-data residuals are plotted at the bottom. Systematic shifts can be seen in these residuals.

4. Combining data and building a model

Also coming from the VSS work on this star is the O – C curve, shown in Fig 6. This has been constructed from VSS sources essentially by Stan Walker. I fitted the variation with a model, corresponding to the blue curve. The 2 key parameters for a general interpretation of the quaternary system, are the projected separation of System B from the centre of gravity 48.5 AU and the estimate of the wide period 49.6y. The problem is that these numbers do not really fit the classic model of the quaternary! Using Kepler's Law the masses turn out to be very sensitive to the amplitude of the O - C curve. The bigger the up-down swing, for a given period, then the (much) bigger masses we need to pull the stars around their larger orbits in the time available.

The classic model of Leung and others from the late seventies shown in Fig 2 rests to a large extent on the spectrographic evidence, which we have not space to go into detail about here. But the spectrographic information is not unambiguous. Around year 2000, for instance, Stickland and Lloyd, well-known and oft-cited observers, published radial velocity curves using UV spectra for System B that also showed the usually undetected motion of the smaller star. The surprise was that Stickland and Lloyd found a larger than expected amplitude of the radial velocity of the O-type dwarf. They realised, of course, that this would imply large masses for both close binaries, but they published their results all the same. We could not confirm this finding in our own spectra. Rather, our spectra tend to confirm the picture of Leung et

al, also recently confirmed in a private communication to me by Pavel Mayer. He used one of the large telescopes at La Silla to get his spectra.

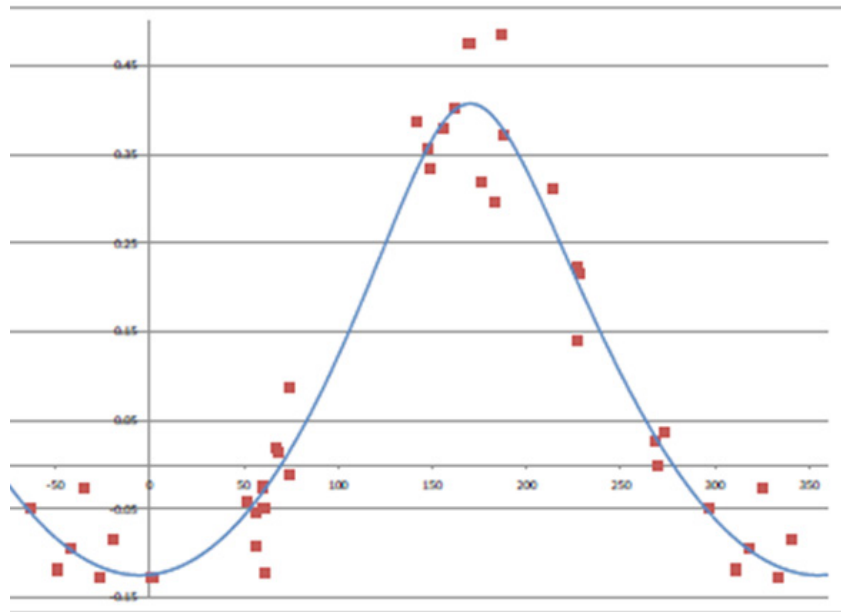


Figure 6. *O-C curve for QZ Car, constructed from accumulated VSS data by Stan Walker.*

QZ Car remains a puzzle for modelling – although we have usually been able to produce results that fit fairly well with theoretical models for other binaries in the programme. The measured radii GG Lup and μ 1 Sco (Budding et al, 2015), for example, fitted well with derived ages and masses. This is not the case for QZ Car – although recently we have realized that radiation pressure may have an important role in accounting for the relatively large physical sizes of the observed components.

Fig 7, taken from a paper on the role of radiation pressure in hot close binaries, by Drechsel et al (1995), is of particular interest. At the top we have a conventional so-called Roche type model which you may have seen from programs like Dave Bradstreet’s popular ‘Binary Maker’, or others based on the well-known Wilson Devinney code of the early seventies. But see what happens when we vary the scale of the radiation pressure, associated with the parameter $d1$ on the left. The semi-detached component changes from having an internal singular point to an external one. This would have profound effects for modelling the binary evolution. But more directly bearing on the photometric modelling here is that the same mass ratio ends up with a quite different ratio of radii and one that is much more in line with what the photometry suggests. We are working on this picture at the present time, and I have been in touch with some of these authorities about it, but that is about as far as I can take it right now. Hopefully we will be finishing a more complete summary of these findings soon.

5. Main points summary

- 1 The ‘eclipse method’ means using light curves and spectrograms together. Light curves give relative sizes of stars, but spectrograms give speeds in km/s. By combining these data-sets you get the sizes, masses and energy outputs of stars. Also distances. And even ages – using evolution models. Our ‘Southern Binaries programme’ is aimed at such absolute data on stars. A longer term purpose is to relate stellar properties to their Galactic environment

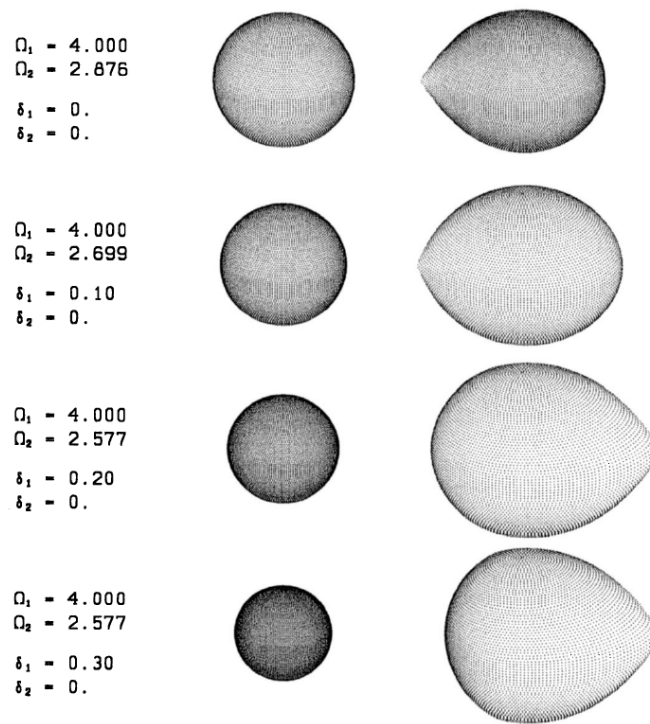


Figure 7. Binary models that take into account the effect of radiation pressure (from Drechsel et al., 1995)

- The 6 day period of QZ Car B (the eclipsing binary) makes things awkward. New light curves of the VSS bring out complications of the system. Some details in the classic picture of the binary are not right. For example, fuller, more recent light curves indicate larger stars than in the old model. There are also systematic shifts in brightness on a night-to-night basis. Surface instabilities, strong interacting winds or micropulsations may account for these effects. It is important to get a better understanding of this challenging system. This type of massive system might well be a progenitor of a ‘black hole binary’ e.g. GW150914(?)

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A toolbox for eclipsing binary stage 1 analysis – Jeff Byron

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Abstract

This paper expands on the author’s presentation at VSSS4 on lessons learned from contributing to “Revised Light Elements of 78 Southern Eclipsing Binary Systems” (Streamer et al 2015) and examines methods for determining the light elements of an eclipsing binary system based on several sets of observational data. It demonstrates the correct interpretation and use of errors (uncertainties) to perform a weighted regression to generate the light elements, gives a quantitative procedure for incorporating ASAS

or similar data into the calculations and introduces new software written by the author to calculate times of minimum with more realistic error estimates than provided by commonly used commercial software.

The O-C diagram

In theory, if one plots Time of Minimum (ToM) on the vertical axis of a graph against cycle number, all such points plotted should lie on a straight line if the period is constant. Even if, as in reality, the ToM values are not exact but instead each ToM_i has an associated uncertainty e_i , if the period is constant it should be possible to draw a straight line within $\sim e_i$ (vertically) of all points.

However, the scale of such a diagram is quite impractical. The vertical axis needs to be many (often hundreds) of days long, yet we are trying to detect errors of the order of seconds.

To overcome this, the diagram is normally re-arranged to show, on the vertical axis, the difference between the “observed” ToM (“O”) and some predicted or “calculated” ToM (“C”), based on a set of proposed “light elements” (“LEs”) – epoch and period. Possible lines drawn through or satisfactorily close to the plotted points give an indication of how good the prediction is.

If such a line can be horizontal, then the data is consistent with the proposed period. If such a line can pass through the “origin” (cycle = 0; O-C = 0), then the data is consistent with the proposed epoch.

On the other hand, if such a line must be of non-zero slope, then the data is suggestive of a different period. And if the line cannot pass through the origin, then the data is suggestive of an epoch differing from the proposed one by the “y-intercept” of the line.

“Satisfactorily close”, “ToM error” and “O-C error”

The qualitative term “satisfactorily close” above refers to the distance from the best-fit line to each observed ToM point being consistent with the time-uncertainty of the observed ToM. That is, in about 68% of cases the difference is less than the uncertainty figure and in 95% of cases it is less than double that uncertainty.

It is important to note that the uncertainty value being discussed here is the observed ToM error. The value “O-C error” is useful *only* to confirm that a *single* observational ToM is consistent with a previously determined set of light elements. As soon as we have two or more new observational ToM values, “O-C Error” is insufficient for confirming that they both match the light elements, as (if the period changes or the data measures are poor) they may both have O-C less than O-C error but one may require the period to have a positive period error and the other require a negative error.

Determination of new light elements

Where the new ToM data points do not match the existing LEs, new LEs can be generated once there are at least three observational ToM values (Richards 2013).

The Excel “Linest” (“linear estimate”) function, as used in the standard “Results” spreadsheet for eclipsing binary analysis, can be used to perform a simple regression on the ToM data. Better still, a weighted regression procedure can be used (see below). In either case an estimate of epoch, period and associated uncertainties is obtained.

In selecting the cycle for the “Reference Epoch” (E_0), the most recent ToM with small uncertainty should be chosen. This minimises errors in future calculated ToM values, maximising the usefulness of the new LEs.

Note that, if the uncertainty obtained for E_0 , (E_0 error) is significantly larger than the measured ToM uncertainty for cycle 0 or that measured ToM is otherwise incompatible with $E_0 \pm E_0$ error, the data is either showing a non-constant period or (more likely) there has been a computational error made.

Weighted regression

As discussed above, determination of light elements is generally based upon a set of observational times of minima. Each ToM measurement will have an associated uncertainty – which should have been esti-

mated as part of the measurement of ToM process.

However, it must be noted that the Excel “Linest” function ignores quoted errors in ToM. Where all measurements have a similar uncertainty, this is often not critical. On the other hand, if some measurements have a larger than “normal” uncertainty, the spreadsheet will ignore this and generate light elements which give these poorer measurements undue weight. See Figure 1.

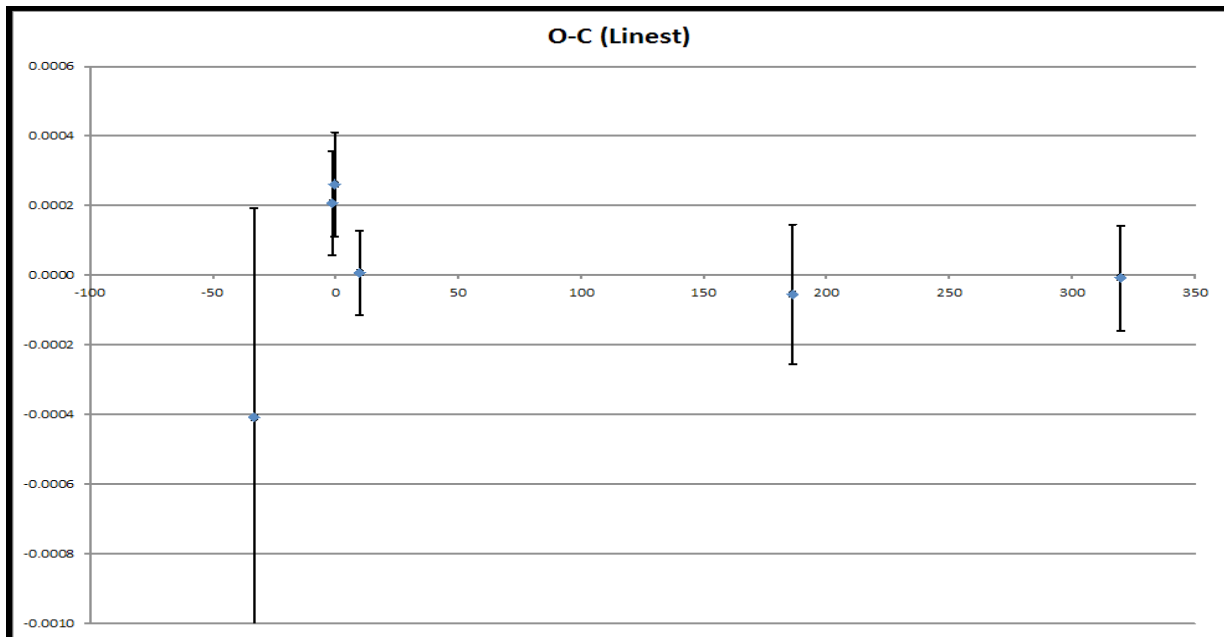


Figure 1(a). Comparison of Linest and Weighted Regression for TZ Cru. (a) O-C diagram plotted for LEs generated by linear estimate: Epoch $2456058.000339 \pm 0.000128$, Period 2.0911555 ± 0.0000008 .

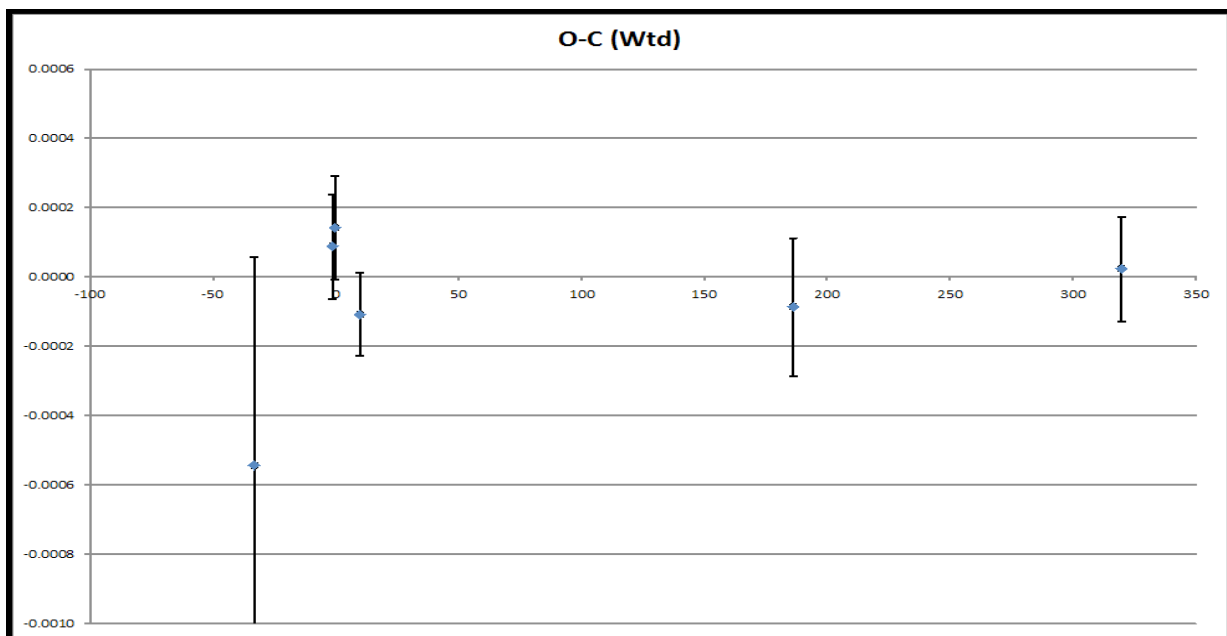


Figure 1(b). O-C diagram plotted for LE' generated by weighted regression: Epoch $2456058.000458 \pm 0.000087$, Period 2.0911550 ± 0.0000005 . Note how the lower weight given to cycle “-33” in weighted regression mean that the error bars in (b) all reach the x-axis, indicating data more in accordance with the LEs. Time of minimum was measured with JK-LC using the KvW process for an observation duration of 0.1 days.

This variation in uncertainty between measurements can occur due to differences in duration of observation or differences in conditions etc. Also very significant is the higher error value of an ASAS-based

“Pseudo ToM” (discussed later) used to incorporate ASAS data into the light element determination process to (in some cases) improve the accuracy of the result.

To overcome this shortcoming in Linest, the author developed a weighted regression routine.

Consider the set of points $\{(i, \text{ToM}_i)\}$ where ToM_i is the measured ToM for cycle “i”. This ToM will have an uncertainty e_i . Then for any offset y from the ToM, the probability that the “actual” ToM is within some small dt of a value $(\text{ToM}_i + y)$ is a function of (y / e_i) , with a highest probability at $y = 0$.

The weighted regression routine effectively finds the epoch and period generating a line passing close to the set of points $\{(i, \text{ToM}_i)\}$ with the highest overall probability value, considering the (y / e_i) values for each point. It also calculates the epoch and period limits associated with a probability 68% of this maximum probability, giving an estimate of the uncertainty values for epoch and period.

Incorporation of ASAS data

Publically available data (eg ASAS) can extend the time frame over which measurements are made.

This has the effect of adding precision to the light elements – provided there has been no changes in period in the intervening time. (This is an important proviso!)

Procedure

- Download text file from ASAS web site.
- For each data set, check the match of RA & Dec to the target. On some occasions the ASAS site can include data from other stars mixed with that of the desired target. Also, on some occasions use of target names (e.g. RR Men) can lead to the selection of the wrong target entirely and the user must select the ASAS target using RA & Dec parameters.
- Extract time-magnitude data (either A and B or A grade only) from the text file.
(To speed the last 2 processes, the author developed a computer program to handle them.)
- Plot phase-folded ASAS (HJD, mag) values along with VSS observers’ data, starting with the epoch and period determined using VSS data alone.
- Adjust the period to obtain the best match (by eye) between VSS & ASAS data.
- In some cases, no period gives a good correlation between ASAS and VSS data. In such cases, there may have been a change of period between the ASAS epoch and the VSS epoch and ASAS data cannot be used to refine light elements.
- Where correlation between ASAS and VSS data appears reasonable by eye:
 - Select an ASAS data point close to the median date of ASAS observations.
 - Note its HJD (HJD_R) and its phase (θ_R) in the phase-folded plot.

Using HJD_R and θ_R as reference, generate a table of “pseudo HJD” and magnitude as though all observations were in one cycle.

That is, for each ASAS data point

$$\text{pseudo HJD} = (\theta - \theta_R) \times P + \text{HJD}_R$$

where θ is the phase of the data point in the phase-folded table and

P is the period determined by eye for best match of VSS & ASAS data.

- After deleting outlier points, use software tool of choice to determine the ToM and associated error value of the pseudo ASAS data.
(Bob Nelson’s Tracing Paper (Nelson 2007) is often suitable in the presence of a large scatter of data points. Do not accept default period error. Manually adjust the period to determine upper and lower bounds; error is half the difference.)
- Add this (ToM, error) pair to the regression procedure to obtain provisional improved light elements.
- Confirm, for each cycle, that O-C is compatible with ToM error as discussed above.

- As a sanity check, visually inspect the plot of all data phase folded with the newly proposed light elements.

Time of minimum and measured minimum time

Along with noting the need in all cases to use corresponding phase intervals in the descending and rising branches of the eclipse, Kwee & van Woerden (1956) noted in their paper:

“In the case of asymmetric minima, it is of great importance that for the same star always the same phase interval is used, for the epoch is only exactly defined by this interval.”

In other words, asymmetries in a light curve cause the KvW process to return ToM values which are *dependant on the phase range analysed*.

Moreover, this effect is not limited to KvW. It also applies to low-order polynomial fitting and Mikulasek modelling. Use of higher-order polynomials sometimes (but not always) improves this situation, but then one must take care to not also be following the noise of the original magnitude measurements. In addition, polynomial fitting has larger associated uncertainties than KvW or Mikulasek modelling.

For this reason, the author considers ToM values calculated by processes analysing the over-all light-curve to really be Measured Minimum Times (MMT) for that cycle. In general the MMT is dependant on the model used to match the light curve (which is never exact) and the phase range analysed, but, if used correctly, provides a precise reference time for each cycle. If the light-curve is symmetrical, the actual zero-phase of the EB orbit should coincide with the MMT and that time can unambiguously be considered the ToM. But otherwise, it is important that as well as recording the MMT, the analyst should record the associated parameters of process used and phase interval, in order that future measures of that target can be measured in a consistent fashion.

By following this recommendation, it should be possible to harness the relatively high precision of Mikulasek modelling or KvW to obtain highly accurate period values.

Issues with Peranso

Peranso (Vanmunster 2015) is a commercial software package commonly used to (among many other tasks) determine ToM of an eclipsing binary. However, its normal KvW (no interpolation) process most frequently returns a secondary extremum close to the start or end of the observation series – clearly not what is required, and thus this process is normally quite useless.

For that reason, analysts have tended to use Interpolated KvW - Linear or Spline. These are designed, according to the documentation, to handle asymmetrical light curves.

However, this has typically resulted in reported error values for times of minima being far smaller than the scatter of these data points in O-C diagrams. An investigation into this led to the discovery that this routine (if there are no deselected data points) always returns a quantised ToM value equal to the time of the first magnitude point for that data set plus an integral number of average time intervals. That is

$$\text{Reported ToM} = T_0 + i \times (T_n - T_0)/n$$

where (n+1) observations have been made at times $T_0, T_1, T_2, \dots, T_n$ and i is some integer.

Thus the error cannot be better than $(T_n - T_0)/2n$, but Peranso quotes more than an order of magnitude less than this.

On the other hand, Peranso reports error values for polynomial-derived ToM values which are much larger than the scatter of O-C data points, suggesting that these error values are being over-stated.

Another concern, not yet fully investigated, is that making measurements (polynomial or KvW) on a data-set by deselecting some data points can return different ToM values and / or errors to those obtained if a new data-set is generated without those data points.

It is also unfortunate that Peranso provides no log file of measurements made along with parameters used. Rather the user must do separate copy and paste operations of ToM, error, minimum value etc and manually record phase (or time) range used as recommended above.

Jackknife Light Curve program

The above issues with Peranso prompted the author to write a new ToM (or rather MMT) program – JK-LC (Jackknife Light Curve).

Features of this program are:

- *Includes standard KvW.*

That is, no interpolation in Peranso parlance. This routine is based on a Fortran routine in (Mallama 1982). However, Mallama's program has the same bug as Peranso that results in the return of a secondary extremum close to the start or end of the observation series. In JK-LC this bug is corrected.

- *Performs Mikulasek model fitting.*

This is based on the technique described in (Brat et al 2012), using least squares to fit the model to the data.

The Mikulasek model takes the form:

$$f(t, t_0, d, \Gamma) = c_0 + c_1 \psi(t, t_0, d, \Gamma)$$

where

$$\psi(t, t_0, d, \Gamma) = 1 - \{1 - \exp\left[1 - \cosh\left(\frac{t-t_0}{d}\right)\right]\}^\Gamma$$

and t_0 is desired time of minimum; d is minimum width factor and Γ is factor describing pointedness of minimum.

- *Performs polynomial model fitting.*

Also uses least squares. Currently the software is configured to fit to degree 5 and degree 9 but could very simply be changed to accommodate other degrees.

- *Rather than relying on errors reported by the KvW or least squares routines, JK-LC uses statistical re-sampling (Jackknife) to more realistically estimate errors.*

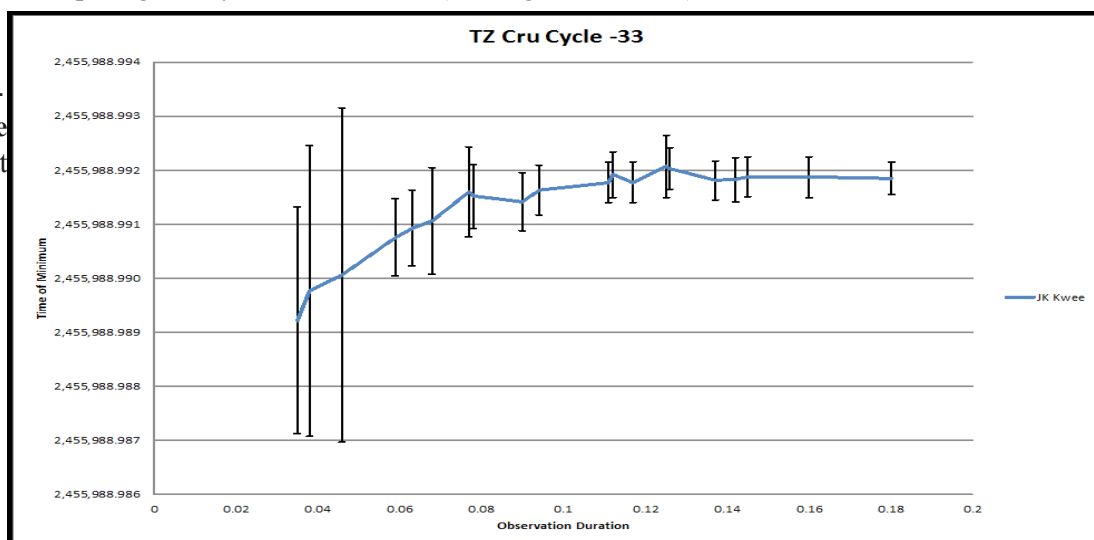
This is similar to the technique described by Brat et al, but their Bootstrap routine is replaced by Jackknife.

Typically Jackknife returns slightly higher error values than reported by the KvW routine (which is known to be overly optimistic) but it drastically reduces the polynomial-fitting error estimates when compared to Peranso. As stated above, Peranso's polynomial error estimates were suspected to be overstated based on O-C scatter. This technique confirms that supposition.

- *Generates a table of MMT values for a range of observation (phase) intervals.*

This simplifies determination of a suitable reportable MMT by allowing plotting (using a spreadsheet) of MMT against phase range for a variety of processing methods. This information assists comparing one cycle with another. (See Figures 2 and 4.)

Figure 2
Plot of
MMT



2.
of

against observation duration for TZ Cru Cycle “-33” using JK-LC and KvW. Note that MMT is fairly

constant for observation durations of 0.1 days or more, but starts to vary with increasing errors below that. Other cycles gave even more constant values of MMT (and smaller errors) near 0.1 days, although cycle “-1” did not have symmetrical observations to go beyond that. Therefore a duration of 0.1 days was chosen to generate the data for Figure 1. Mikulasek modelling gave similar results and errors.

The software has been tested on a selection of pseudo-data for which the real ToM is known. This pseudo data was generated by:

- Polynomials
- Normal Bell Curve
- Bell Curve plus linear asymmetry function
- StarlightPro (Brunton 2016) generated data for RS Vul with and without a (fictional) 10 degree star-spot

All the above tests were performed with various degrees of observation noise.

Even though the fictional RS-Vul with star-spot generates an asymmetric light curve, KvW and Mikulasek both give minimum times which are constant with phase range analysed provided that phase range is more than a certain threshold. However, those measured minimum times are not exactly equal to the actual ToM, demonstrating the value of the MMT concept, as they can be used to accurately determine periods even though they are not the actual minimum light of the eclipse. See Figure 4.

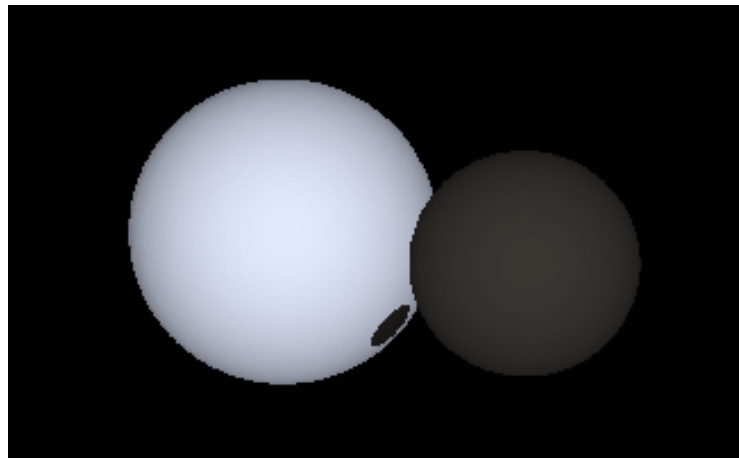


Figure 3. The fictitious 10 degree diameter Star-spot as RS Vul enters eclipse.

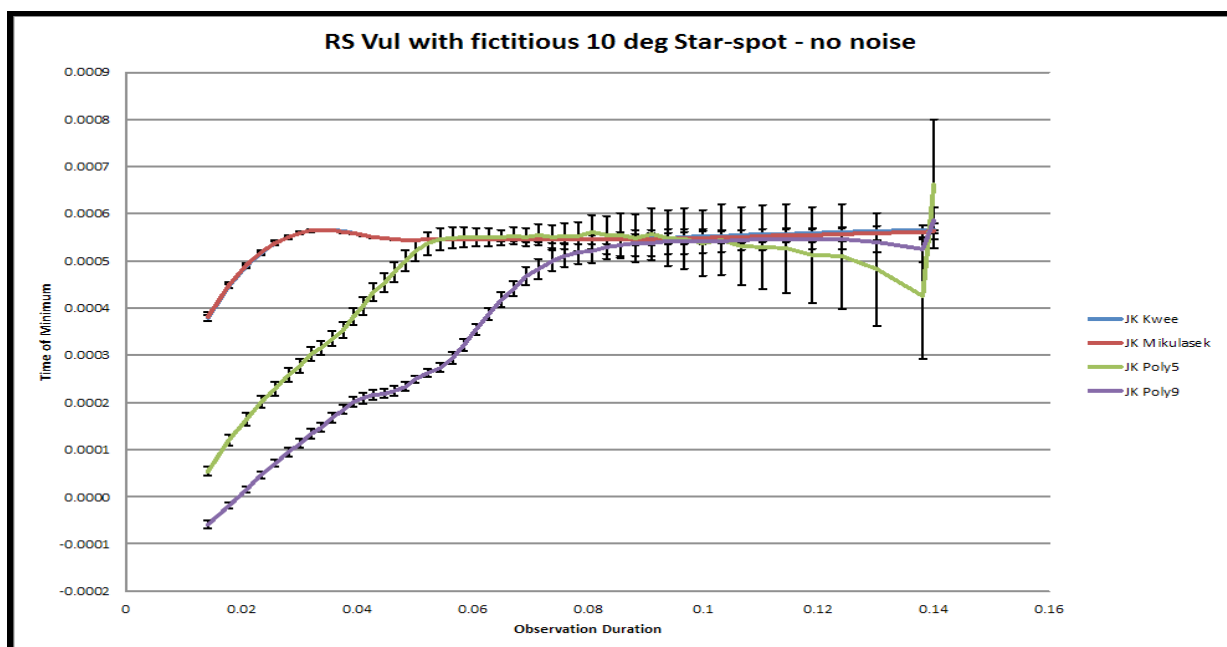


Figure 4(a). JK-LC plot for RS Vul with a fictitious 10 degree diameter Star-spot. As this was using pseudo-data the test could be done with a known minimum at time zero. (a) No observational noise. KvW and Mikulasek are co-incident on the plot. However, as can be seen, the stable value of MMT (for observation duration above 0.06 for most models) was about 0.00056. As observation duration tends towards zero, in this no noise situation we can see that the MMT is tending closer to zero, but not in precisely the same way for all models.

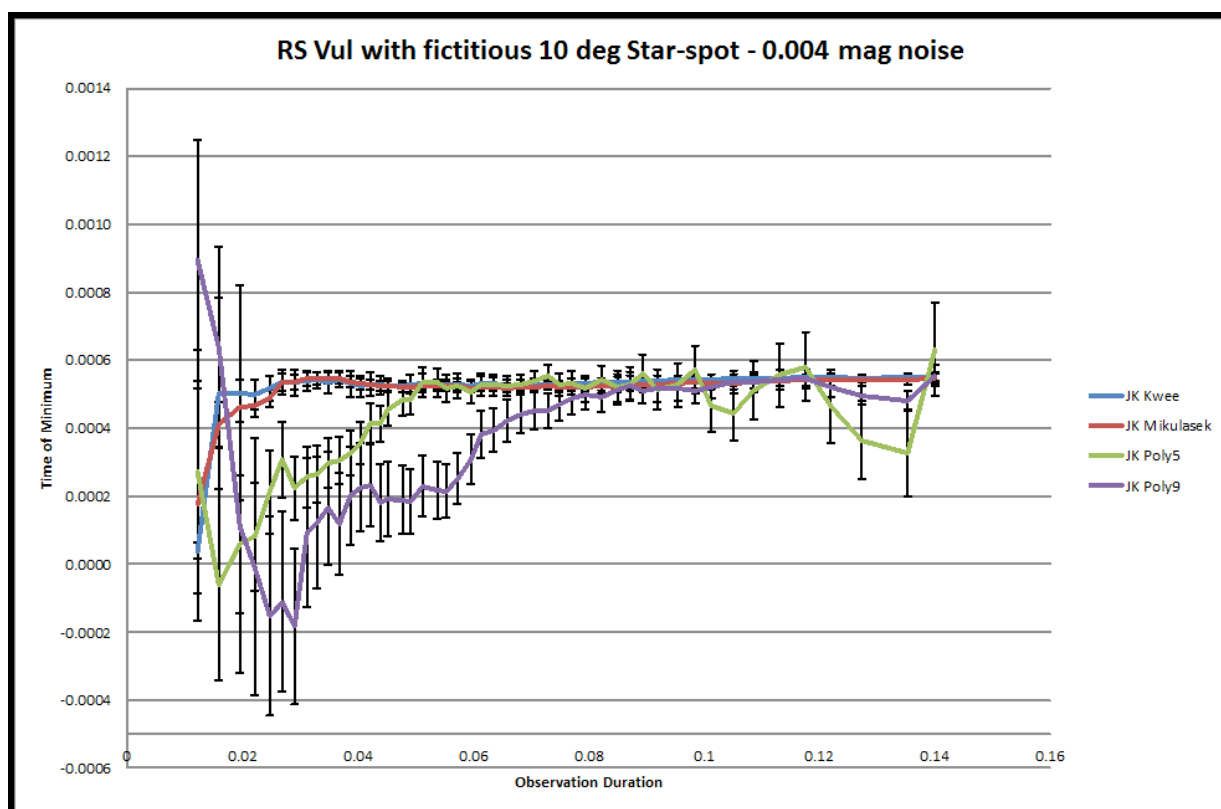


Figure 4(b). Repeating this test with realistic magnitude noise of 0.004 mag produces the same shape of graph, although only Mikulasek modelling held errors low enough as the observation duration tended towards zero for the tendency of MMT towards zero to be unambiguously seen amid the increasing error values. Thus MMT provides a relatively precise reference time for a cycle, even though it is not the same as ToM. (Time between pseudo magnitude measurements was set at 0.000105.)

Note that the practice of deleting data points at the bottom of a flat light curve may be of assistance with Mikulasek and polynomial modelling, but will almost certainly result in systematic errors with KvW (and not just the JK-LC Implementation.)

Software availability

Software developed by the author as part of this project (WtdReg & JK-LC) does not currently have a Windows-style user-friendly front end. That may be provided at some future time by incorporation of these routines into another package.

At present, readers wishing to utilise these routines, who are prepared to accept the command-line type user interface, are encouraged to contact the author who will happily provide them, with samples and instructions, free for personal use.

Acknowledgements

Margaret Streamer and other VSS observers and analysts for information and comments during development of “Revised Light Elements of 78 Southern Eclipsing Binary Systems”

My wife Julie – without whose help I would never have had the time to develop this paper.

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An improved method for correcting atmospheric extinction – *Murray Forbes*

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This article has been adapted from the presentation given by myself at VSSS4 in Sydney, March 2016.

One of the major sources of uncertainty in our measurements of a star's magnitude is due to the scattering and absorption of some of that light by the Earth's atmosphere (the extinction) during the last instant of its journey to our telescope. I will first describe the standard method used to correct for this and then describe an improved method that allows for changes in the extinction coefficient during the night.

Most of the plots I present will use results from the Vilnius filter system, with observations made some time ago when I was doing my PhD (Forbes, 1996) at Victoria University of Wellington, New Zealand. This system uses seven intermediate passband glass filters designed by the Vilnius Observatory in Lithuania. These filters, going from short (blue) to long (red) wavelength are U, P, X, Y, Z, V and S (see Figure 1).

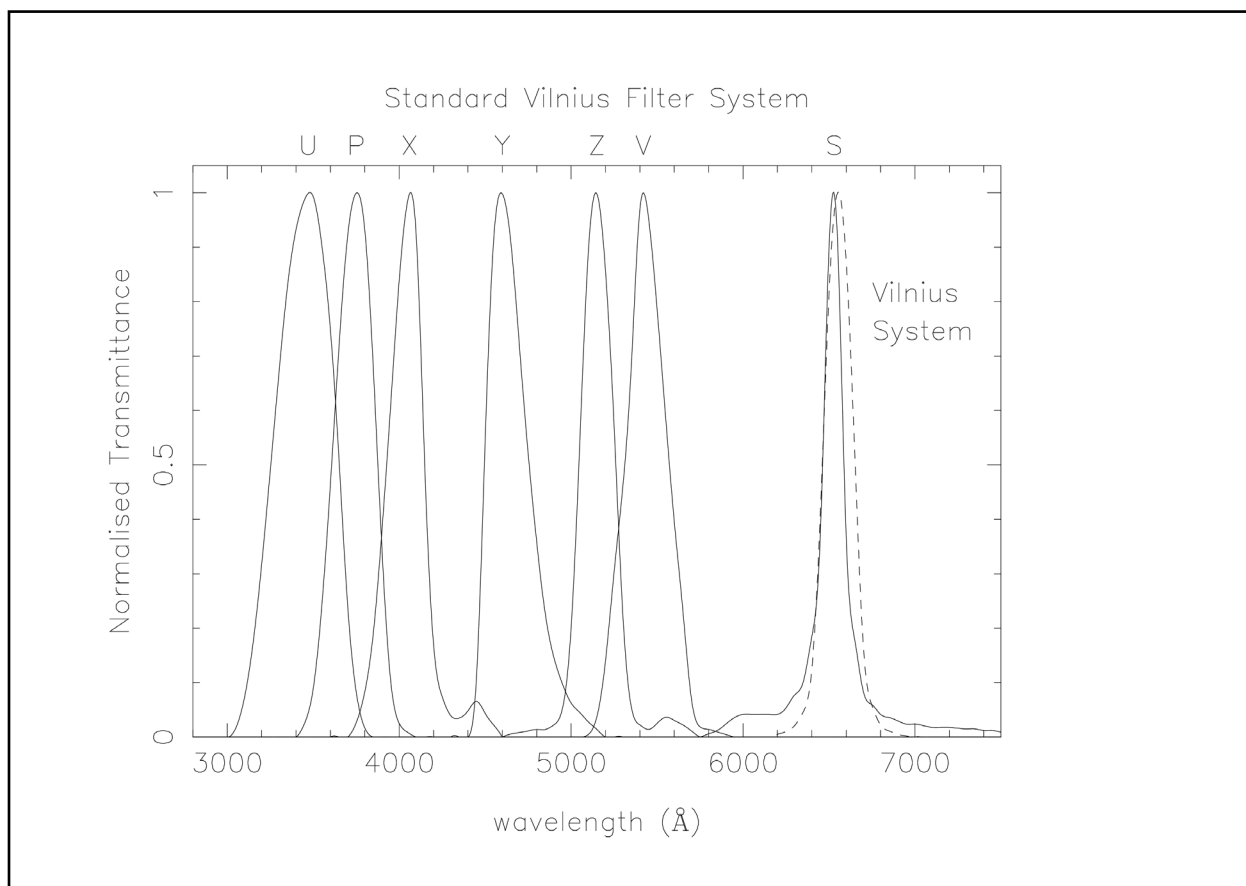


Figure 1. *Vilnius standard filter passbands*

To measure the extinction coefficient for a night, an 'extinction' star is measured at regular intervals during the night as it rises in the east, crosses the meridian and finally sets in the west. Figure 2 shows

a set of such measurements made in the Vilnius P filter over a night. The vertical axis are the measurements of the star's magnitude (the 'instrumental' magnitude) while the horizontal axis is the air mass (the amount of air that the star's light passed through, with the air mass at the zenith being defined as 1). A straight line is least-squares fitted to the measurements;

$$m_0 = m + k \cdot X \quad \text{----- Equation 1}$$

where m are the instrumental magnitudes and X are the airmasses. The intercept of the line (extrapolating to an airmass of zero) is the actual magnitude of the star m_0 . The slope of the line is the extinction coefficient k – in this example it is 0.460.

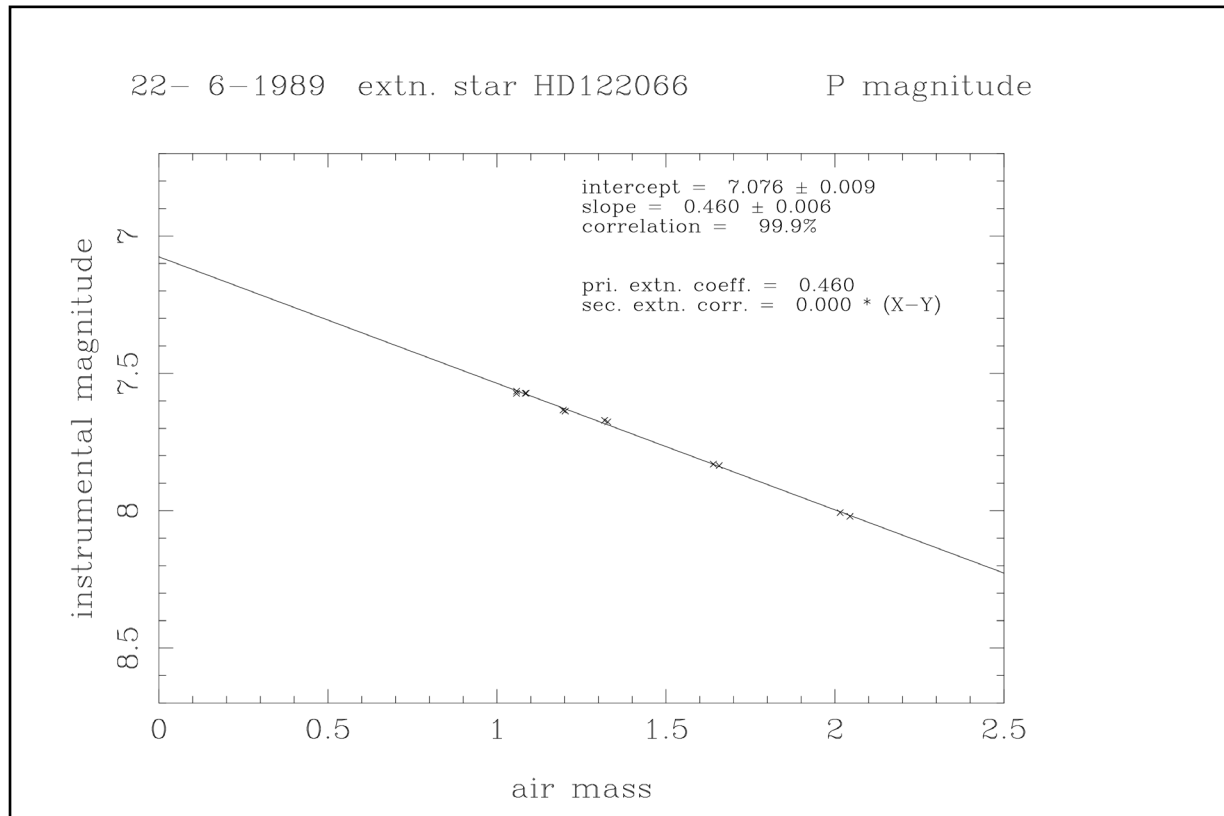


Figure 2. Instrumental magnitude versus air mass for one night's data using P filter

So how do we go about choosing an extinction star?

- The most important criteria is that it isn't a variable star. A good source of candidate stars are standard star catalogues, for example the E-region standard stars. I recommend then using the SIMBAD astronomical database (<http://simbad.u-strasbg.fr/simbad/>) to check your candidate star is not listed in any of the variable star catalogues.
- Other stars that are near in the sky to your candidate star can cause problems, as they may, or may not, be included in your measurement aperture or PSF fit depending on the seeing conditions. For this reason I suggest that you use star position catalogues, double star catalogues, your own CCD images etc to check that your candidate star does not have any nearby stars that are brighter than your instrument's sky or dark current background level.
- You should also check that the candidate star is not a spectroscopic double star, as this would give the wrong secondary (colour) extinction coefficient (I will say more about the colour coefficient later) and it may turn out to be an eclipsing binary star.
- Finally, only include stars that are on the main sequence (luminosity class V). I'd also recommend avoiding stars with spectral classes A-F, where the instability strip intercepts the main sequence.

You may sometimes see advice that you should pick extinction stars with similar brightness as your target star (to reduce the effect of any non-linearity in your instrument system), but;

- If this means picking a faint star, you may have signal to noise problems

- Further, you may be observing several target stars on the same night

So I believe it is better to pick a bright star, as it;

- Gives good signal to noise
- Minimises the effect of a sky or dark current background correction
- It should still be in the linear region of your instrument
- Is easier to find than a faint star
- Takes less time to measure than a faint star

Similarly, you may see advice to pick extinction stars with the same colour as your target star (to reduce the effect of inaccuracies in your secondary extinction correction), but;

- Your target star may vary significantly in colour over time
- And again, you may be observing several target stars on the same night

So I believe it is better to pick a star that has a zero colour extinction correction, for example stars with the colour $(B-V) = 0$ in the Johnson filter system.

Thus far I talked about the extinction coefficient, as if there was only one. However the extinction coefficient changes with wavelength, as can be seen in Figure 3. The coefficient generally decreases as you move towards the redder (longer) wavelengths – which is due to Rayleigh or aerosol scattering of the star's light (for scattering off molecules or dust/droplets respectively). Added on top of that at certain wavelengths is absorption by molecules such as water (H_2O), oxygen (O_2) and ozone (O_3). Extinction due to molecular absorption, especially water, can change quite quickly. The passbands of the Vilnius filters are given at the bottom of the diagram, showing that they mostly avoid wavelengths with the troublesome molecular absorption.

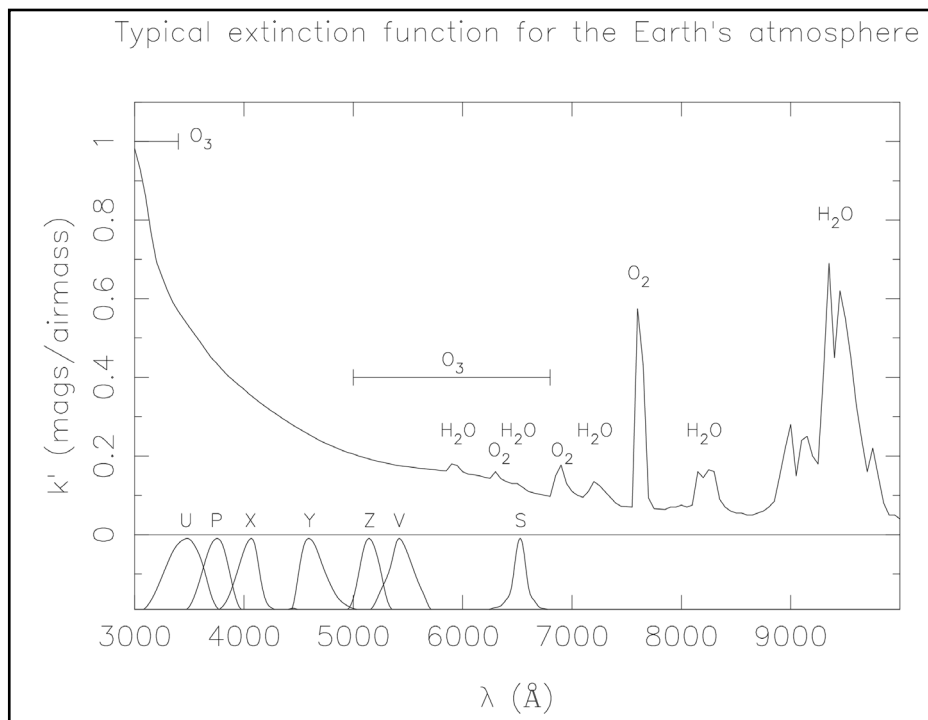


Figure 3. Shows how the extinction coefficient varies with wavelength. The Vilnius passbands mostly avoid the wavelengths at which water and oxygen are absorbed.

If we zoom in on one of the filters (Figure 4), we can see that the extinction is usually much stronger on the bluer (shorter wavelength) side of the filter's passband than on the red side. This means a star that is brighter at shorter wavelengths (e.g. an O or B spectral type) will suffer greater extinction (at the same airmass) than a star that is brighter at longer wavelengths (e.g. a K or M spectral type). To properly allow for how the extinction is affected by the star's spectrum, we need to know the shape of the extinction curve within the filter's passband. Measuring the extinction coefficient with this filter will give us one point somewhere along the extinction curve. Ideally we would also have additional filters closely spaced

about our filter, so we get measurements of the extinction at different wavelengths and can trace out the actual extinction curve. However I don't know of anyone actually doing this. Instead a simple correction is made using a single colour index based on other filters in the filter system, for instance B-V in the Johnson filter system – see Figure 5.

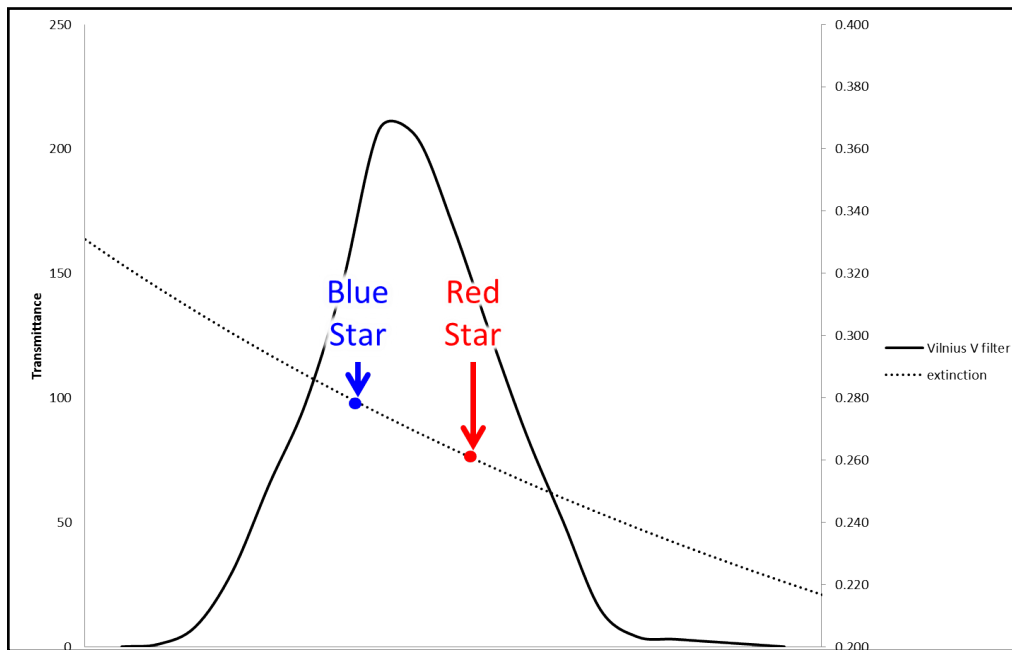


Figure 4. Because the overall trend is for reducing extinction with increasing wavelength, for any single filter the extinction is stronger for a blue star than for a red star

The extinction correction formula now becomes;

$$m_0 = m + (k' + k'' * colour) * X \quad \text{--- Equation 2}$$

where k' is the primary extinction coefficient and k'' is the secondary (or colour) extinction coefficient, which is related to the slope of the extinction curve inside the filter's passband.

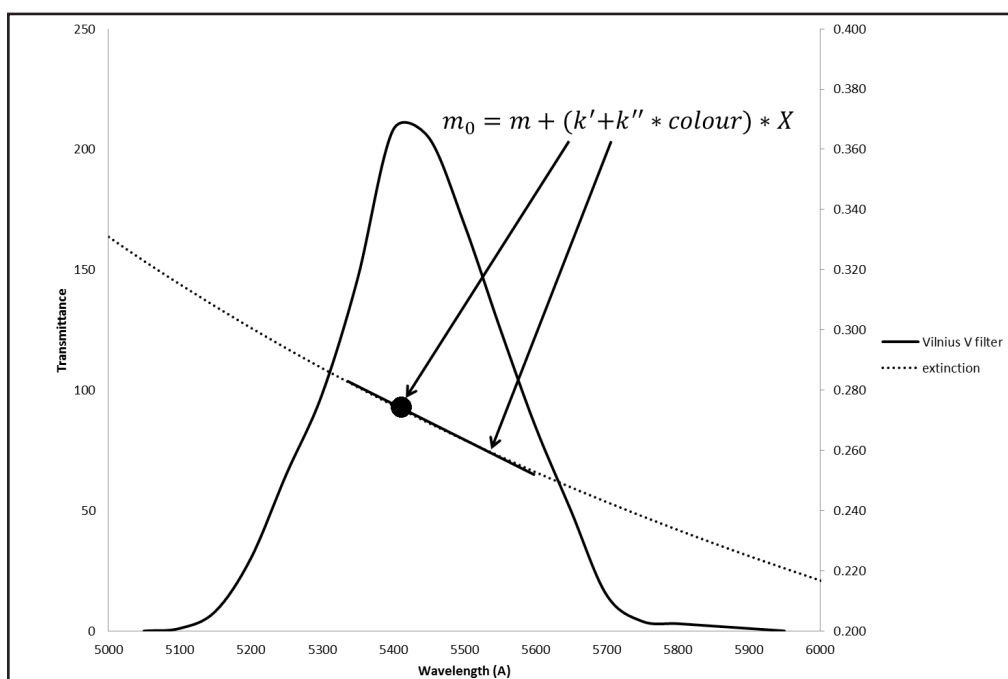


Figure 5. Correction made using a single colour index based on other filters in the filter system, for instance B-V in the Johnson filter system

I'll now describe some observing techniques to get good measurements of the primary extinction coefficient;

- In the best observing sites in the world (eg Chile or Hawaii), the atmospheric extinction may not change much from one night to another and an average value could be used. However for the rest of us, it *will* be different every night and so has to be measured every night.
- Although observations made at larger airmasses should improve the accuracy in determining the extinction coefficient (as the line is fitted over a larger range of values), this is offset by the error in the observations increasing with airmass. Young (1974) found $X \sim 2$ is the optimum maximum airmass. Further, the formula used to calculate the airmass X is not very accurate at wavelengths where ozone and aerosol extinction is strong. Fortunately the corrections to the standard calculation due to ozone and aerosol extinction are in opposite directions and partially cancel, and are not significant for airmass < 2.3 (Young, 1974).
- Also make measurements when the star is at its highest in the sky (ie at the lowest airmass, about 1). Remember extinction is usually stronger on the blue (shorter wavelength) side of a filter. The effect increases with increasing airmass. For example, if the extinction on the blue side of the filter is twice the extinction on the red side at some airmass, then doubling the airmass increases the blue extinction by a factor of four over the red extinction. This reduces the effect of the star's colour on the extinction coefficient, which changes the slope of the airmass plot and is known as the Forbes Effect (Forbes, 1842). This means fitting a line to measurements *only* made at large airmass will give an incorrect extinction coefficient.
- Make measurements when the star is rising from the East towards the meridian and when the star is setting towards the West. You will see why this is important later, in Figure 7.
- Get *at least* five measurements – to enable a good least-squares fit to the line (of the star's magnitude verses airmass). So measure the extinction star *at least* once per hour (and maybe even once every 30 minutes).
- You will often see advice to choose an extinction star that is close in the sky to the target star.
- However this may contradict the advice above to make measurements over an airmass range of 1 – 2. And again, you may be observing several target stars in a night. So I believe it is better to pick one star to use as an extinction star following the advice given earlier and have different stars for comparison & check stars to use for differential photometry with your target star(s).

We also need to measure the secondary (colour) extinction coefficient. This is done by choosing a series of extinction stars that have different colours – see Figure 6.

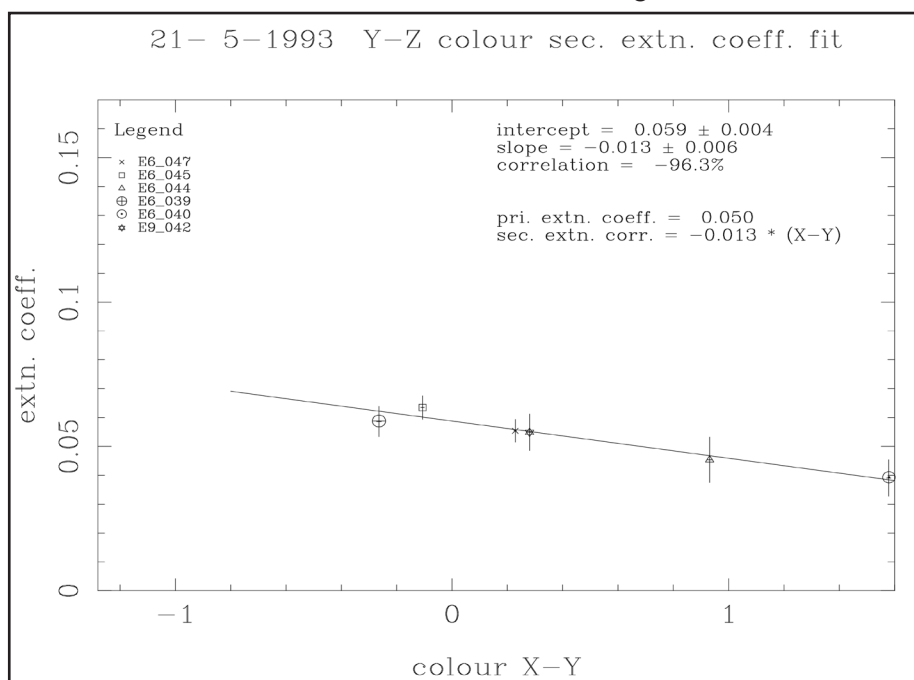


Figure 6. Each data point here is the primary extinction coefficient found for a particular extinction star, with all the extinction stars measured over the same night. In this case, they are the primary extinction coefficients for the Y-Z colour of the Vilnius filter system.

The slope of least squares fitted line gives the secondary extinction coefficient (k'' , which equals -0.013 here) that can be used when correcting for atmospheric

extinction for any star. The primary extinction coefficient (k') is taken from the best fit line at the colour used from the particular filter system, for example in the Johnson filter system it is read where the colour $(B-V) = 0$ and would be the intercept (0.059 in Figure 6);

$$m_0 = m + (k' + k'' * (B - V)) * \text{airmass} \text{ --- Equation 3}$$

However the Vilnius filter system takes the primary extinction coefficient from G0 V stars, which corresponds to the colour $(X-Y) = +0.78$, which gives the coefficient as 0.050 in Figure 6, and uses the following equation for the extinction corrections;

$$m_0 = m + (k' + k'' * ((X - Y) - 0.78)) * \text{airmass} \text{ --- Equation 4}$$

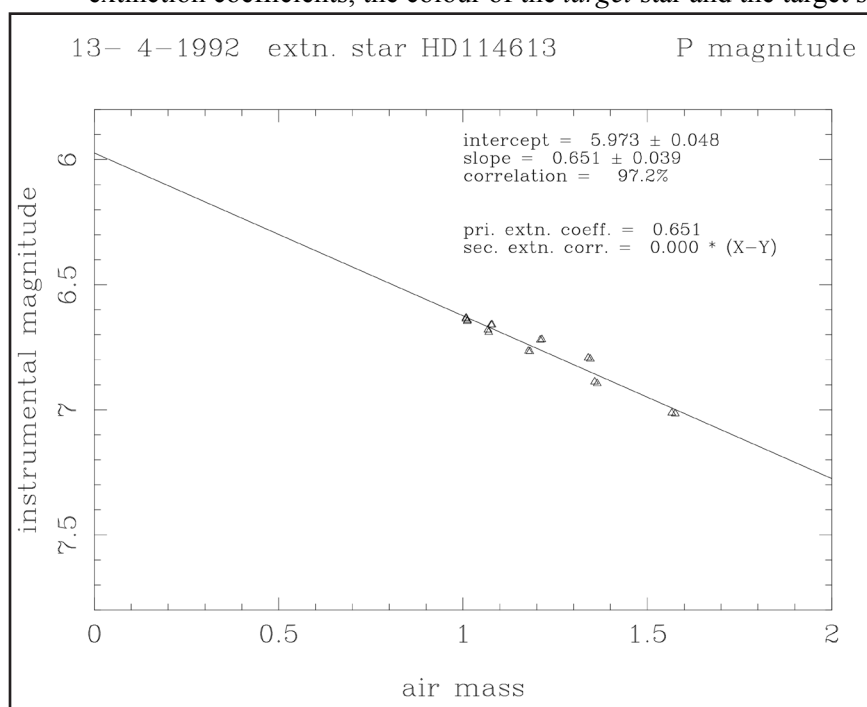
So how do we pick suitable extinction stars to use for measuring the secondary extinction coefficient? You need to pick stars as you would for a primary extinction star, *except*;

- You need to pick stars with different spectral types (colours).
- They need to be close to each other in the sky, to minimise any errors in calculating the star's primary extinction coefficient that night due to variations in extinction across the sky.
- Each of the regular extinction measurements should be made on all of the stars at the same time, again to minimise errors in calculating the star's primary extinction coefficient that night due to variations in extinction during the night. You may have noticed in Figure 6 that I'd picked stars from the same E region of standard stars, in this case E6. Another possibility, especially if you're using a CCD, is to find a suitable open cluster of stars.

How often do you need to measure the secondary extinction coefficients? These coefficients only depend on the *slope* of the extinction curve versus wavelength and shape of the filter's passband. Neither of these are expected to change very quickly, so you don't have to make the nightly measurements required for the primary extinction coefficient. The advice I seen ranges from measuring the secondary extinction coefficient once per month, to once per year.

To summarise;

1. The slope of the extinction star's magnitude verses airmass gives the extinction coefficient k for *that* star.
2. Subtract the secondary extinction coefficient times the colour of the extinction star to get the primary extinction coefficient .
3. To correct each observation of the target star for extinction, use the primary and secondary extinction coefficients, the colour of the *target* star and the target star's airmass X .



Given measurements like those in Figure 2, why would we ever want to have an improved method for correcting for extinction? Because we frequently get results like those in Figure 7 instead, where the measurements when the star is setting do not lie on the same line as when the star was rising earlier.

Figure 7. The slopes of the instrumental magnitude vs airmass are different for the star when rising and when setting.

Although I haven't previously mentioned this, the standard

method is actually based on two assumptions;

- The extinction is the same throughout the entire night, and
- The extinction is the same no matter where you look in the sky

On this particular night, one of these assumptions was probably wrong.

In Figure 8, I've shown three possible explanations for these measurements;

- The extinction slowly changes during the night. The curve in the top diagram shows the extinction assuming it changes by a small, constant amount per hour.
- Another possibility is that the extinction is different when you look at the zenith compared to looking lower in the sky (rather than changing with time). In the middle diagram the curve shows the extinction assuming it changes with the zenith angle of the star.
- The third possibility is that the instrument system is changing during the night – perhaps it is sensitive to temperature and things got cooler as the night worn on. In the bottom diagram I've modelled the zero-point of the instrument changing by a small, constant amount per hour. Another possibility, which produces identical results, is that the extinction star's brightness was changing.

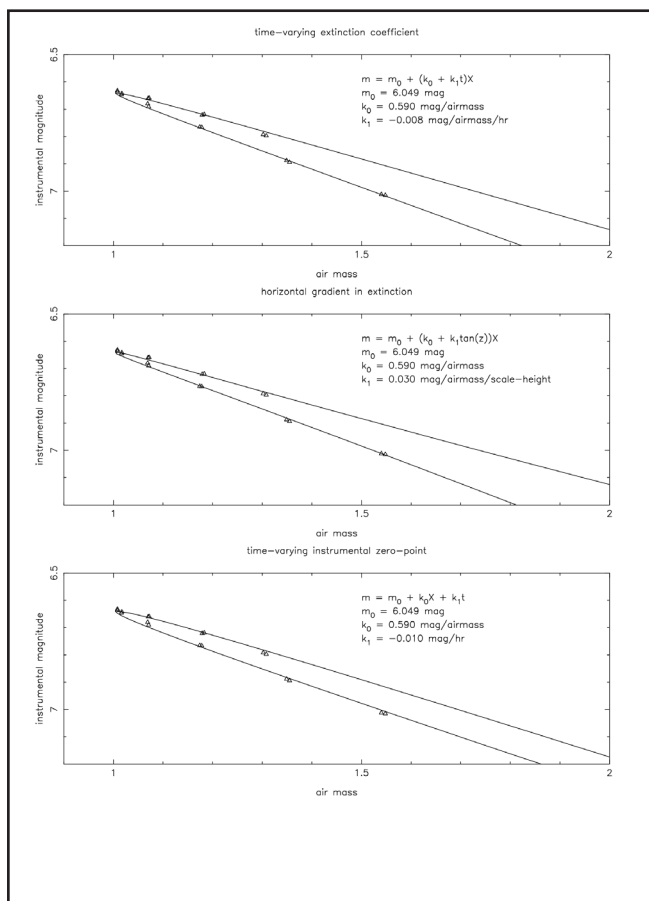


Figure 8. Shows three possible explanations for the change in extinction coefficients for a rising and a setting star.

As you can see, these simple models produce equally good fits to the measurements. In fact, if you've only used one star to measure extinction during the night then you can not tell what was actually causing these odd results.

Now the improved method I'm going to describe was developed by the Vilnius Observatory and is intended to deal with the first possibility, i.e. where the extinction changes during the night but is uniform across the sky at any moment in time.

The Vilnius method is all about working out the actual magnitude of the star (. So why is this important? If we re-arrange the extinction correction equation (Equation 1);

$$k = (m_0 - m)/X \quad \text{--- Equation 5}$$

we can calculate the extinction coefficients k at every time we've made a magnitude measurement m by calculating the airmass of the star X at those times, *provided* we already know the star's actual magnitude.

And that is what the Vilnius method aims to

do. It uses two extinction stars, labelled 'extinction' and 'control' respectively. The stars are chosen so at the beginning of the night the extinction star is near the meridian and the control star is rising from low in the sky to the east. At this moment the two stars are simultaneously measured. Later when the control star is crossing its meridian and the extinction star is setting, the two stars are again simultaneously measured. As I'll show you shortly, it only takes these four measurements to calculate the extinction star's actual magnitude. However once you know that, you need regular measurements of the extinction star throughout the night in order to calculate the extinction coefficients throughout the night. I have also proposed a slight modification of this method, where the control star is also measured at regular intervals throughout the night – with each control star measurement again being made at the same time as an extinction star measurement.

The extinction and control stars should be chosen in the same way you normally would for a primary extinction star, except;

- The two stars should have the same spectral type (colour). If the stars have different colours, then correcting for the difference in the secondary (colour) extinction between the stars complicates the calculations.
- To reduce errors due to any non-linearity in your system, the two stars should be a similar brightness.

The procedure is as follows;

1. Get the extinction star's *approximate* magnitude ($\tilde{m}_{0,extn}$) using the standard method, for example in Figure 7 it would be the intercept (5.793).
2. Improve the accuracy of your approximate value by taking the average of these values from several nights ($\tilde{m}_{0,cntl_i}$). Remember what you're measuring is the star's magnitude in your instrumental system, which may slowly change as, for example, your filters age. You can get an idea of how stable your system is by looking at if, and how fast, the exact magnitude of the extinction star and control star found each night appears to change over the months – which we'll get to in a few more steps.

3. For every simultaneous measurement of the extinction star (m_{extn_i}) and control star (m_{cntl_i}), calculate the control star's approximate magnitude;

$$\tilde{m}_{0,cntl_i} = m_{cntl_i} - (m_{extn_i} - \langle \tilde{m}_{0,extn} \rangle) \frac{Airmass_{cntl_i}}{Airmass_{extn_i}} \quad \text{--- Equation 6}$$

4. Plot the airmass ratio on the horizontal axis and the approximate magnitude of the control star on the vertical axis (see Figure 9). The intercept is the *exact* magnitude of the control star, while the slope is the difference between the *exact* magnitude of the extinction star and its approximate magnitude ($m_{0,extn} = \langle \tilde{m}_{0,extn} \rangle + \text{slope}$). The original Vilnius method would have only had the two circled points – by including further control star measurements for a least squares fit, the accuracy is improved and the standard deviations give an indication of how accurate the exact magnitudes are.

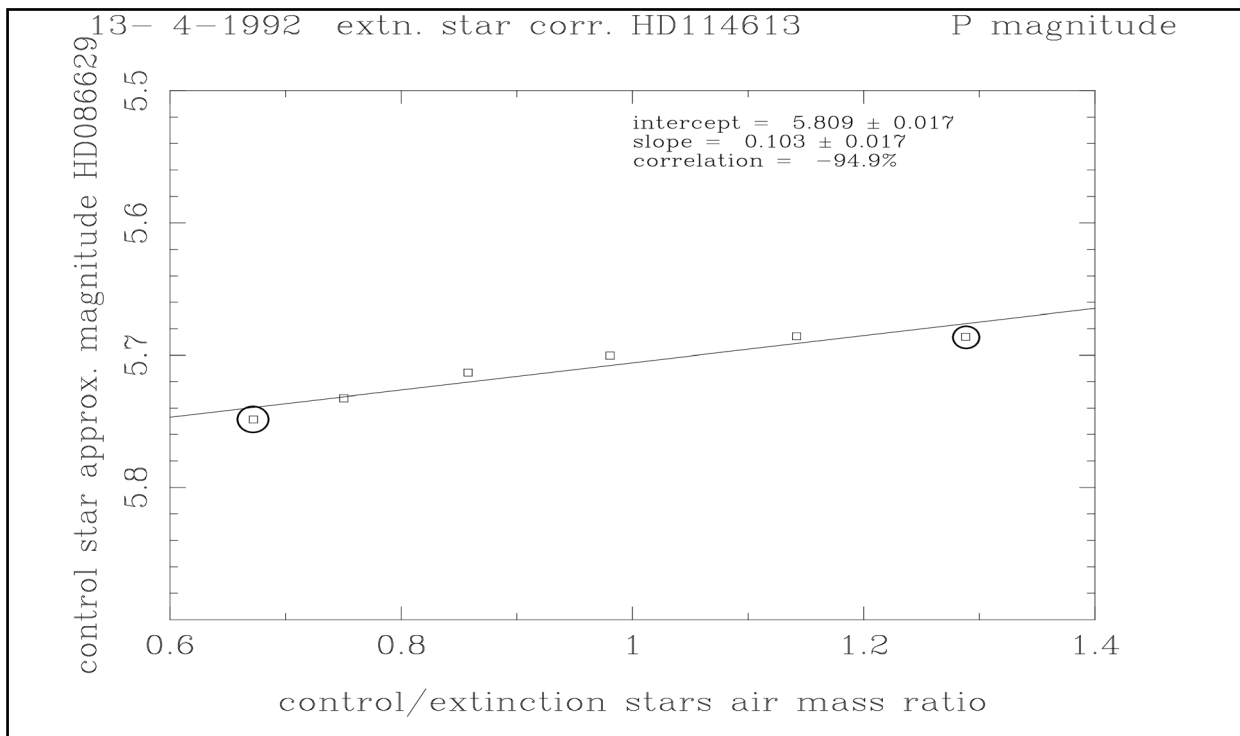


Figure 9. Plotting the approximate magnitude of the control star against air mass now gives the exact magnitude of the control star; while the slope is the difference between the exact magnitude of the extinction star and its approximate magnitude.

- Finally, improve the accuracy of the exact magnitudes of the extinction and control stars by averaging these values that have been found for each night over, say, the last month. You can get an idea of the stability of your instrumental system (and so choose an appropriate period to average over) by plotting the exact magnitudes found in step 4 for each night against the date and seeing if there are any trends in the magnitudes (ideally, you will only see a small random scatter about a horizontal line for each star).

Now that we know the exact magnitude of both the extinction star and control star, we can use these to calculate the extinction coefficient for every time we measured those stars – see Figure 10. This is from the night that I talked about earlier (Figure 7), where the star had a U shaped curve in the magnitude versus airmass plot. We can see now that the extinction slowly decreased as the night went on. Apparently this is due to a slow fall-out of aerosols in the atmosphere during the night as the convection driven by solar heating, which was stirring up the aerosols, ceases.

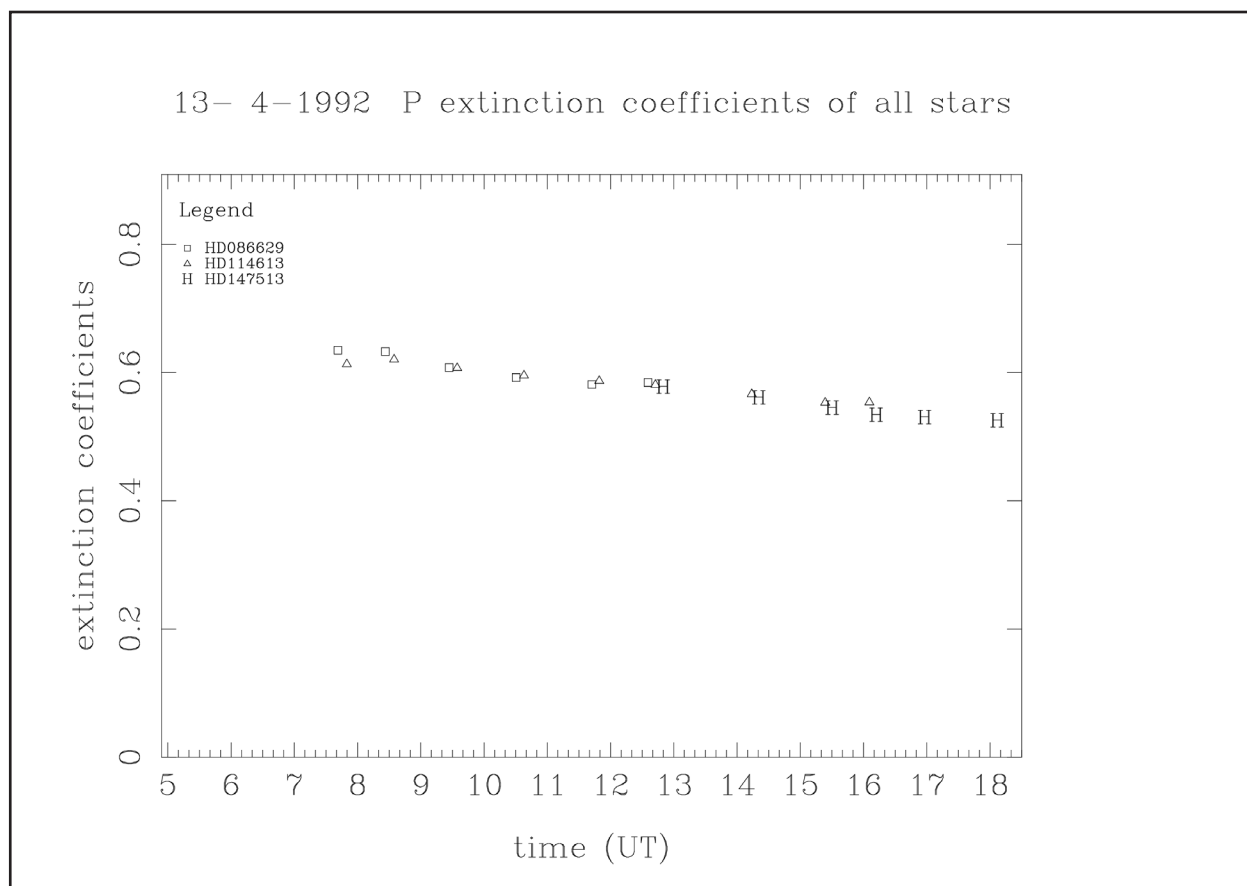


Figure 10. *Extinction coefficients during the night for three stars plotted against time.*

Those of you who are still awake may have noticed I have three stars plotted here. These observations were made in April, where the nights are about 12 hours long. However it only takes about 6 hours for a star to set after culminating so the extinction star, here HD086629, sets about midnight. By this time the control star (HD114613) was crossing the meridian, so it became the extinction star of an extinction-control pair of stars. In the middle of winter, it can be possible to use yet another pair of extinction-control stars for the last part of the night.

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It appears that some members are unfamiliar with O-C diagrams and period change analysis methods so some explanation seems warranted. The interest in period changes is based on the presumed evolutionary tracks shown in the Hertzsprung-Russell diagram. Mira stars are giants, occupying a cool region known as the asymptotic giant branch, AGB, and are presumed to move upward in this region, becoming brighter and cooler. If the star brightens as the star cools then its radius must expand. The period of a pulsating star is related to radius and density so in theory this expansion will see a change to a longer period. A good example to look for this is Figure 1 which shows periods of RR Sagittarii, a Mira star not apparently showing secular changes of period over an interval of 116 years. Why?

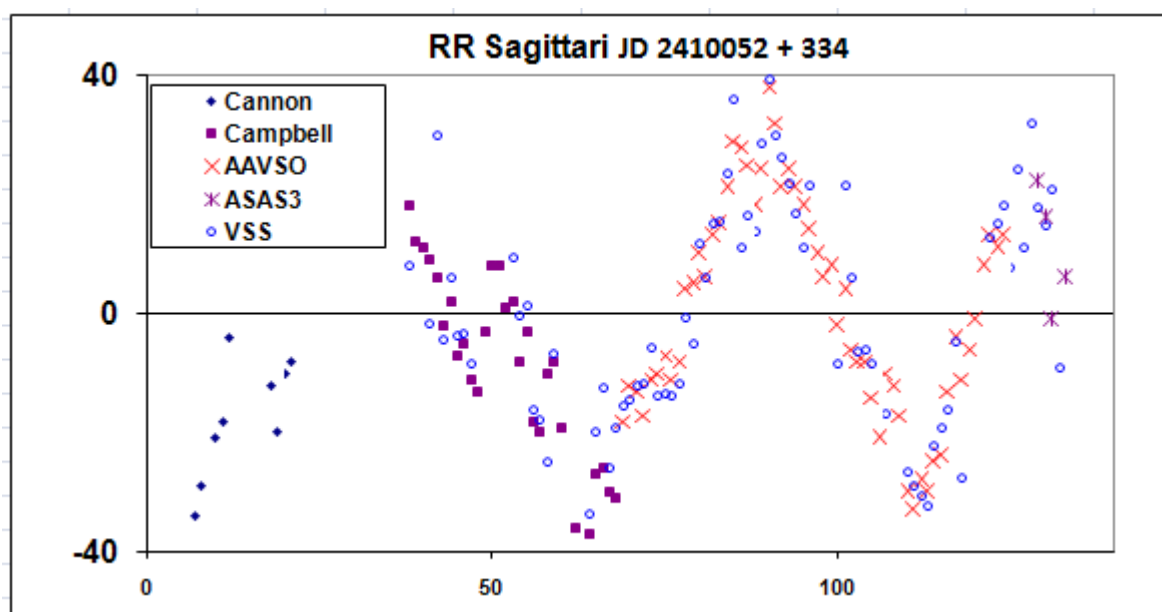


Figure 1. An O-C diagram of the Mira star RR Sagittarii from 1892 to 2008.

The periods of any star can be described using an ephemeris, or light elements, in this case an initial epoch of JD 2410052 and a mean period of 334 days. The points marked in this diagram represent individual epochs of some particular marker in each cycle. For pulsating variables it is usually the brightest point in the cycle, although some analysts have used the time of a particular magnitude on the rising branch and in the case of dual maxima Miras it's better to use minimum if it can be observed. Eclipsing binary epochs are best determined using mid eclipse. If the period of a star is unchanging then the subsequent epochs will all lie on the zero line.

The vertical scale shows how the observed (O) epochs differ from the calculated (C) times, those occurring late being positive, those early being negative. Why these deviations? In this case the star sometimes pulsates with a longer period, at other times shorter. Why is not clearly understood. The horizontal scale shows epochs since the fundamental epoch. Notice that the first measures made were when the star's maxima were occurring some time earlier than the mean ephemeris.

The two altering periods can be calculating by taking epochs at the extremes of the rising or falling branches and dividing the interval in days by the number of cycles between. In this case they are ~336.88 days from JD 2431391 to 40150 and ~330.62 days in the interval 40150 to 47093. But due to the reversals embedded in these intervals the true long period is greater, the short period less.

What can this tell us about the changing period due to evolution? Visually O-C diagrams are messy and it's not clear whether the slopes are changing. If you look at the GCVS almost all Miras are noted as having changing periods and it's clear that if you pick any two epochs at random the results will differ.

The graph shows that the variations of RR Sagittarii from the mean line do not exceed 40 days. Other stars seem to reach up to 40% of the period. Given these uncertainties it is impossible to conclude that even after 116 years the true mean period of this star has been found. Should the current short period turn into a much more enduring long period this will distort the mean period value.

Can the true periods be determined from the slopes in the diagram? Perhaps a Mira star might spend 10^7 years on the AGB during which time its period may change by from 150 to 450 days, a difference of 300 days over 33,333 cycles. This equates to a difference of 0.009 days/cycle, or 13 minutes. Over the 116 cycles of this graph we might see a change of 25 hours which is detectable, but difficult to determine with certainty due to the inaccuracy of the epoch determinations.

The advantage of the O-C method is that it clearly shows the presence of small period changes by adding these together if the change is in the one direction. It's very useful in Cepheids and eclipsing binaries where the changes in period are extremely small and it is the only way their reality can be established.

Other Methods

Is there something better? There is a large variety of period search software available. If we used it on the 10,000 or so measures making up this graph it might provide better values for the alternate periods but no better mean period - and it would simply indicate that two periods exist but not when they were present, which is important in the sense of evolution. The accuracy would be debatable.

Very much resembling the O-C method is 'Wavelets' software, designed to avoid the need to calculate individual epochs. It is popular with professionals but due to its need to use sliding windows much longer than the star's period it smears the detail shown by the graph above. But by using mean light curves, MLCs, it's just as fast to produce a graph like Figure 1 of any LPV. But MLCs are not widely used even though they have distinct advantages.

Other types of star - mainly those with very short periods - are better suited to techniques involving Fourier transforms. High speed times series photometry produces the hundreds or thousands of measures needed for accuracy. CV orbits are one area but on the evolutionary time scale O-C methods are better suited to plot intervals between outbursts of these stars.

If the periods are changing dramatically then a periodogram is more useful. It does not rely, as does O-C, on knowing the exact number of cycles during any interval. ST Puppis was such a star where several unobserved intervals of two or more years completely destroyed the cycle count.

A better contrast is shown in Figure 2 where an O-C diagram of BH Crucis appears on the left, a periodogram on the right.

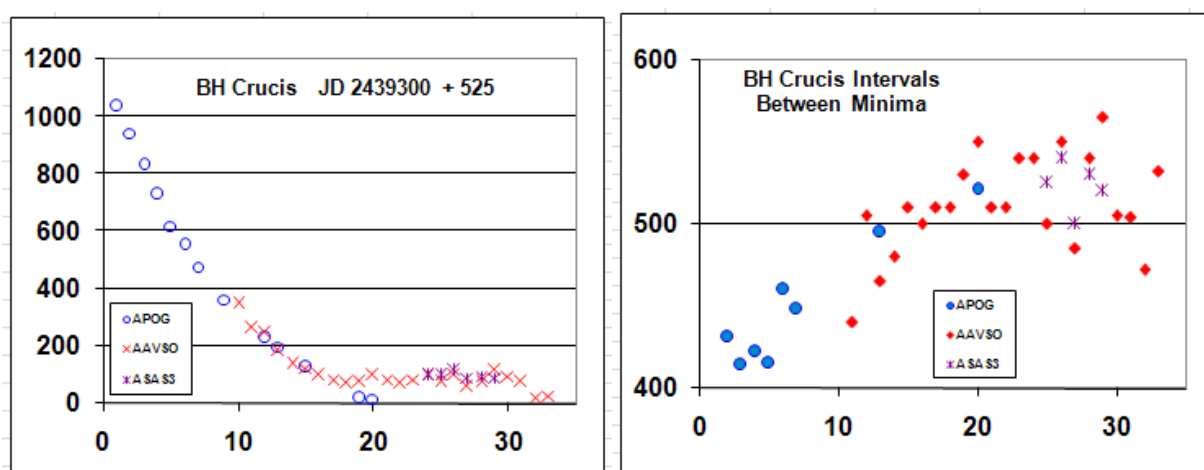


Figure 2. The period of BH Crucis changed dramatically over two decades, from 421 days to 525 days. It's hard to see anything in the O-C diagram except that the period is changing fast. It's more clearly shown in the periodogram where the actual periods are concerned. Only a few dozen known variables have large enough period changes to be usefully displayed in the latter manner.

The choice of methods is determined by what the author is trying to show. Each has its place and it's useful to be familiar with all. The following article about U Carinae makes extensive use of O-C diagrams.

U Carinae - an interesting Cepheid – *Stan Walker, Peter Williams, Alan Plummer, Andrew Pearce and Neil Butterworth*

Abstract

We present up-to-date epochs of maxima of the bright Cepheid U Carinae and examine period changes in the O-C diagram. Apart from the well known abrupt period change about 1970 there is clear evidence of a shorter term variation over a time scale of decades.

Introduction

This Cepheid has been observed since 1889. An O-C diagram showing fluctuations in period since then is shown in Figure 1. There is a noticeable oscillation from JD 2444000 onward and this was also present during Roberts' early measures although it's not apparent on this scale. There is clearly an abrupt period change around JD 2440000 from a mean of 38.7953 to 38.835 days. The vertical scale is in days, epochs occurring early are negative, those late are positive. The horizontal scale is JD -2400000.

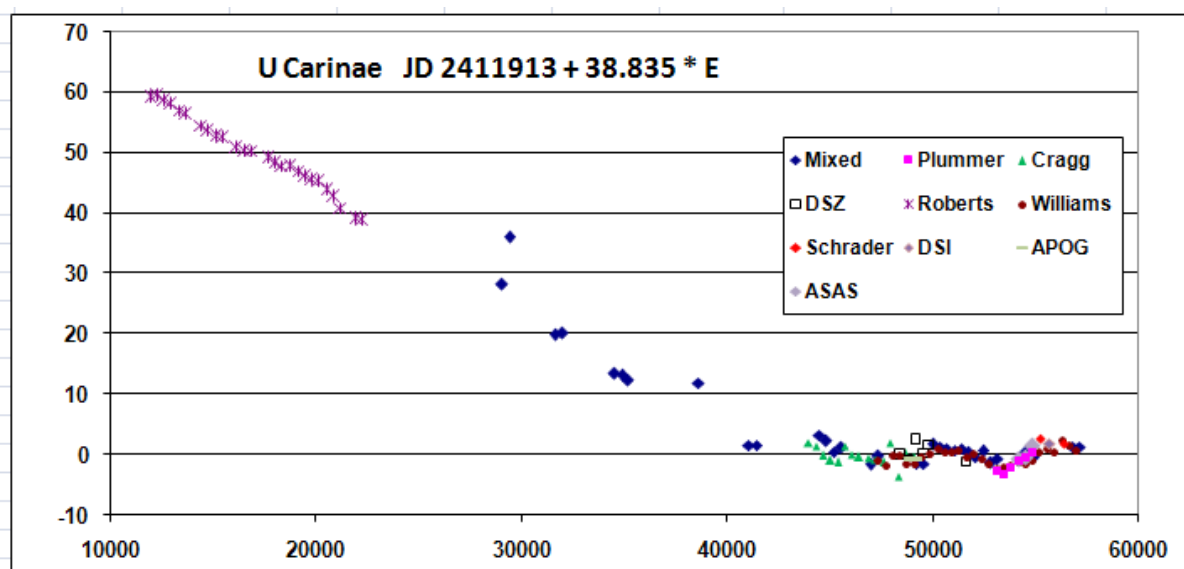


Figure 1. All available epochs of maximum are shown with the exception of most photographic ones during the interval JD 2422000 to 35000. Images were taken with a variety of emulsions and epochs are difficult to determine. The few shown are confusing. Epochs occurring late on the ephemeris are shown as positive, those early as negative. This provides a historical record since 1889. To understand this better we consider sections of the data in Figures 2 and 3.

The theoretical O-C pattern should show a steady parabolic increase or decrease of period. AQ Puppis is a typical example. In reality, abrupt changes of period are just as frequent. U Carinae has shown this latter behaviour but the oscillations may be unique.

Many of the epochs are based on visual measures fitted to a mean light curve. This raises the question - are visual measures sufficiently accurate for this purpose?

Accuracy of visual measures and epochs

Results show that provided the comparison star sequence is reliable and the spacing between comparisons is closer than for the much larger amplitude Mira stars, visual measures are adequate for the determination of epochs.

We plotted the visual epochs from JD 2446000 to 2457300 in Figure 2. We then plotted epochs derived from CCD V measures, Berdnikov, 2007, and from DSLR V observations by Butterworth to verify the visual epochs. The fit is quite good. Regrettably there are no other photoelectric measures available during the interval shown. ASAS-3 measures suffer from saturation at this level of brightness. The data are best fitted by periods of 38.8010 and 38.9274 days as shown by the slopes in the diagram.

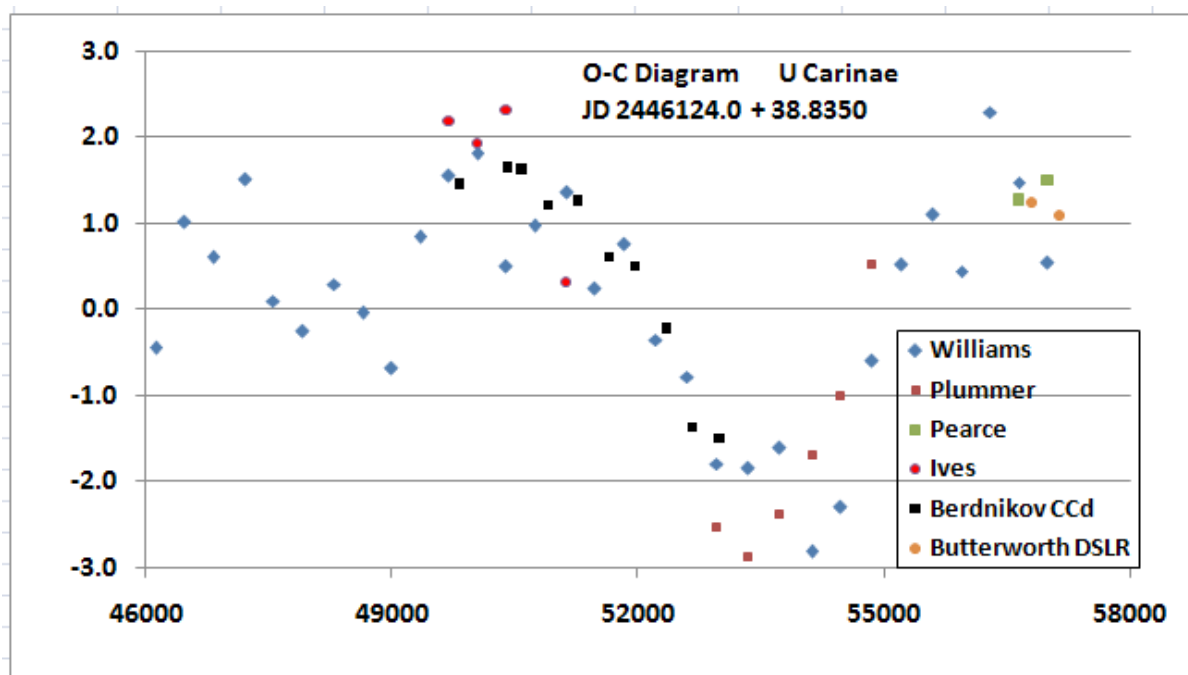


Figure 2. Epochs derived from measures by four visual observers show an amplitude of about 5 days when plotted against the ephemeris shown. Berdnikov and Butterworth epochs are photoelectric.

We then plotted Roberts' measures with a visual photometer during the period 1889 to 1922 in Figure 3. The alternate periods are 38.745 days and 38.776 days with a few at the end showing ~38.73 days.

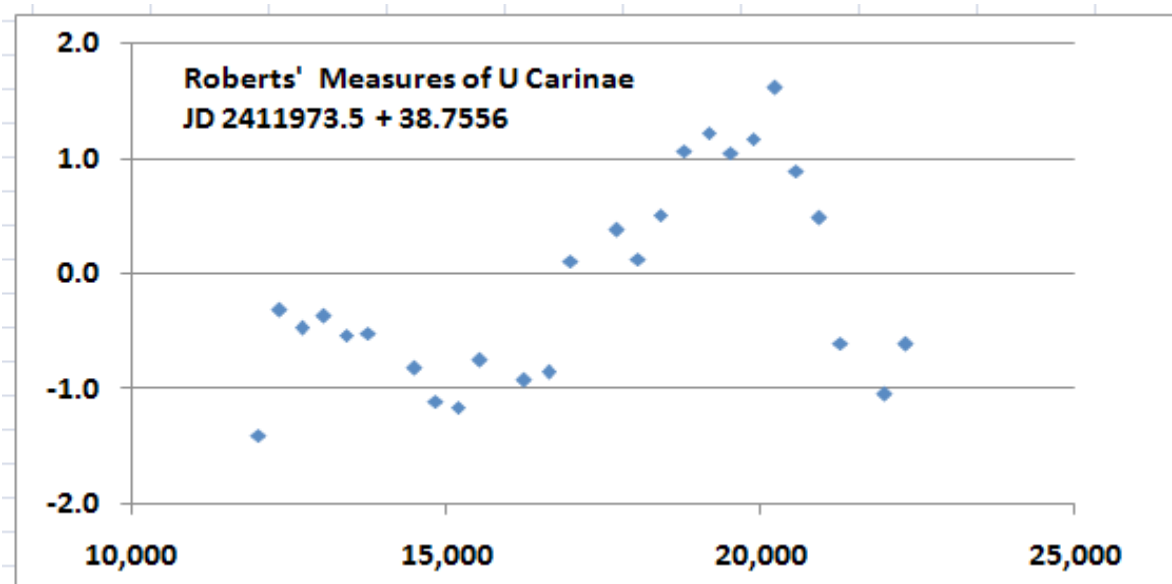


Figure 3. Epochs derived from Roberts' visual measures from 1889 to 1922 show much the same behaviour as those during the interval 1985 to 2015.

The epochs are derived by our standard procedure - fitting seasonal measures against a mean light curve derived from photoelectric V measures and taking the smallest RMS deviation. This eliminates most of the small cycle to cycle variations but is slightly less accurate than the photoelectric epochs. The table of epochs is available on the website www.variablestarssouth.org

The light curve in V, B-V

We present measures by Butterworth using a DSLR camera over two seasons, 2014 and 2015, in Figure 4. The light and colour curves are unremarkable but the large amplitude in V is quite clear. Noticeable is the slightly earlier maximum in B which is why, in the interests of uniformity, epochs in B are not used.

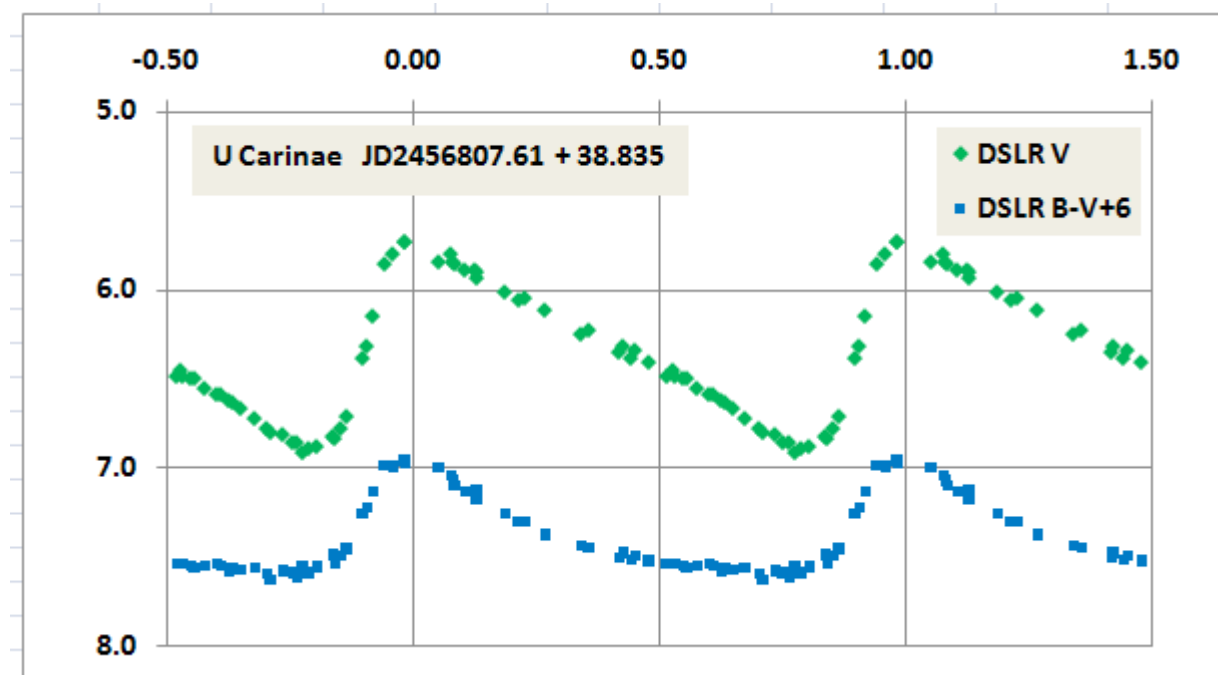


Figure 4. The V light curve of U Carinae phased to the light elements shown: The B-V colour has been offset by +6 magnitudes but is to the same scale. Thus the amplitude in the B filter is close to two magnitudes.

Conclusions

There is clearly a small but definite cyclic period with a time scale of decades. We are uncertain whether this type of variation is present in other Cepheids with very long periods in excess of 30 days. In the case of U Carinae it is similar to the alternations shown by most Mira stars, Walker et al, 1995, but with a much smaller percentage of the period. Other bright Cepheids with pulsation periods in this range are I Carinae and RS Puppis which are being analysed at present.

Another important issue is that comparison with photoelectric epochs has proven that period changes of large amplitude Cepheids can be effectively monitored by visual observers.

For those unfamiliar with O-C diagrams, periodograms and period analysis software we refer you to the preceding article.

Acknowledgements

Figure 1 is largely based on an unpublished analysis by Schrader, 2014, with some recent epochs added.

The International Database maintained by the AAVSO was the source of the early measures by A Roberts of South Africa, as well as the visual measures since 1986, almost all of which were made by members of Variable Stars South and its predecessor, the RASNZ VSS.

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Abstract

Five bright, southern, eclipsing binary systems have been examined (Bembrick & Blackford, 2016) using DSLR photometry. The V band light curves have been used to interpret preliminary (in the absence of readily available radial velocity data) astrophysical models of these systems with the aid of Binary Maker 3. As these are bright binaries (typically V magnitudes 6.5 to 7.2) their spectral classifications are published – in some cases for both components. This aids significantly in the modelling as it serves to initially constrain the possible photosphere temperatures. In this paper three of those systems will be discussed – CN Hydri, RR Centauri and V535 Arae – with particular reference to determining the mass ratios.

Introduction

Five eclipsing systems were presented in the poster paper by Bembrick and Blackford (2016), but only three will be discussed here. A further two – GG Lup and μ^1 Sco will be the subject of a following paper.

All three of the systems discussed below are overcontact systems where the stars have come into approximate thermal equilibrium and the surfaces have extended beyond their critical photospheres. This means that the light curve is continually changing in flux and the eclipse depths are very nearly equal (see Fig 1, CN Hyi) because of nearly equal surface temperatures (Bradstreet & Steelman, 2004).

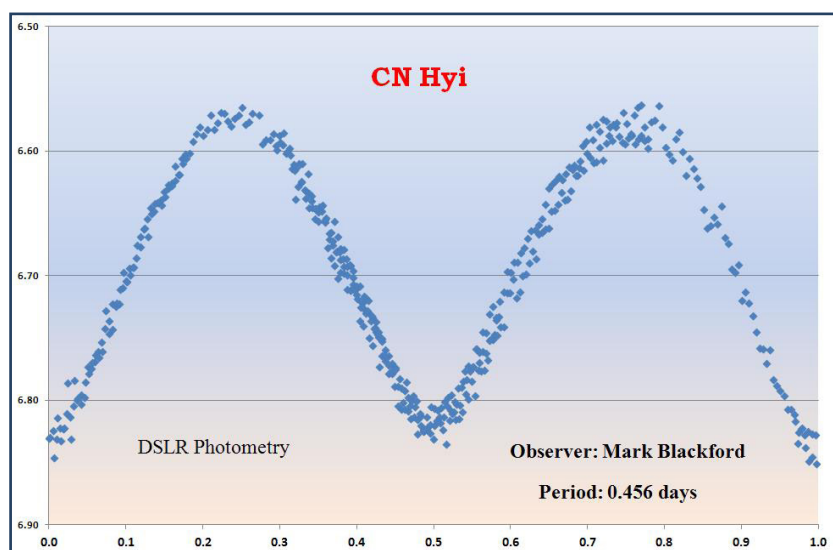


Figure 1. *CN Hyi*, showing continuous variability of the light curve and the nearly equal eclipse depths. Neither eclipse is total.

The periods are typically short – in these three cases < 0.6 days – and thus the systems are likely to be a W-type UMa overcontact systems where the larger star is the cooler. (see Fig 2, RR Cen)

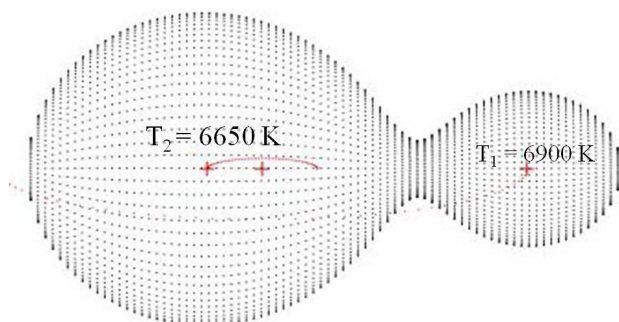


Figure 2. *Binary Maker 3* model of RR Cen, showing a considerable degree of ‘overcontact’, leading to distinctly non- spherical star shapes.

Modelling approach

In the initial approach to our modelling exercise it is useful to follow the scheme outlined by Richards (2016) and just sit down and eyeball the light curve while thinking about the basic geometry of the system. In this we can be aided by diagrams such as the ones to be found in Hoffmeister et al (1985).

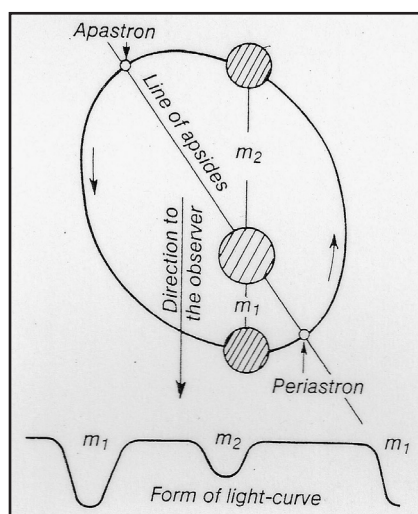


Figure 3. adapted from fig129 of Hoffmeister et al.

Looking down on the (eccentric) orbit and with the typical light curve below, showing the deep primary eclipse and the shallow secondary eclipse – in this case of eccentric orbit, not at phase 0.5. As this example is not a contact system, the light curve does not vary out of eclipse.

Another way of visualising the system geometry – particularly for W UMa binaries is shown below – adapted from fig 125 of Hoffmeister et al.

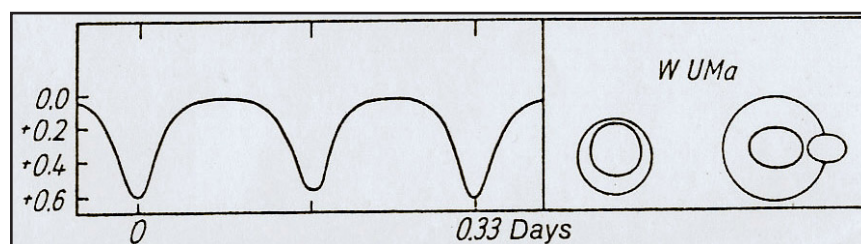


Figure 4. The light curve of a short period W UMa system with virtually continuous change of flux exhibited in the light curve. Note the eclipses are of very nearly equal depth and both stars are non-spherical in this instance – although they are not ‘overcontact’.

In the study of eclipsing systems the professional and the non-professional observers often adopt a different approach. The professional commonly (but not always) has spectroscopic and radial velocity (RV) data to work with, the system being well studied usually by large aperture telescopes. In the amateur or non-professional situation, the data available are usually more restricted. The star may be poorly studied, with little or no spectral classification published and no RV data available. A phased light curve (possibly only in one bandpass) is often the best the amateur can acquire, with some B-V or other colour indices perhaps. As the stars are often relatively faint, spectroscopic information is almost invariably lacking.

As there are very many unstudied or poorly studied eclipsing system – particularly in the southern hemisphere – the question arises as to what is the best and most efficient way for the amateur to attempt to model these systems. Binary Maker 3 (BM3) provides one approach to enable the amateur to model these stars, but there are various other software packages around which are championed by different groups – eg Winfitter, Phoebe, Wilson-Devinney, etc. The author’s experience to date is solely with BM3 and that will be the tool for modelling the systems described here.

Following the presentation of a poster paper at the 27th NACAA (Bembrick & Blackford, 2016) the opportunity has been taken to attempt some comparisons between BM3 modelling of bright eclipsing systems (using no RV data) and the professional models (which include RV data) published in the literature.

Professionals attempting to model eclipsing systems without RV data often advocate the “q-search” or “q-grid” method. This is a method by which some sort of best estimate may be made of the crucial parameter q, the mass ratio (see Wadhwa & Zealey, 2005). The exact method is somewhat involved and

time-consuming, particularly if implemented on BM3 where every iteration must be manually initiated. Consequently, a ‘quick ‘n nifty’ abbreviated version of this q-search method was used for this exercise to see if useful results could be obtained. In BM3 this involved varying q in discrete steps while noting the residuals of the model fit to the observed data – the light curve. This residual number is output by BM3 after the model has been rendered each time. Choosing to use residuals in BM3 is time consuming as it slows the program down considerably – and even more so if eccentric orbits are involved. The starting values for q are decided by an initial good eyeball fit in the modelling exercise. This fit is derived by some trial and error with BM3, taking into account the spectral type (if available) and B-V index to derive an initial temperature (T_1) for star 1. Various sources may be used to relate B-V to stellar temperature (see Flower, 1996).

The technique is to then plot q on the abscissa and the residuals (scaled) on the ordinate. If all goes to plan, then the minimum of the curve obtained should give a best estimate of the correct mass ratio, q . This then can be fixed in the model, together with T_1 and modelling can proceed to adjust the inclination, i , the other star temperature, T_2 and other factors. In this way there is some chance that the best model that can be expected in the absence of RV data will be achieved. Without RV data of course, the model cannot be definitive.

The bright stars chosen for this exercise rely on the excellent DSLR photometry (transformed B,V,R) provided by Mark Blackford – as shown in our poster paper (Bembrick & Blackford, 2016). These have the advantage in this project in that they are bright, have spectroscopic classifications and are well studied in the literature. The results of these comparisons are presented in the following sections.

RR Centauri

Discovered to be variable in 1925, RR Cen is listed in the literature as a main sequence system with spectral/luminosity types A9/F0 V. The period is given as 0.605 days, with a magnitude range of 7.32 to 7.75 from Blackford’s photometry.

A full coverage of the phase plot is available, with the secondary eclipse obviously a total event - as compared to the primary which is a transit according to the model.

For the purpose of this exercise, assuming this is a star without any RV data and utilising the spectral classification data to derive an input temperature for star 1, a preliminary model was derived from BM3. As outlined in the previous section, the mass ratio, q , was then varied in discrete steps and a q plot obtained (see Fig. 5).

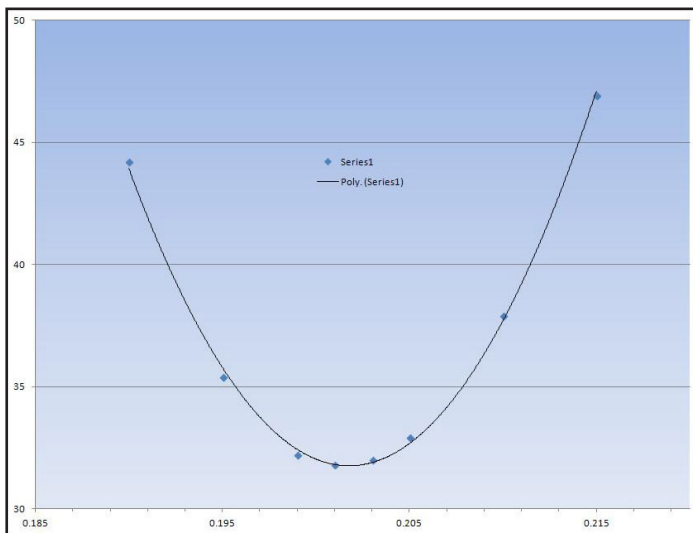


Figure 5. *RR Cen q plot – note the excellent fit of the 2nd order poly to the data and this gives a well-defined minimum at $q = 0.201$ to 0.202*

On this basis we would expect to have some confidence that this was a reliable estimate of the mass ratio, q . The question then arises as to how this compares with the published model (Yang et al, 2005) where RV data was used in the interpretation. Table 1 below summarises and compares the model parameters.

PARAM	Author, 2016	Y Q Z paper, 2005
q	0.202	0.205
T ₁	6900K	6912K
T ₂	6650K	6891K
i	81°	81°
Omegas	2.20	2.199
Fillout	0.25	0.35

Table 1. Shows there is a very good measure of agreement between the published results and the BM3 derived model parameters. The mass ratio and the inclination are particularly well matched.

I think we could say that the ‘quick ‘n nifty’ q search method has yielded a reliable, believable result here – is this a fluke? Read on, further interesting comparisons follow.

CN Hydri

CN Hyi was identified as variable in 1991, with a quoted magnitude range of 6.68 to 6.93. Our observed magnitude range is 6.57 to 6.83. The period is short at 0.456 days. The spectral classification/luminosity class is quoted as F6 V in the literature. Photometry shows the eclipse depths are very nearly equal, but neither eclipse is total.

Deriving a temperature for star 1 based on the spectral type and doing a preliminary model with BM3 gave a starting value for the q search. The resulting q plot is displayed in Fig 6.

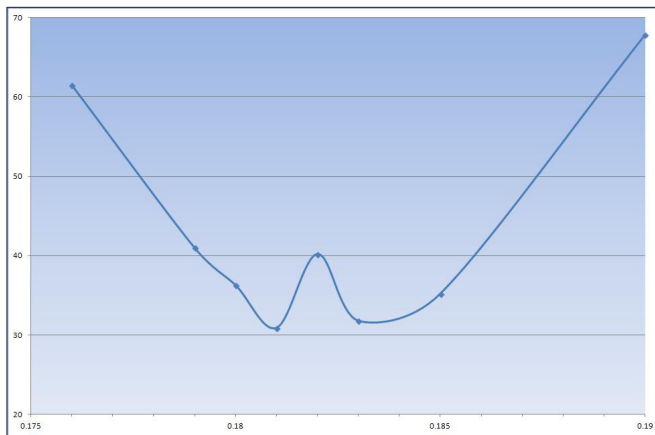


Figure 6. The q plot for CN Hydri displays a broad minimum, with two sub-minima within the broader minimum.

The broad minimum stretches from q of 0.1805 to 0.1845, with the subsidiary minima at 0.181 and 0.183-4.

A 2nd order polynomial fit to this gives a minimum for q of 0.182 to 0.183.

So we have no clear-cut answer here. We can pick and choose what q we use. The author’s modelling picked q = 0.181, whereas the published model using RV data (Ozkardes et al, 2009) uses q = 0.184. This should be a definitive value.

However, we find that the modelling of Wadhwa and Zealey (2005), using their (rigorous) method of q search, derives a value of q = 0.25. This is somewhat discrepant from both the (definitive) model using RV data and my ‘quick and dirty’ q search method. The latter two agree fairly well within reasonable limits, but the value of 0.25 is discordant and remains to be further investigated.

We should count this as very close to a success for the ‘quick ‘n nifty’ method of q search, particularly taking into account the value of q suggested (0.182 to 0.183) by our poly fit to the curve. The discrepancy with the more rigorous(?) method of Wadhwa and Zealey (2005) remains unexplained, but the similarity to the results of Ozkardes et al, (2009) – where RV data is used - is most encouraging.

The comparisons are summarised in table 2 below.

Table 2.

PARAM	Author, 2016	Ozkardes et al, 2009	W & Z, 2005
q	0.181	0.184	0.25
T_1	6490K	6500K	6510K
T_2	6360K	6360K	6310K
i	62°	63.7°	60.10
Omegas	2.14	2.14	2.67
Fillout	0.38	0.42	0.34

V535 Arae

Identified as a variable in 1966, V535 Arae has a spectral/luminosity classification in the literature as A8 V. The period is 0.629 days and Blackford's photometry gives a magnitude range of 7.19 to 7.78 – close to the quoted values. Similarly to RR Cen, the secondary minimum is total.

Once again a preliminary model gave a starting point for a q search by the 'quick and dirty' method. The resulting q plot is shown in Fig 7 below.

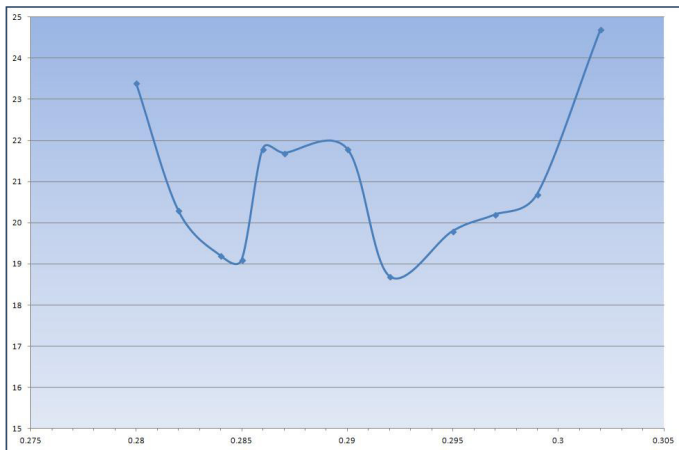


Figure 7. For V535 Ara a broad minimum is evident, but with a large 'hump' dividing it into two portions.

A 5th order polynomial fit to this curve led the author to use $q = 0.297$ in the poster paper model (see table below).

Is this a useful approximation? Table 3 below gives the comparisons.

Table 3

PARAM	Author, 2016	Schoffel,1979	Leung &Schneider,1978
q	0.297	0.311	0.36
T_1	8900K	8200K	8750K
T_2	8600K	8050K	8572K
i	82°	81.6°	81.1°
Omegas	2.4,2.3	2.46	2.59
Fillout	0.05,0.47	-	-

Here we see that the 'quick 'n nifty' method of q search has yielded a result not too far from the value of Schoffel (1979), who had the benefit of RV data. However, the value of Leung & Schneider (1978) is considerably different as they did not have access to RV data for their model.

So, perhaps we could count this as a qualified success for the 'quick 'n nifty' method of q search, However, we are on more dubious ground here as the figure of $q = 0.311$ is really outside the range which would have been chosen by any 2nd order poly fit interpretation of the 'quick 'n nifty' method.

Summary

Although only a sample of three, all of the above examples lead one to the conclusion that the ‘quick ‘n nifty’ method may give excellent results in some cases but it needs to be treated with caution.

It appears that if one has a ‘well behaved’ q plot then the results for q can be in excellent agreement with those derived from interpretation using RV data. If the q plot is less well behaved – as in the case of CN Hyi – then a poly fit should be used to estimate q. If the q plot is even less well behaved and exhibits a complex minimum or several minima (eg V535 Ara), then a poly fit can be used with caution. It may give a value close to the correct mass ratio q, or it may be significantly adrift. However, in the absence of any RV data, it is most likely the best estimate available to the modeller.

A more rigorous application of the q search method will be applied to GG Lup and μ^1 Sco in a later paper.

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TT Centauri – an interesting carbon Mira – Stan Walker, David Benn, Terry Bohlsen, Peter Williams, Alan Plummer, Andrew Pearce, Michael Heald and Neil Butterworth

TT Centauri is one of the stars listed amongst Miras with probable dual maxima and this has encouraged some photoelectric measures recently. It has also been observed extensively by visual observers since about 2000. Prior to that Tom Cragg made most of the measures over a twenty year interval, but in this century Albert Jones, Peter Williams, Alan Plummer and Andrew Pearce have been the main visual observers. Mike Heald, Terry Bohlsen and Neil Butterworth have measured it photoelectrically. This combination of observers and techniques reveals an interesting picture.

Figure 1 shows the available results from the International Database as compiled by David Benn. He draws attention to the quite significant decline in brightness since 2004 which reached a minimum in 2012 but the star is now brightening - perhaps to the earlier level?

The phased colour curve over three cycles as shown in Figure 2 reveals a very red star with some interesting features. There is a very wide maximum, about 150 days, which appears double at times in this and the visual data of Figure 1.

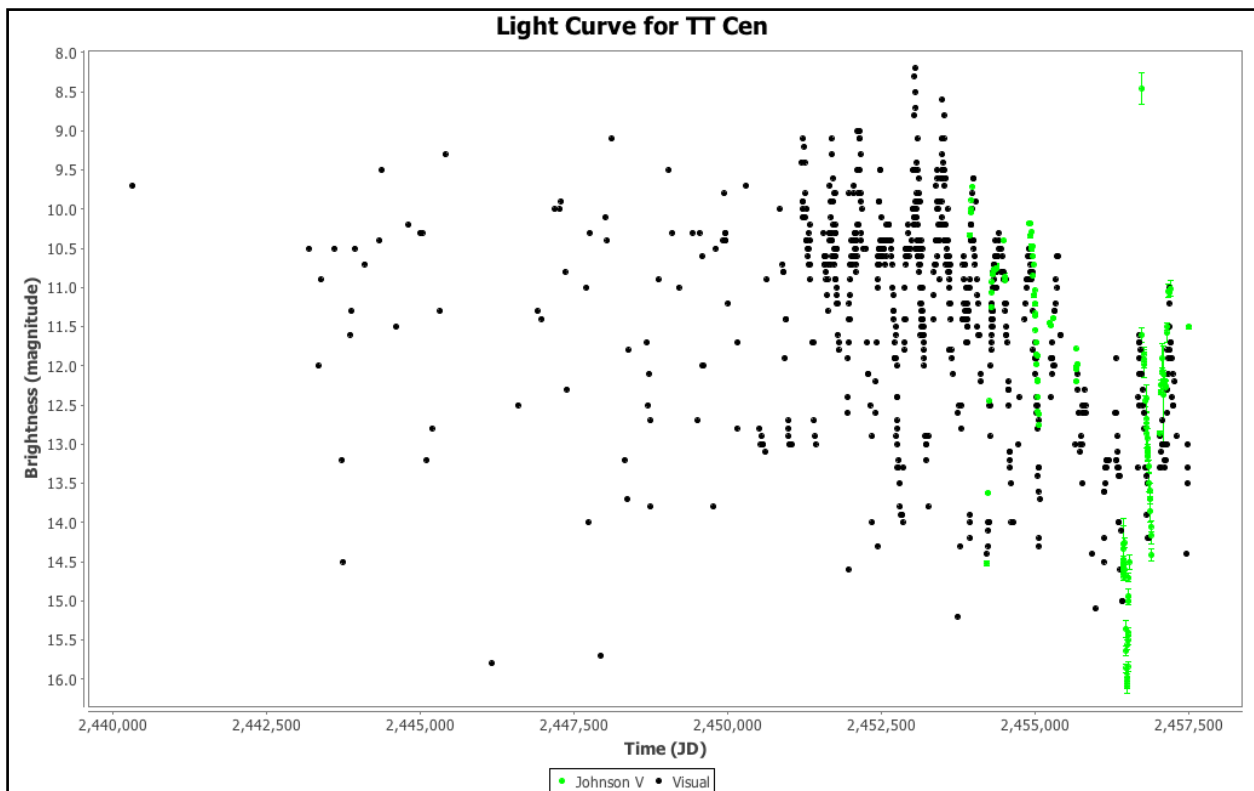


Figure 1. The light curve in visual and V shows the substantial changes in brightness over the last 16 years.

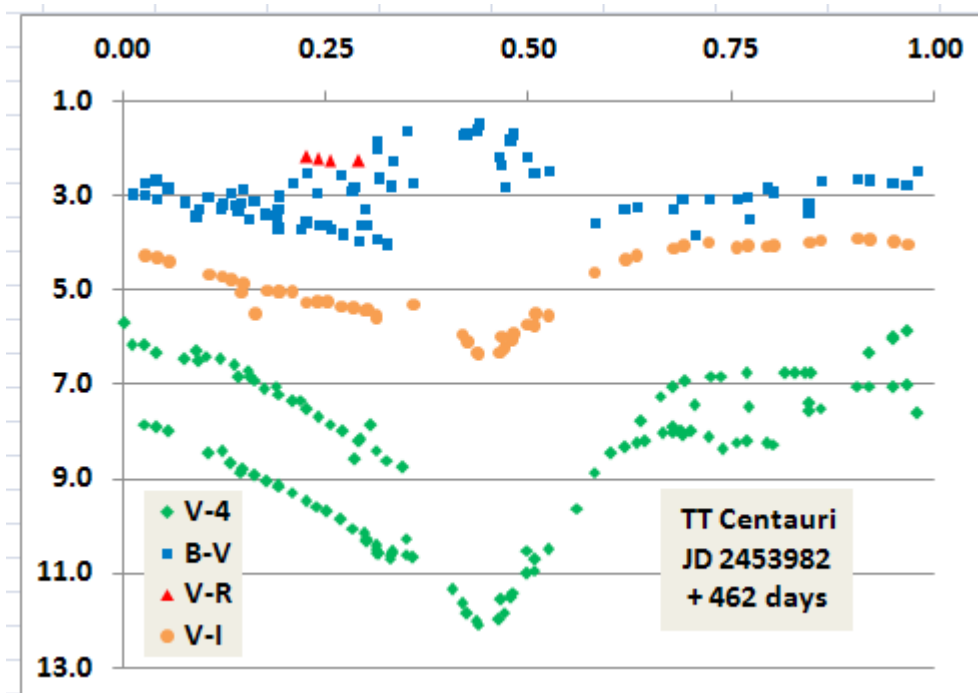


Figure 2. The V measures have been offset by -4 magnitudes in this graph to put everything on the same plot. So it has really changed from $V = 12$ to $V = 10$ at maximum over one cycle. Apart from this the scales are identical and the values are actual. The change in brightness is quite clear. Positive values indicate that the star is brighter in the second filter of each pair. The concept relates to temperature and the larger the colour (often called a colour index) the cooler the star. But chemical composition and also density affect these values so some care is needed.

The B-V colour of ~ 2.8 at maximum is typical of carbon stars - some are even redder. All three photoelectric observers contributed to this and the data is similar with some slight scatter. The upper part of the B-V curve from phase 0.25 to 0.50 is probably not real - the star is about $B = 18-20$ in those phases and there's probably another faint blue star ($B = \sim 16$) in the measured aperture which causes an apparent but unreal colour change. The four V-R measures were made by Neil Butterworth and are close to the normal relationship of $V-R = B-V * 0.52$. There may be a little input in R from the Ha emission line as seen in Figure 3.

Returning to the B-V values - the discordant ones occurred in the first cycle shown which was two magnitudes fainter than its successor. These two cycles show a startling rate of rise. It is not advisable to discard these B-V measures on an assumption as they may indicate something unusual about this star at minimum but the more likely explanation is that given. Were U measures possible this question would be resolved immediately but the star is far too faint for that.

The V-I colour is normally similar to the B-V colour in value but here it's much brighter, probably indicating strong radiation from dust around the star. Terry Bohlson obtained the spectrum in Figure 3 on 21 April, 2016.

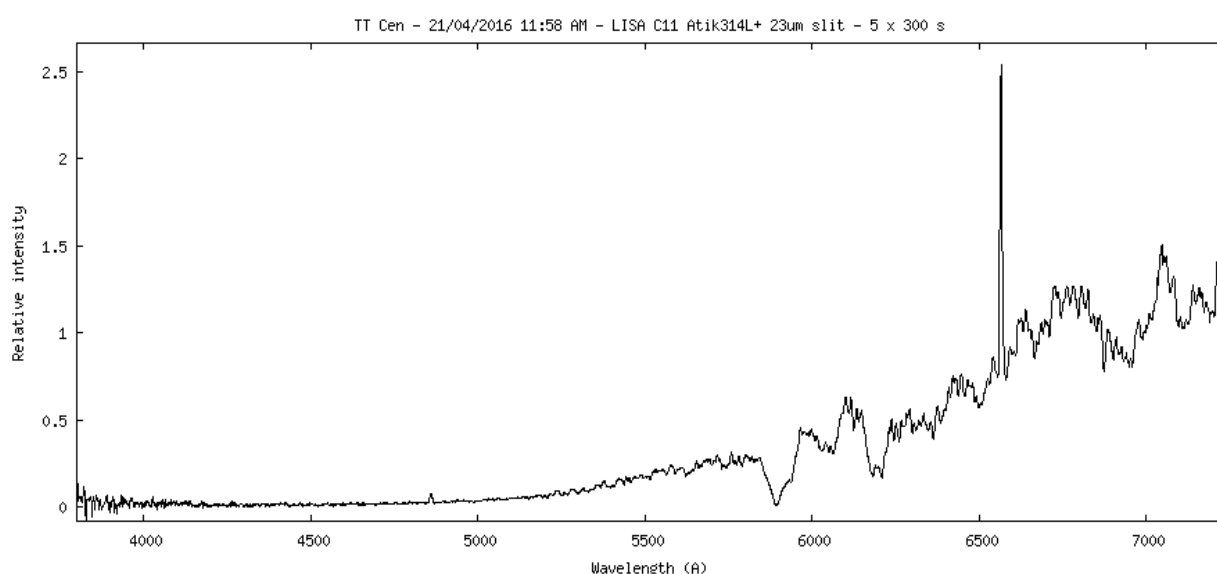


Figure 3. This shows the energy distribution of TT Centauri which is near or rising to maximum at present. This supports the bright V-I colour of Figure 2. The bright Ha emission line affects the R measure and there is some evidence of the beginnings of the Balmer discontinuity emission just before the wavelength cut-off at $\sim 3800\text{\AA}$.

Robert Wing in an IAU Symposium devoted to carbon stars, Miras, SRs and LPVs, in 2000, discussed this star along with others, including R Fornacis and R Sculptoris, both very red objects with some variations in overall brightness at intervals - but these variations are somewhat random and are generally attributed to dust cloud ejection events.

The longer period Miras - $P = 400+$ days - seem to be more subject to period changes and longer term overall brightness variations. The radial pulsation cycles are related to the size of the star and the surface gravity of a Mira, bearing in mind its large radius, is quite low. Mass loss is continuous, resulting in the emission spectrum, and dust clouds, attributed to more dramatic mass ejection events, have been detected around many of these.

To conclude this brief article - it shows the value of better communication between observers. With the visual observers aware of unusual behaviour from their for the long term observations of a star and bringing it to the attention of all, then filtered colour measures to provide information about what is going on during a pulsation cycle and spectra to see the intensity distribution to better understand the more sensitive but rather cruder photoelectric measures can all come into the picture to great advantage.

CCD targets for May to July 2016 – Tom Richards

tomprettyhill@gmail.com

For this three-month period I have chosen target systems of V magnitude 10.0 or fainter in the RA band of 15-20 hours inclusive. Brighter targets are better handled by DSLR equipment.

We begin with some EAs (detached, semi-detached). Using data from the former VSS EA/SPADES project, Streamer *et al* (2015) provided revised light elements of 25 southern EAs. These systems need more minima measurements as confirmation, so they are all good and useful targets. The following are the systems from that list within our RA band.

GCVS	RA 2000.0	Dec 2000.0	Mag	Epoch	Period [d]
KZ Lib	155559.8	-171139.00	11.14	2456086.1355	1.238737
V0626 Sco	171711.2	-401725.00	11.4	2456510.9553	1.033683
V0632 Sco	172030.4	-430434.00	11.5	2456476.8968	1.610148
V0634 Sco	172139.1	-364511.00	11.7	2455769.9765	1.224029
V0638 Sco	172407.3	-430203.00	11.3	2456114.1140	2.358234
V0490 Sco	173754.5	-335704.00	12	2456128.9342	3.003763
V0849 Sgr	190237.2	-310741.00	12.9	2455818.9621	2.950654
V5552 Sgr	194855.3	-371212.00	12.86	2456152.0751	1.347661

The periods and epochs in this table are from VSS data in (Streamer *et al* 2015). V5552 Sgr was previously catalogued at twice this period, so it is particularly important to capture secondary minima for it as well as primary.

Next, the EBs (near-contact, usually distorted). The following table from the GCVS lists all entries in our RA band south of -30° declination and with mags in the 10-11 range. The light elements of BT Mic are from the AAVSO VSX (www.aavso.org) since the GCVS doesn't list any.

GCVS	RA J2000	Dec	Type	Max	Epoch - 2400000	Period	Spectrum
EL TrA	161321.3	-695804	EB/KE	10.8	40381.98	0.545509	
LP Ara	164001.8	-463935	EB	10	51965.81	8.533069	B8
V0619 Sco	171416.0	-412121	EB/KE	11.9	29458.23	0.75462	
FY Aps	171420.2	-700048	EB/DM	10.9	28745.13	5.49935	
V0474 Sco	171851.4	-313459	EB	10.3	26472.51	1.62004	B3-5
V0633 Sco	172120.4	-415818	EB:/KE:	11.9	29458.3	0.493333	
IT Ara	172458.2	-595425	EB	11.9	52770.78	0.528395	
V0700 Sco	173113.2	-312243	EB:/DM	10.19	28066.28	2.3469	B5
FU Ara	173332.3	-580950	EB:	10.3	51940.94	0.86451	
LO Aps	174710.2	-773720	EB/KE	11.3	36729.33	0.7988	
V0833 Sco	175356.0	-363202	EB/KE	11	31293.22	1.187827	F0
V5535 Sgr	182457.4	-302443	EB	10.65	51950.29	2.2517	A0
V0731 CrA	183051.8	-371649	EB	10.9	52796.75	0.537745	
GY Tel	185540.0	-480531	EB	11.43	46973.76	0.446035	
PR Tel	192940.8	-521950	EB	11.1	51965.32	0.590637	F
TV Ind	203354.6	-552831	EB	11.7	36786.29	0.57686	
TV Mic	203722.4	-383016	EB/AR:	11.7	36807.3	2.0762	
BT Mic	203957.3	-433623	EB	10.14	48501.06	1.5057085	
CO Ind	205629.6	-475043	EB	10.64	52175.54	0.597959	A2/3V:
RY Ind	205802.1	-460400	EB/KE	10.83	43019.89	0.712114	A5

For EW (contact, over-contact) binaries, the catalogue of (Pribulla, Kreiner & Tremko, 2003) is a useful source, listing stars for which some spectral and other astrophysical data are known. The following table contains its entries south of -30° in our RA band for stars brighter than mag. 10.

Star	RA2000 h:m:s	DE2000 d:m:s	HJD0-2400000 d	Period d	SpType	Vmax mag	Vmin mag
V701 Sco	17:34:25	-32:30.16	48072.96	0.285464	K1V	10.8	11.4
V1084 Sco	17:37:57	-39:11.23	48500.08	0.516285	A8V	10.49	11.07
V535 Ara	17:38:06	-56:49.17	45920.1	0.283997		13.2	14.1
FS CrA	18:06:12	-37:30.54	44826.55	0.307357	G8V	10.6	10.94
V870 Ara	18:08:23	-56:46.02	48500.18	0.432567		10.7	11
AB Tel	18:37:36	-50:57.48	45885.46	0.259516		11	11.4
LT Pav	19:48:36	-71:01.30	45991.67	0.263638	K3	13.8	14.6
V386 Pav	20:55:58	-65:25.58	48500.27	0.311784	G9V	11.4	12.1

If you want to work on these targets and you're not in the SEB group, have a look at the Southern Eclipsing Binaries subweb of our website (or go directly there at www.eclipsingbinaries.prettyhill.org). There you will find comprehensive guidelines on eclipsing binary work. The first step is to find a time of minimum in your data. Once you have some data, please contact me and I'll send you an invitation to share the VSS EB-EW Dropbox folders. There you will find project information, useful papers, and our data for each target under observation. You can add yours will, and you will be a co-author when we publish anything with your data in it..

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Publication watch

VSS members are encouraged to provide abstracts of papers they have had published recently in refereed journals. Roy Axelson has had a number of such publications during 2014 and 2015 as follows.

Axelsen, R A, 2015, *Recently Refined Periods for the High Amplitude d Scuti Stars V1338 Centauri, V1430 Scorpii, and V1307 Scorpii*. JAAVSO Volume 43, p 182

Abstract Digital Single Lens Reflex (DSLR) photometry of the high amplitude d Scuti stars V1338 Centauri, V1430 Scorpii, and V1307 Scorpii was taken during the southern autumn and winter of 2015. Fourier analysis revealed pulsation frequencies corresponding to periods very close to those previously reported with significant contributions from harmonics. Only in the case of V1430 Scorpii was another independent frequency detected. The oscillation periods were refined by calculating linear ephemerides based on previously published epochs for each star, and the epochs determined by the author. These periods are: V1338 Centauri, 0.13093808 d; V1430 Scorpii, 0.08377709 d; and V1307 Scorpii, 0.11703066 d.

Axelsen, R A, Napier-Munn, T. 2015, *Recently Determined Light Elements for the δ Scuti Star ZZ Microscopii*. JAAVSO Volume 43, p 50.

Abstract The δ Scuti star ZZ Microscopii (HD 199757) was studied by photoelectric photometry (PEP) on three nights in 2008 and by DSLR photometry on three nights in 2014. PEP yielded 51 magnitude measurements in V, including 4 peaks of the light curve, and DSLR photometry yielded 622 measurements, including 14 peaks of the light curve. Fourier analysis of the DSLR photometric data found a principle frequency F1 of 14.8853 (0.0001) c/d, and a harmonic frequency 2F1 of 29.7706 (0.0007) c/d, similar to the results of others. Another frequency F2 of 22.2049 (0.0025) c/d, of much lower amplitude than F1, was identified. F2 is higher than the frequency (19.15 c/d) previously reported in the literature, and its accuracy is regarded as uncertain as the semi-amplitude of F2 is low. Regression analysis of an O-C diagram, plotted from 33 historical times of maximum from 1960 to 2003, 4 times of maximum from our PEP in 2008, and 14 times of maximum light from our DSLR photometry in 2014 indicated that a cubic regression provided the best fit. The fitted curve confirms conclusions of others that the period of ZZ Mic was increasing at a constant rate during the years 1960 to 2003, and indicates that the period has decreased during more recent years. The following cubic ephemeris was derived, with zero epoch defined as the first peak of the DSLR photometry light curve on 19 July 2014: $T_{\max}(\text{HJD}) = 2456858.0131 (0.0002) - 7.644 (2.532) \times 10^{-19} E_3 - 2.646 (0.973) \times 10^{-13} E_2 + 0.06717917 (0.00000001) E$.

Axelsen, R A, 2014, *Methods for O–C (Observed Minus Computed) Diagrams and for the Determination of Light Elements of Variable Stars with Linear and Second Order Polynomial Ephemerides*. JAAVSO Volume 42, p 451

Abstract Methods are described for the construction and analysis of O–C (observed minus computed) diagrams and for the determination of light elements (ephemerides) of variable stars and the standard errors of the elements. The methods described are those that apply: (1) when the period of the star is constant, and (2) when the period of the star is changing continuously, and the light elements can be represented by a second order polynomial function.

Axelsen, R A, 2014, *Current Light Elements of the δ Scuti Star V393 Carinae*. JAAVSO Volume 42, p 292

Abstract V393 Carinae is a 7th magnitude δ Scuti star which has a principal period of 0.1413 d and an amplitude of 0.2 magnitude in V. Previous publications have suggested the existence of a second period, but its duration has so far evaded discovery. In view of the uncertainty, and since the only two papers on this star were published in 1984 and 2001, DSLR photometry was performed to obtain time series data. Images were taken during 6 nights from December 2013 to March 2014. The data were analyzed using a discrete Fourier transform, which yielded a principal frequency of 7.07727 (± 0.00005) cycles/day, corresponding to a period of 0.141297 (± 0.000001) day. Prewhitening for this frequency revealed a harmonic frequency precisely twice that of the principal, but no further dominant frequencies could be found. O–C diagrams suggested that it would be appropriate to derive a new linear ephemeris from three times of maximum obtained by another author from 1977 to 1979, combined with the 6 new times of maximum reported in this paper. The light elements are: $T_{\max} = \text{HJD } 2456732.0484 (6) + 0.14129328 (1)$. It is concluded that the current principal period of this star is almost identical to the period determined approximately 37 years ago. The issue of a second period is unresolved. None was detected, but it cannot be excluded that a second pulsation frequency of low amplitude could be hidden due to a low signal to noise ratio.

Axelsen, R A, 2014, *EQ Eridani, a Multiperiodic δ Scuti Star*. JAAVSO Volume 42, p 287

Abstract DSLR photometry of the δ Scuti star EQ Eridani (HD 28665) was undertaken on six nights between 2 November and 8 December 2013. Comparison and check stars were HD 28508 and HD 28901, respectively. Inspection of the light curves revealed an irregular pattern and variation in amplitude that signified the presence of two or more periods. Fourier analysis using the software `period04` yielded at least three pulsation frequencies of 14.3663, 11.6862, and 7.2128 cycles per day, corresponding to periods of 0.0696, 0.0856, and 0.1386 day, respectively. The first of these frequencies is very close to the period of 0.0700 day listed in a catalogue of δ Scuti stars published in 2000. This is the first report of multiperiodicity in EQ Eri. None of the period ratios fall within the range of 0.74–0.78 expected for the ratio of the first overtone to the fundamental mode of δ Scuti stars pulsating in the radial mode.

Axelsen, R A, 2014, *New Light Elements for the High Amplitude δ Scuti Star RS Gruis*. JAAVSO Volume 42, p 44

Abstract. Photoelectric and DSLR photometry of the monopерiodic high amplitude δ Scuti star RS Gruis yielded 16 times of maximum determined by the author from 2007 to 2013. These data are combined with historical observations obtained from 1952 to 1988 and more recent observations by others from 2003 to 2010. This combined dataset, comprising 50 times of maximum spanning 61 years, was subjected to O–C analysis, which revealed an obvious change in the period of the star between 1988 and 2003. Separate O–C analysis of the data from 2003 to 2013, comprising 28 times of maximum, yielded a quadratic fit, with the pulsational period increasing at the rate of $dP/Pdt = 84.95 (15.74) \times 10^{-8} \text{ yr}^{-1}$. To our knowledge, this rate of increase in period is the highest ever reported for a Population I high amplitude δ Scuti star with radial pulsation. From a quadratic (second order polynomial) ephemeris, the period was calculated to be 0.14701118 (0.00000011) d at HJD 2452920 (in October 2003) and 0.14701241 (0.00000012) d at HJD 2456497 (in July 2013).

Axelsen, R A, 2014, *New Light Elements for the High Amplitude δ Scuti Star BS Aquarii*. JAAVSO Volume 42, p 37

Abstract DSLR photometry of the monopерiodic, high amplitude δ Scuti star BS Aquarii yielded five times of maximum in September and October 2013. These data were analyzed with twenty-two times of maximum obtained by other observers from 1973 to 1995. New light elements were calculated, revealing a period of 0.197822765 day (± 0.000000010) at HJD 2456543.0250 (± 0.0005). These light elements represent a linear ephemeris, with no significant change in the period of the star from 1973 to 2013. The data do not support the previous suggestion in the literature of an unseen companion affecting the O–C diagram.

About

Variable Stars South is an international association of astronomers, mainly amateur, interested in re-searching 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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