



Newsletter 2010/3

2010 August

From the Director

OUR WEBSITE IS CHANGING

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Variable Stars South is a totally online organisation, a phantom in cyberspace with no earthly home, no "headquarters", no mailing address. It communicates with us mortals through www.varstars.org, and allows us to communicate with each other via vss-members@googlegroups.com. The success of our organisation relies on these media; and the present website is not adequate to our growing needs.

I set up this website a year ago in some haste, as without it VSS had little to offer its many members. I used a simple and easy website development tool, which within its rather severe limits worked quite easily. But now we need to move beyond that; and we need to move beyond having me play Webmaster. It's a hat I really don't need to wear - I have enough others to wear in VSS.

I'm very pleased indeed to announce that David O'Driscoll, a name known to many of our Australian members, has volunteered not only to take over as Webmaster, but to re-make the site totally in a much more interactive and user-oriented style, as a content management system. If you want to have a look at some of David's work, visit the website of the Astronomical Association of Queensland, <http://www.aaq.org.au/cms/index.php>. It's his creation.

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David writes of himself "David O'Driscoll joined the Astronomical Association of Queensland in 2005 after many years interest in astronomy, including 2 years as a member of the Northern Districts Society of Amateur Astronomers in Sydney in the late 1980's. As an IT professional for some 25 years, David has naturally gravitated to the world of online, remote astronomy, which allows him to combine his interests in astronomy with his IT skills. In recent years he has been balancing interests in variable star photometry and double star astrometry. While David loves using remote scopes to take images, he acknowledges that none of them will ever win a

David Malin award!!" He modestly didn't add that he received the Astral Award for the best paper at the recent NACAA conference in Canberra, for his paper on using remote robotic telescopes. I first got to know David about three years ago when I discovered we were working together in an American project on some eclipsing binaries in Ara. I was using my backyard observatory - everyone else including David was using the GRAS remote robotic scope in Moorook, South Australia. Now David is collaborating on our Equatorial Eclipsing Binaries Project - using the New Mexico GRAS telescope!

The new website is now largely constructed, and we expect to launch it in September. Closer to the time we will have a lot more to tell you about it. Meanwhile, here are some of the major changes:

- The website will have a new domain name, more mnemonic of Variable Stars South. The old website will remain for quite a while with redirections in place so that nobody gets lost.
- The website is being hosted at no charge by Flexihostings (<http://www.flexihostings.net.au/web/>) to whom we are very grateful. This will be a major saving for a not very affluent organisation.
- It will have a login area for VSS members only, to contain member information and other organisation-specific material, including a members-only forum to replace vss-members@googlegroups.com.
- It will host as many forums and blogs as members wish to set up. Thus for example people working on Delta Lib can have their own forum.
- There will be a forum open to anyone, member or not, interested in southern hemisphere variable star work.
- It will be easy for nominated people to add news items and other material directly - not just me!
- People in charge of projects or specific campaigns will be able to set up areas of their own to which they can add content themselves, and have their project colleagues upload their data and other information.

David writes of the new site: "The new VSS website has been designed with two primary aims: making the site more friendly and useful for members, and making it easier for the VSS project leaders to update their own information. The result will be a site that can be supported by several people (rather than just the hard-working Tom Richards!) and at the same time can grow with the membership and projects that are undertaken. Features that may be of interest include: easier to access news articles that will be tailored to project areas; support for online discussion groups by project, allowing team members to exchange information relevant to their projects; easier sharing of files between project members; support for other collaboration tools, such as calendars and private messaging; and a new modern look-and-feel that can be refreshed easily without extensive work by the team managing the site."

It is very important at this stage to feed any ideas you may have for the website to David. Many of you will be aware of valuable features on other websites that we could well copy, or see possibilities for the use of the website that we've not thought of. Please email David your ideas, at webmaster@varstars.org (for now).

One important associated change in VSS policy is that project participation is now open to non-members of VSS. The members-only restriction was to encourage membership; but now that we are growing strongly with much member activity, this no longer seems necessary. But we will of course encourage non-members taking part in our projects to join up!

New Projects

There are also two or three more projects waiting in the wings to be launched via the new website, rather than duplicating work by creating new areas for them on the present website. A particularly exciting one is SPADES: Search for Planets Around Detached Eclipsing Systems. This was first suggested by Dr Simon O'Toole of the then Anglo-Australian Observatory, now the Australian Astronomical Observatory, in a paper he presented to the Canberra NACAA. He and I had a conversation about it, and since then have been working it up. It requires a lot of careful planning, especially since it will actively involve a number of professional astronomers, and because we plan in the future to use some very big telescopes indeed for the spectrographic aspects of the project. But more about that in due course.

In addition, I'll be launching a project on southern eclipsing binaries, and Stan Walker and Alan Plummer are cooking something up on CVs at minimum.

Reaching the Multitudes

Alan Plummer has an excellent spread on observing variable stars in the August edition of *Australian Sky and Telescope*. It appears that Alan will have a regular column from now on. Congratulations Alan, and let's hope that brings in a few more observers.

In the same edition there's a very good account of this Easter's NACAA in Canberra by Ross Gould, giving due weight to the variable star presence. And with articles by Yaël Nazé on massive stars and Renée James on jets, it's a great read for variable star observers.

THOUGHTS FROM THE EDITOR

Stan Walker

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Most of these thoughts don't relate to editorial policy or anything of that nature. The material is now coming through in a style I can handle more readily—although I'd like rather more on the observational front.

I note Tom Richards refers to 'something about observing CVs at minimum' and this is described on pages 21-24. Unfortunately the old idea of visual measures of variable stars is disappearing and everything is being done by computer. The art of finding things in the sky is being lost—we now need to own a 'goto' telescope which will get there faster. And to measure anything it seems essential to use a CCD camera which immediately demands a computer to see what the camera is seeing.

My own favourite project is the Bright Cepheids and there is a report on progress beginning on page 32. We're still in the exploratory stages but some interesting things—such as the offsets between U, B, V and the eye are important in any analysis of measures—and the new methods, particularly Glen Schrader's idea of three different pairs of comparisons, are producing the accuracy required to check these offsets and produce reliable O-C diagrams.

Bob Nelson has produced the final instalment of his series on eclipsing binaries, beginning on page 12. Once the new website is up and running, Bob has agreed that the whole series will be accessible there permanently. After reading this article I've decided to get out some of the old EB measures made at Auckland and see if I can get an a believable model—something to do this summer . Many thanks to Bob for this interesting series.

Back in 1997 when I began making CCD measures the reduction method involved using SBIG's CCDOPS and 200 hours of 30s measures of V803 Centauri took forever to convert into magnitudes. Then the first version of Munidos—based on Peter Stetson's methods—came along. A great set of software which even allowed the measurement of the crude CCD measures of those days (no automatic tracking so many stars were trailed). Now it's been developed into a very useful reduction system and Phil Evans describes this in detail from page 25. It's inexpensive and it's reliable and Phil uses it well!

Mention of V803 Cen brings me back to the CV ideas of page 21. The old VSS was strong in this field but with the eyeball we couldn't see too many at minimum. The 50cm Edith Winstone Blackwell at Auckland could measure down to $V = 16.3$, but only by offset photometry as you had to place the star in a 1mm focal plane aperture. Not a problem with CCDs where anywhere withing 5-10 arcminutes is often good enough. So this is a good project for any group wanting a change of scene on occasion. It needs an enthusiastic armchair astronomer willing to learn a little bit about the field and reduction methods to move it forward.

And, finally, Rod and Albert mention a couple of interesting objects which are worth further study. And a rather belated UBV analysis of R Centauri reveals some difficult to explain colour changes during each cycle—but back in the 1970s. Is anyone looking now?

STARS OF THE QUARTER

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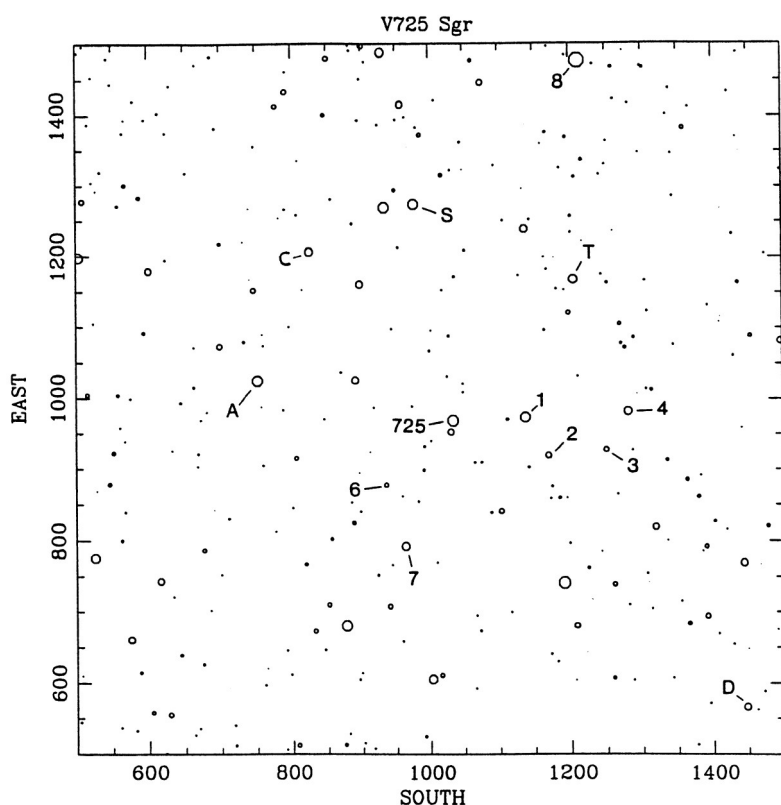
V725 Sagittarii

a Rod Stubbings target

Rod Stubbings drew attention to this star which was featured in the Star of the Season, Autumn 2006, by John Percy, on the AAVSO website <http://www.aavso.org/vstar/vsots/fall06.shtml>. Regretfully this has had only one noticeable effect—that Rod Stubbings has joined Peter Williams in observing this star visually.

The star was identified in 1935 by Henrietta Swope as an unusual variable. From 1926, when its period was 12 days with an amplitude of 0.3 magnitudes, its period had increased smoothly to 21 days with an amplitude of over magnitude. A later analysis by Percy et al, 2006, suggests periods of 5-9 days from 1899-1915 and 8-10 days from then to 1925. Ignored until 1968 it was then thought to have a low amplitude (0.4m) period of ~45-50 days. Danie Overbeek in South Africa measured this star for a time and it seemed to show a period of 60 +/-3 days from 1985-1996 after which a period of 75 days was evident until the end of the century. Hugh Lund measured the star in 1997-8 and his data were fitted by two periods, a primary of 96.2 and a secondary of 74.0. Peter Williams' data from 1999-2004 was analysed by Percy et al and a period of ~90 days found.

Rod has observed it on 212 occasions since 2006 and a search of his data reveals a strong period of 74.598 days and a weak period of 53.094 days. In all of this confusion I turned to ASAS3 data but this is quite poor with this star and shows nothing helpful, except that it may support the other datasets of Williams and Stubbings with periods of little variation mixed with periods of quick variation. All of this is fairly consistent with SR stars. Along



Rod Stubbings uses the chart to the left with magnitudes provided by Amelia Wehlau from measures made by Sergei Demers. Details are:

1	12.235	1.623	1.56
2	13.70	0.695	0.22
3	14.05	0.564	0.04
4	13.045	1.58	2.07
6	14.42	0.81	0.36
7	13.01	1.24	1.29
8	10.835	0.15	0.07
Next	13.63	1.257	1.16:
A	12.20	0.37	0.03
C	13.03	0.47	0.05:
D	13.30	0.59	0.08
S	12.24	0.11	0.13:
T	12.86	0.55	0.06:

V725 has a close companion at ~7" which is called 'Next' in this table. The AAVSO incorrectly identifies this as V725.

The illustration shows Rod Stubbings's measures since JD 2454000 folded to JD 2454000 + 74.59842. But a greater density of measures would allow annual epochs!

the way it was called a Type II Cepheid—low mass, high luminosity, erratic pulsations—but not this erratic!

V725 is worth following because of these dramatic changes. But it needs a better approach than has been used to date. The visual observers will, no doubt, do most of the observing but they need assistance. Visual measures would usefully be made several times a week if possible. Alongside these, a season of colour photometry, fully transformed, would be interesting. UBV, BVRI or whatever is possible.

Peter seems to have gone away from this star and his data is now too sparse for analysis—there are too many aliases present to determine a good period. What is needed is at least 100 measures per observing season from each visual observer.

If you decide to participate please use the chart on the previous page—or at least the magnitudes provided which are far better than those provided by the AAVSO (Not a criticism of the AAVSO but in many cases the only magnitudes available below $V = 10$ are from surveys for other purposes, often with unusual filters. Measures should be sent to the AAVSO in the normal manner, but keep the website informed.

R Centauri and other DM Miras

Peter Williams sends in measures of these stars each month and with these and other historical data a picture is beginning to emerge. Whilst there are only a few of these objects see NL 2009/2 pp 21-22.—

they seem to comprise a rather diverse bunch. R Centauri's period has shortened from ~550 days to ~500 over the past few decades and it appeared that, like BH Crucis, it was turning into a single maximum star. But after the second maximum had become quite small about 2004 Figure 1 shows that it is now recovering to a more normal amplitude.

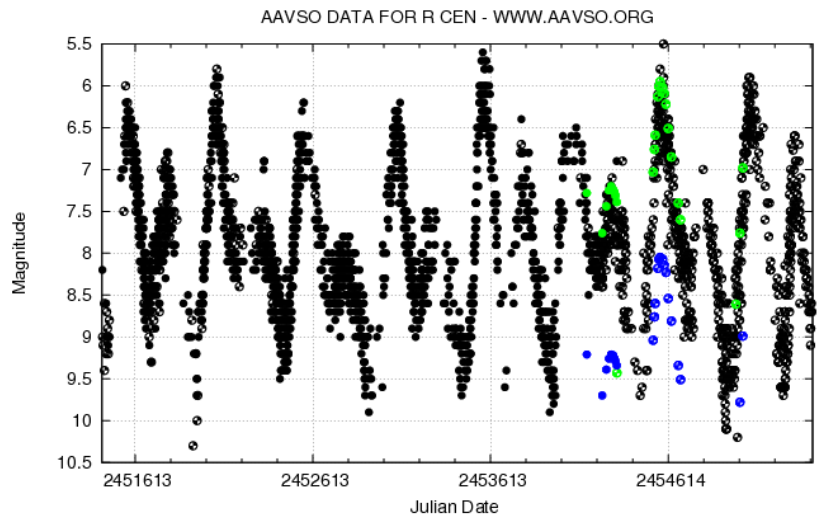
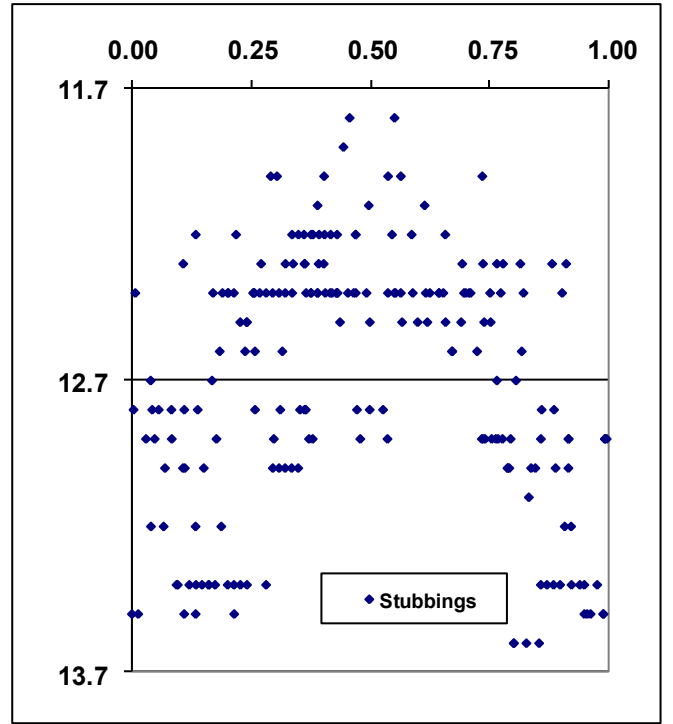


Figure 1: The last 4000 days of R Centauri from AAVSO measures.

V837 Arae = CPD-56 8032 = He3-1333

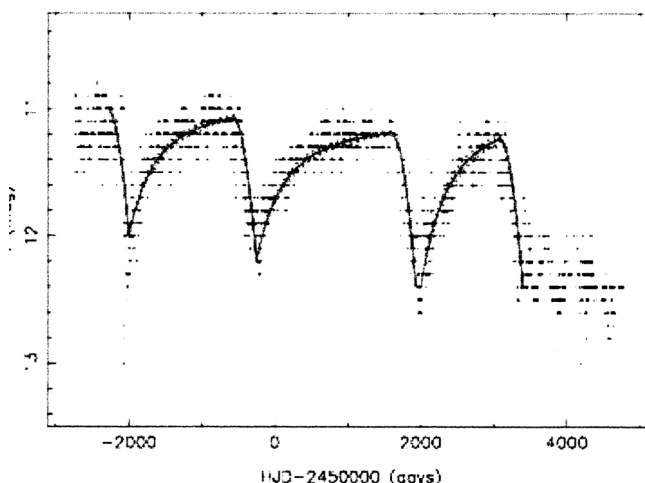
Albert Jones

As I had been monitoring V348 Sgr for years, when I read about three other similar stars, they were put on my “to do” list. One was too far north but the other two were well placed. One object scarcely varied but the other one, CPD-56 8032 did vary. Warrick Lawson accepted the offer of my estimates and produced a paper for the “Observatory” which led to its being named V837 Ara.

Periodically it suffered RCB like fadings and then latterly it faded after a briefer rise to maximum and thereafter stayed around minimum. The black points show my estimates.

Fortunately, around the time of my fall, I asked Rod Stubbings to monitor it, so its behaviour is still being recorded. There are many references to be obtained over the internet.

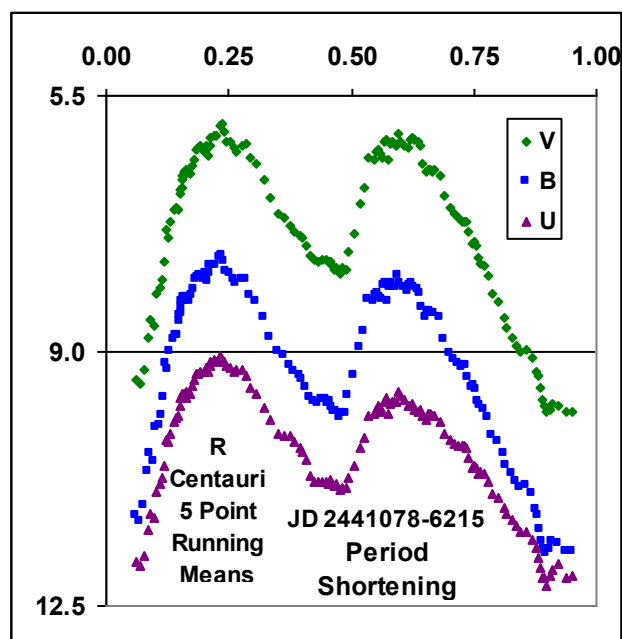
Albert



Albert sends in Figure 2 from a paper in which he is a co-author.

R Centauri and other DM Miras—Continued

V415 Velorum and R Normae show the classical symmetrical double maxima light curves and their periods are not changing. R Cen’s light curve is more like the normal Mira with a fast rise and slower fall. But the second maximum is much smaller in amplitude as the wavelength decreases—unlike the normal Miras. It appeared earlier that R Cen might evolve into something like R Hydrae but this may not be the case.



To the left is shown a composite VBU graph of R Cen from 1972-85 where the measures have been phased in accordance with the decreasing period. This illustrates the above comments relating to the lack of symmetry and the curious colour changes which may be occurring because of an accreting companion star.

In order to secure a more detailed colour curve we have been investigating the possibility of using some of the AAVSO’s robotic telescopes to secure BVRcIc data over two cycles of each of these target stars—plus a few normal Miras for comparison purposes.

EQUATORIAL ECLIPSING BINARIES PROJECT

CU HYDRAE

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CU Hydrae is a target system in the joint VSS-BAA Equatorial Eclipsing Binaries Project. This report summarises the observational work carried out in the recent observing season, February to May 2010. Seven observers, three from the Northern Hemisphere, submitted a total of 32 nights of CCD time series data. From these data we can derive very accurate light elements and a good light curve. In this report we do not investigate the colour data, evidence of period variation since discovery in 1933, or stellar modelling. Those are reserved for a future paper.

CU Hydrae (RA 08 54 20.56 Dec +03 42 23.4 J2000) was included in the Equatorial Eclipsing Binaries Project because although moderately bright, very little is known about it. It is described in GCVS4 (<http://www.sai.msu.su/gcvs/gcvs/iii/iii.dat>) as an EA (Algol-type light curve), discovered in 1933. Its GCVS light elements are $HJD\ 2427155.4070 + 0.7190774 \times E$. (Samus 2007), and mags 13.5-14.5 pg. This data is repeated in the AAVSO VSX portal. The Krakow elements (<http://www.as.up.krakow.pl/ephem/>) are much more up-to-date: $HJD\ 2452500.5309 + 0.71907148 \times E$. (Kreiner 2004). (Brat 2009) lists 10 times of minimum since 1933, which effectively confirm the Krakow period and epoch. However only the four most recent are CCD measures, and the five visual estimates can be disregarded - the other is the original 1933 photographic measurement. The Svechnikov catalogue (Svechnikov & Kuznetsova, 1990) gives the spectral class as F0 + G7IV but this is speculative and apparently not based on colour photometric or spectroscopic data, and nor are the other astrophysical parameters listed in the catalogue.

Observations

Observers contributing to the campaign are listed in Table 1, along with the number of nights of data they contributed (all time series up to several hours' duration), and the measurable primary and secondary minima recorded. All observers used CCD cameras.

Observer	Country	Nights	Filter	Minima I	Minima II
Terry Bohlson	Australia	11	V, R (transformed)	1	0
David Boyd	UK	4	unfiltered	4	0
Phil Evans	Cook Is.	5	unfiltered	1	2
Yenal Ogmen	North Cyprus	1	V	0	1
Roger Pickard	UK	2	unfiltered	1	0
Tom Richards	Australia	3	V (one night unfiltered)	2	0
Margaret Streamer	Australia	6	unfiltered	1	0
Totals		32		10	3

Table 1. Observer information

All observers used as comparison star GSC 0217:0020 (star "2" in Figure 1 below) and as check, GSC 0217:0456 (star "1"). David Boyd kindly provided V magnitude measurements on the comp and check. See Table 2 which also includes V-R information derived by Boyd from the 2MASS catalogue .

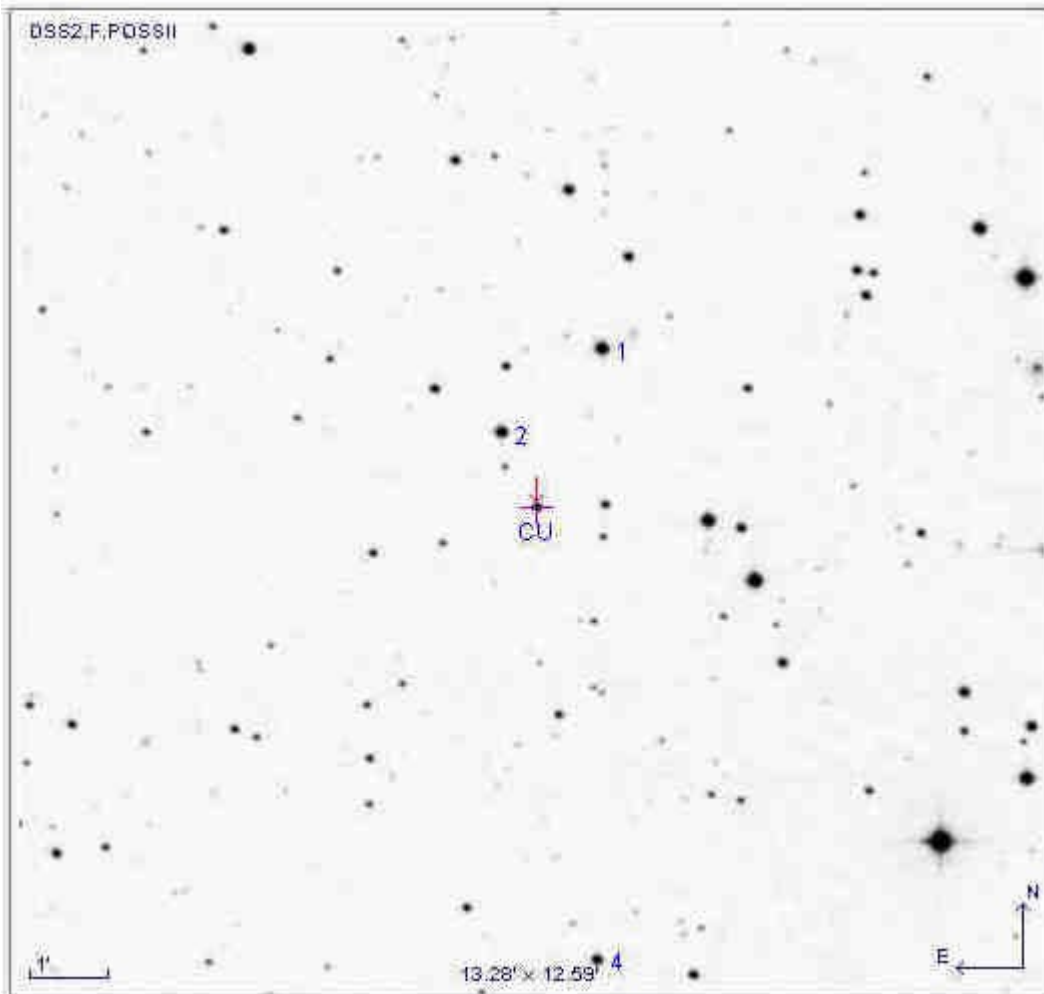


Figure 1. A 13 arcmin field centered on CU Hya. The comp star is "2" and the check is "1". POSS-II image.

Table 2. Comparison and check star magnitudes. Note the close colour agreement.

Star	GSC 0217:xxxx	V mag	V mag error	V-R mag
CU Hya				0.33
Comp "2"	0020	13.32	0.02	0.39
Comp "1"	0456	12.65	0.02	0.35

Analysis

Altogether 10 observation sets included well-captured primary minima. These were all measured separately using Bob Nelson's Minima program (<http://members.shaw.ca/bob.nelson/software1.htm>). This program measures the light curve data around a minimum using six different algorithms, and produces a weighted mean of the results. A typical primary eclipse light curve is shown in Figure 2 (from Phil Evans).

The ten resulting times of minimum are listed below as HJD, with observer initials. The parenthesised figure shows the uncertainty in the rightmost decimal place. Note that

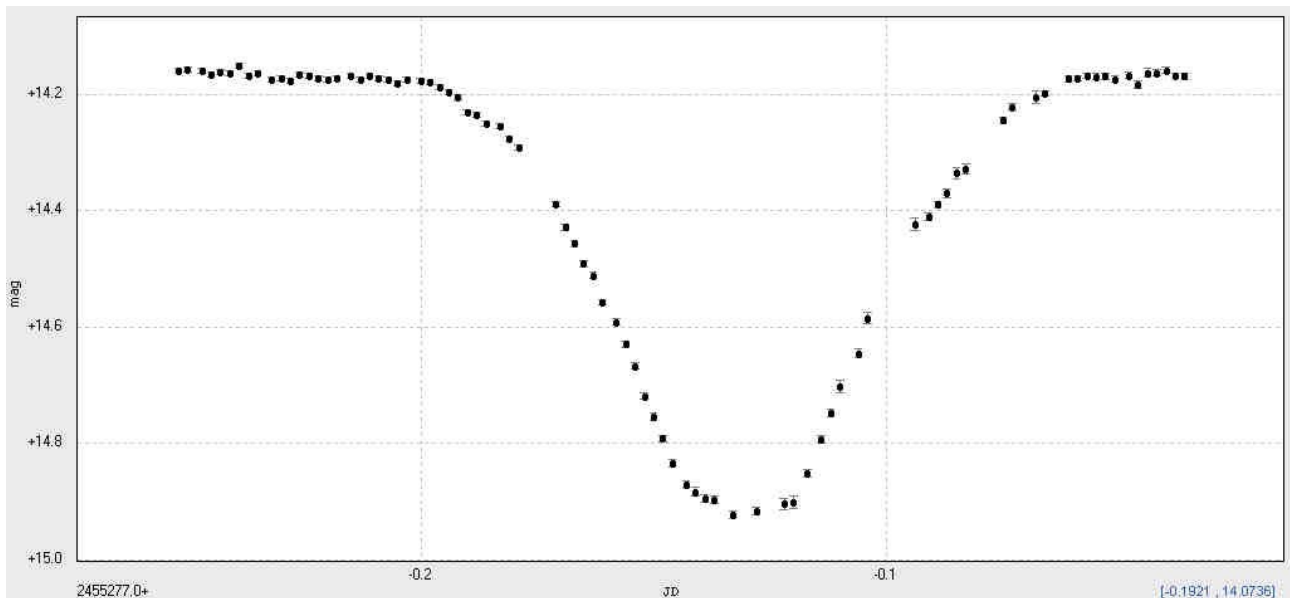


Figure 2. Primary eclipse observed by Phil Evans on 2010-03-21 UT.

Boyd and Pickard observed the same minimum separately, with indistinguishable results!

2455229.40931(5) DB	2455260.33015(5) DB
2455247.38718(6) DB	2455268.95901(3) TR
2455250.98280(6) TR	2455273.99295(8) TB
2455257.45284(6) DB	2455276.86934(7) PE
2455260.33013(5) RP	2455304.91128(5) MS

The first minimum was taken as a working initial epoch, and using a trial period of 0.719d to obtain epoch numbers for the times of minima, a linear least squares regression was performed of the times of minima against their epoch numbers. See Figure 3.

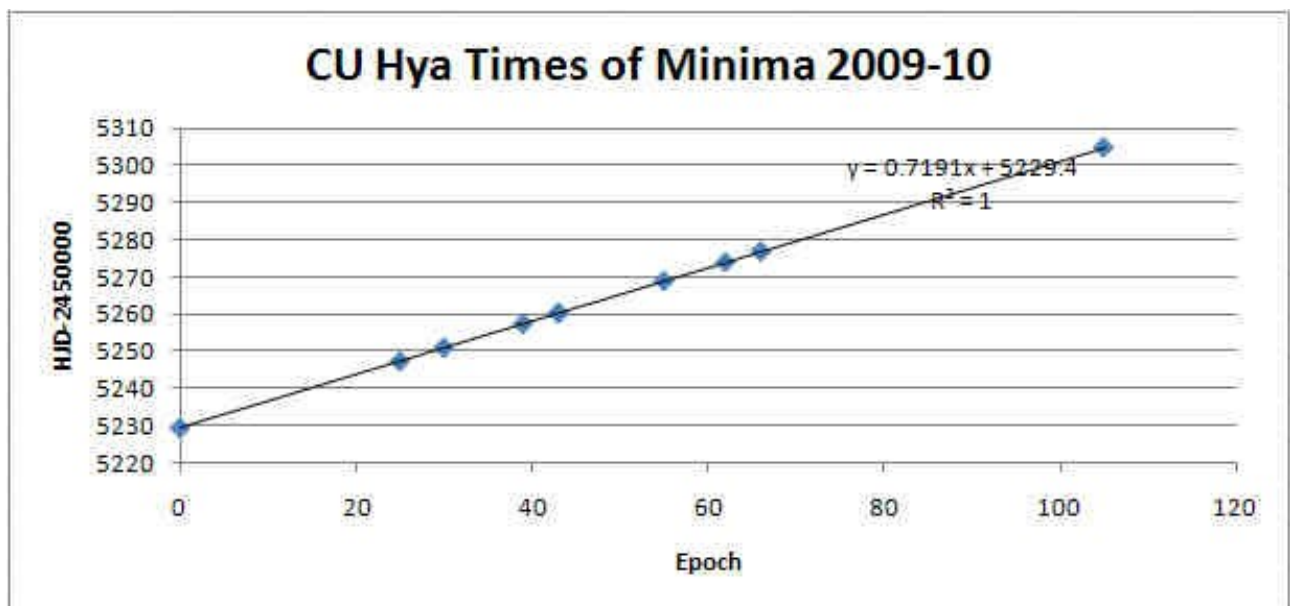


Figure 3. Observed times of minima (HJD) of CU Hya (y-axis) against epoch numbers (epoch 0 at HJD 2455229.41016).

The regression gave the following results:

$$E0 = \text{HJD } 2455229.41016(45)$$

$$P = 0.719067(8) \text{ d}$$

The mean residual of the regression was 42.46 s. The phase plot folded on these light elements (Figure 4) exhibits the typical profile of two well-separated stars of different luminosities partially occulting each other. The "straggler" data points that can be seen are due to either noisy data from a setting target, or the use of different filters.

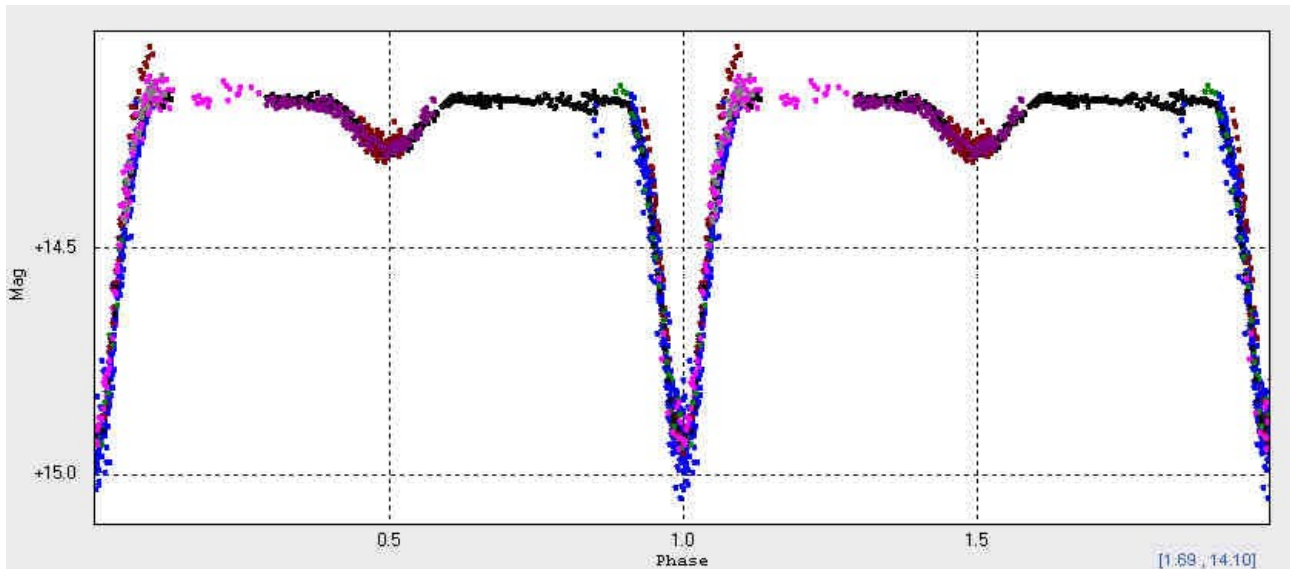


Figure 4. Phase plot of CU Hya, folded on 0.71907 d.

Conclusion and Future Work

Six observers obtained ten primary minima data sets for CU Hya in 2010. Each time of minimum was derived using six methods. A linear regression on these times of minima gave the following light elements:

$$\text{HJD } 2455229.41016(45) + 0.719067(8) \times E$$

Further work on this system using existing data will comprise:

- Times of Minimum of secondary eclipses,
- (O-C) comparisons with earlier data from other observers,
- Derivation of colour information,
- Stellar modelling.

When concluded, the work will be submitted for publication under the names of the observers as a refereed article.

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Tom Richards Project Leader

ECLIPSING BINARIES FOR FUN AND PROFIT PART V

LIGHT CURVE MODELLING

Bob Nelson, PhD

Introduction

In this article I shall describe how to do light curve modelling for eclipsing binaries. What are we talking about here? Recall from previous articles that eclipsing binaries (EBs) consist of two stars that revolve about their centre of mass. They are almost without exception too distant for any Earth-bound telescope to see them as anything but a point source of light. We know that they are eclipsing because if we follow their light intensity over a full period (getting a *light curve*), we see dips in the intensity which correspond to one star passing in front of the other (or eclipsing). In previous articles, I have talked about the types of EBs, the distinguishing shapes of the light curves, how to observe them, what equipment one needs, and how to determine accurate times of minima.

In this article, I will describe how to derive real, physical parameters from the light curves. The software is freely available to anyone with a pc. (Sorry Mac and Linux – I don't use these platforms.) The using of it, however, requires a somewhat lengthy learning curve. For beginners, there is much that can be done here; however to become accomplished, you will need lots of experience.

The Problem

You have these light curves, hopefully in several passbands. B, V, R, I are the usual filters; you might use the subset BVI (if the star is bright enough to do B), or VRI (if B is just too faint, especially if the star is later in spectral type). What we would like to determine are the real parameters such as the stellar masses, the surface temperatures, the radii, and the orbital inclination.

Star modelling attempts date back to Russell and Merrill (1952). In this method, "light curves were 'rectified' to get rid of the 'ellipticity' and 'reflection' effects, and such other perturbations from the light curve as could be modelled by a truncated Fourier series" (Kalrath and Milone, 1998). Needless to say, this complicated and messy approach – while the best that could be done with the limited computing power available at the time – left much to be desired. Other approaches were also tried.

The modern analysis procedure of choice is the Wilson-Devinney (WD) method (Wilson and Devinney 1971). In it, the program uses stars with real, Roche star shapes and calculates the light intensities that an observer – placed at a specified angle (or inclination, i) off the normal (or face-on position) of the orbit -- would see throughout a full period. Modern stellar atmosphere models, together with limb-darkening values are used. In this way, a full light curve for each passband is calculated. This is the process of *light curve synthesis*. You start with some basic parameters and calculate the light curves.

Later on, we will tackle the *inverse* problem – that is, starting with real, observed light curves, how do you end up with the basic parameters? I shall not go into any theoretical

considerations but would refer the reader to Kalrath & Milone (1998) for full discussions. What is needed here is a bare-bones description of what you, the reader, need to get going.

Software

Before I get started, I'd like to mention that there are many resources on the web to help you, as well as commercial packages such as *Binary Maker 3* [www.binarymaker.com]. BM3 is superb for allowing you to input some parameters and see immediately what the light curve will look like (as well as other goodies such as the radial velocities and animated 3-D shapes of the stars). If you want to get into EB modelling, I'd encourage you to buy BM3. (It, of course, uses WD code as its 'engine'.) However, in order to actually solve the system, you will want to use the full WD code.

The full WD code, available from Bob Wilson's website at the University of Florida, is in FORTRAN 4. The raw code needs to be compiled and linked to become an executable. Different platforms require different compilers. I have one for the pc, and have done the necessary compiling and linking to get the executable files. Next, in order to run these, you need to create large and complicated text files that the executables will read and run the software in a DOS window. Sadly, Bob Wilson uses formatted input code which requires you to get the many data fields perfect, or the software will not run correctly.

Some years ago, I wrote a Windows interface *WDwintxx.exe* (where xx is the version number) that writes the correct files, runs the (DOS) executables, and reads and displays the output files. (The latest version is available on my website at members.shaw.ca/bob.nelson.) This windows front end, written in Visual Basic, uses all the convenient Windows tools, such as drop boxes, menus, short-cut keys etc. It also has clickable labels that open help boxes for the many quantities, and much more. It makes modelling a lot easier and quicker.

To use this software, you need to set up the program and some included files in a suitable folder, and create a separate sub-folder for the data files for the star you want to model. Owing to the limitations of DOS, no folder name in the path can contain a space. (The underscore is fine.) Failure to adhere to this condition will mean that the DOS executable will not run.

Initial Steps

Before you get started, you should get a coil notebook or a scribbler into which you record firstly the basic data for that star: spectral type, temperature T_1 , log g , and the limb darkening values (see below). Include all references and be thorough. It pays to be methodical. After that, I recommend assigning a row for each trial fit with typically 10 columns, one for each parameter to be adjusted (such as inclination, temperature T_2 , etc.). That way, you can keep track of the changes, look down the page and see which way the fit is going.

Note: By convention, the star that is eclipsed at the primary (deeper) minimum is called star 1; its companion, star 2.

The next thing that you need to do is prepare the light curve data files, one for each band-pass. You will have somewhere (I use Excel spreadsheets for everything) differential mag-

nitudes, m , and the corresponding Heliocentric Julian Dates (HJDs). The former need to be converted to light values using the formula $I = C \cdot 10^{-0.4m}$, where C = arbitrary constant. This conversion, of course, is done on a spreadsheet. Adjust C so that the maximum between eclipses is close to 1.0.

Although the WD software allows you to work with HJDs, I recommend working with *phase*. The latter can be calculated in the spreadsheet by the formula $\phi = (\text{HJD} - \text{HJD}_0)/P - \text{INT}((\text{HJD} - \text{HJD}_0)/P)$ where HJD_0 = heliocentric time of minimum of some initial primary eclipse, and P = period in days. You can get a set of elements from the appropriate O-C file on the AAVSO website (Nelson, 2010). Your data (text) file will then consist of pairs of values (*phase, light*) with one line for each pair of values. Again, see the documentation for more details.

The next thing that you need to do is determine the surface temperature T_1 of the brighter star. The simplest way is to get on SIMBAD (simbad.cfa.harvard.edu/simbad/sim-fid), key in the star name (e.g., AC Boo, V0839 Oph) and scan down the page for the spectral type. If that is not available, try to get the infrared colour index J-H, available from the same page. If that is not available, use the visible colour index, B-V. (The problem there is that there may be interstellar absorption, in which the B-V index will be subject to reddening. The infrared index is less susceptible to absorption. Do your best.)

With the spectral type or colour index in hand, you can go to tables which will yield T_1 . Another quantity you need is the $\log g$ value, where g is the acceleration of gravity at the surface of the star, in cm/s^2 . (I have a table on my website, MS_PROP5.xls, which lists these and other quantities as functions of spectral type.)

Bandpass	X	Y
u	0.671	0.257
v	0.641	0.258
b	0.410	0.486
y	0.244	0.596
U	0.690	0.217
B	0.522	0.363
V	0.247	0.590
R	0.113	0.638
I	0.032	0.624
J	-0.067	0.640
K	-0.159	0.604
L	-0.070	0.389
M	-0.037	0.283
N	-0.025	0.169
Rc	0.133	0.640
Ic	0.056	0.632
Bolometric	0.187	0.530

Temperature and Log g

Limb Darkening Law

☐ Linear Cosine

☐ Logarithmic

☒ Square Root

Temperature: 5784

Log g: 4.415

Interpolate

Exit

Figure 1. The program *VHLimb* with the limb-darkening values for CV Boo.

The next set of quantities you need are the *limb darkening values*, x_1 , x_2 , y_1 and y_2 (one set for each filter plus bolometric). These are the coefficients that describe the upper atmosphere of each star and how the intensity fades as you move towards the edge. These values are available from the very convenient interpolation program *VHLimb*, written by Dr. Dirk Terrell (see Fig. 1); this also is available from my website. For further information about which limb darkening law (logarithmic, square root) to use, etc., please see the documentation that comes with the *WDwint* package. Write down all the values in your notebook.

WDwint - CV_Boo173V.lci

File Rad/Conv Crit.Pot'l's Adjust Datafiles Spots Misc Run LC Display LCO Load DCO Display DCO Contours Help

Wilson-Devinney Windows Interface (Kurucz atm.)

ISYM mpage nref mref ifsmv1 ifsmv2 icor1 icor2 Limb dark ☒ LC (Light Curve synthesis) ☐ DC (Differential Corrections)

1:LC 1: simple 0 1 3: SqRt

JDPHS J.D. zero Period dP/dt Ph.shift fract. sd. noise seed

2: phase 7522.6643 .847 0 -.0017 0 1:yes 138472375

JD start JD stop JD incr Ph. start Ph. stop Ph. incr. Ph. norm.

7523.0000 7923.0000 10.0000 0.0000 1.2000 .0020 .2500

MODE IPB IFAT1 IFAT2 N1 N2 N1L N2L Arg.Per. dPer/dt THE V unit (km/s)

2: detached 0 1 1 30 30 5.23500 .00000D+00 100.00

eccen. s.m. axis F1 F2 Vgamma Inclination g1 g2 [M/H]

0.0000 4.67100 1.000 1.000 -.0330 87.890 .320 .320 0.00

T1 (*K) T2 (*K) Alb.1 Alb.2 Pot'l 1 Pot'l 2 M2 / M1 x1(bol) x2(bol) y1(bol) y2(bol)

5784.0 5639.0 .500 .500 4.8441 4.7585 .970810 .186 .207 .530 .510

band Wavel (μm) L1 L2 x1 x2 y1 y2 el 3 opsf m zero factor

7: V .5500 6.548 5.952 .246 .283 .591 .558 0.000 0 0.00 1.000

Fig. 2. The main screen of WDwint with the final values for CV Boo.

Now, once you have started *WDwint*, carefully look through the values on the main screen (see Fig. 2). Yes, it's bewildering at first! However, if you click on any label, a window appears with an explanation of that quantity. Many of the quantities are simple specifications for which you can use the default values. However, you need to set the following:

Row 1: Box 1: select '1:LC'; Box 5: select '2:Log' or '3:SqRt' depending on which limb darkening law you are using (click on 'Limb dark' for further info). Also make sure 'LC' radial control is chosen.

Row 2: For 'JDPHS', select '2: phase'. Do not worry about the period, which only enters the picture if you are using HJDs instead of phase, and/or using radial velocity data as well.

Row 4: For MODE, make the choice that corresponds to the type of light curve you have. Mode 2 = detached systems, Mode 3 = overcontact binaries, Mode 5 = semidetached (Algol-type) systems. You should be able to look at your light curves and get an idea. See Part I of this series for descriptions and pictures of the types of light curves.

Row 6: Enter into the last four boxes the bolometric limb darkening values you got from *VHLimb*. (Note that x2 and y2 are for the slightly different temperature of star 2. For start-

ers, you can use the same values as for star 2. The choice is not critical but one likes to get it right.)

Row 7: For 'band', select the type of light curve you are fitting (B, V, etc.), for boxes 5-8, enter the limb darkening values for that band. Note that the Cousins filters R_c and I_c are at the bottom of the list.

Rows 3 & 5: No changes needed.

Here are the five key parameters: T_2 = temperature of star 2; q = mass ratio, M_2/M_1 ; i = orbital inclination; Ω_1 , Ω_2 = potentials; and L_1 = light intensity for star 1 (for mode 3, you don't adjust L_2 -- the program does that).

For starters, set $T_2 = T_1$, set $q = 0.3$, set $i = 80^\circ$, and set $L_1 = 6$ or 8 .

Note that, in mode 3 (overcontact binary), by definition $\Omega_1 = \Omega_2$, so you can only adjust the former. Similar restrictions apply in mode 5 (Algol-type), where $\Omega_2 = \Omega_i$, the inner Roche potential. The Roche critical potentials are a function of the mass ratio alone. You can get these by clicking 'Crit. Pot's' on the menu bar.

Omega i (Ω_i) is the inner potential, the potential of the Lagrangian point 1. When a star is filled out to this point, it starts to spill matter over to the other star.

Omega o (Ω_o) is the outer potential, at which matter can leave the system of two stars. It represents the largest possible physical size for an overcontact binary.

Note that the potentials, always positive, increase as the radius decreases. Therefore $\Omega_i > \Omega_o$.

You need to get the potentials right for the type of system you have:

Mode 2 (detached): $\Omega_1 > \Omega_i$ and $\Omega_2 > \Omega_i$

Mode 3 (overcontact): $\Omega_i > \Omega_1 > \Omega_o$ and $\Omega_i > \Omega_2 > \Omega_o$

Mode 5 (Algol): $\Omega_1 > \Omega_i$ and $\Omega_2 = \Omega_i$

Pick values for Ω_1 and Ω_2 that satisfy these conditions; don't worry about the exact values, you will get to adjust them later.

Save the settings under a convenient filename in the folder for that star, e.g., CV_Boo001.lci. By convention, .lci is for the LC input files, while .lco is for the output files.

Now you can run the program. Click [menu] 'Run LC' > 'Standard'. A black DOS screen should appear for 1-5 seconds. If it lasts for only a fraction of a second, the program did not run and there was a problem. (Was the pathname free of spaces? If this was not the problem, look at the output file with a text editor and see if you can sniff anything out. If all else fails, read the documentation or email me.)

If the program ran successfully, you can look at the output by [menu] 'Display LCO' > 'Standard'. A nice graph should appear (see Fig. 3) and you can load your data by [menu] 'File' > 'Load LC Data Points ...' in the graph window. The computed LC won't match

your data, of course. Read on.

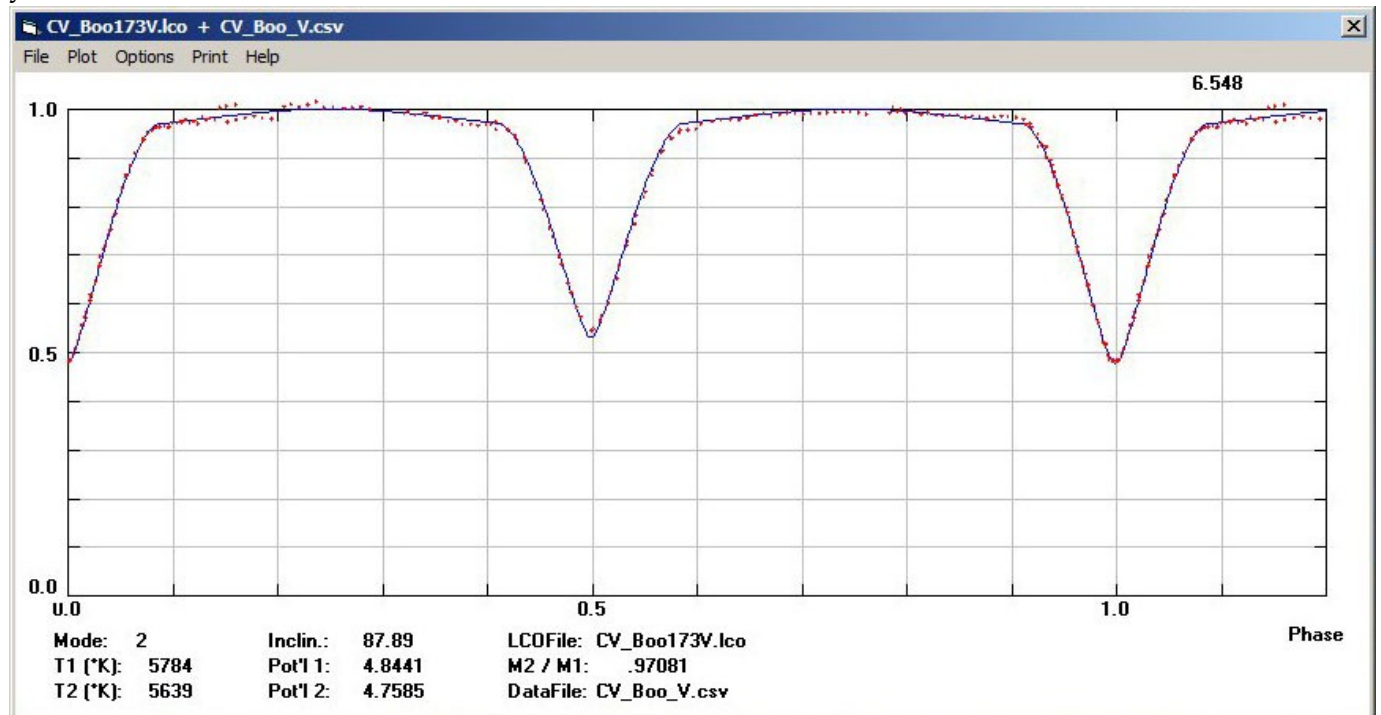


Fig. 3. The output screen of WDWint, LC side, using the final values for CV Boo.

Fitting Procedure

Now you are into an area that is a bit of an art; however, there are some guiding principles.

1. To make the eclipses deeper, either increase the inclination or increase the mass ratio $q = M_2/M_1$. (But if you make the inclination too close to 90 degrees, you will generate a flat bottomed minimum, which may not be what you want.)
 2. To make the secondary eclipse shallower, decrease T_2 .
 3. To make the eclipses narrower, and with more of a shoulder, increase Ω_1 or Ω_2 (this makes each star smaller). The shoulders mark the first and last contact times – in between is the partial (or total) eclipse.
 4. Adjust L_1 to make the computed curve lie near 1.0 at phases 0.25 or 0.75. The number at upper right on the plot page is the suggested value of L_1 for this to happen.
- Now save the file, re-compute, and re-examine the output curve. In this way, going back and forth, you should be able to obtain a preliminary fit.

There is a glitch in this fitting. Terrell and Wilson (2005) proved, by using artificial data, that it is impossible to attain an accurate solution for mode 3 (overcontact binary) or mode 5 (semidetached, Algol-type) in the case of partial eclipses. If your binary makes complete or total eclipses, fine. However, if your system undergoes only partial eclipses, you will need radial velocity data to 'break the degeneracy between inclination and mass ratio'. (This latest bit of jargon means that, for the computed curves of the partial eclipse case, increasing the depths of the eclipses by increasing the inclination can be cancelled out by decreasing the mass ratio.)

Once you have a reasonable fit, you can switch to the DC (Differential Corrections) side of the program. (Note that the screen will be slightly different from Fig. 2.)

This is the implementation of WD that allows you to zoom in on the best fit. For every set of parameters, it calculates the sum of the deviations squared for each data point (which is a measure of the goodness of fit). What happens is that you now specify which quantities are to be varied in turn (by increments you can set). The program runs with the different parameters and, from analysing the resulting sum of deviations squared for each case, the program calculates the corrections to each of the parameters you need to make to make the fit better. (It also calculates the predicted sum of residuals squared.)

To start, merely click on the LC/DC radial button at the right of the main screen. You will then need to load all your light curves, together with the limb darkening coefficients that you got from *VHLimb*. (Click on [menu] 'Datafiles', select the number of files that you have, and fill in the boxes and load the files (see Fig. 4). Type in the appropriate digit for 'band' and the appropriate wavelength appears. (For a list, click on 'band' on the main screen.) Type in values for L_1 (one for each filter) that would correspond to the value(s) you found in the LC fit. Do not worry about L_2 ; the program sets that. For 'Sigma', put in the estimated random error in the LC data. This might be 0.02 mags $\sim$ 2% for example. For 'Noise' and 'EL 3', use 0.

Data Files and Parameters													
Radial Velocity Files													
# of Files	Load or Unload	band	WaveL	L1	L2	x1	x2	y1	y2	Sigma			
File 1	CV_Boo_RV1-100.cs	Load	0	.4100	6	6	0.799	0.799	0.12	0.093	0.1		
File 2	CV_Boo_RV2-100.cs	Load	0	.4100	6	6	0.799	0.799	0.12	0.093	0.1		
Photometry Files													
# of Files	Load or Unload	band	WaveL	L1	L2	x1	x2	y1	y2	Sigma	Noise	EL 3	
File 3	CV_Boo_V.csv	Load	0	.5500	6.588	6.588	0.246	0.283	0.591	0.558	0.015	0	0
File 4	CV_Boo_I.csv	Load	0	.7890	6.555	6.555	0.055	0.086	0.632	0.606	0.015	0	0
File 5													
File 6													
File 7													

Figure 4. The Data File window for WDWint. The values are for CV Boo.

.Now you are ready to look at varying the parameters. These will likely be the five parameters mentioned above (i , T_2 , q , L_1 , Ω_1 -- and Ω_2 for detached systems) and you may want to add phase (in case you did not get the elements HJD_0 and P quite right) and spots.

But wait – not so fast! It turns out that you cannot vary all the parameters at once – this is because some of the parameters are *correlated* (for example, Ω_1 and L_1 in Fig. 6). What you

Figure 5.

The Adjust page for WDWint.

need to do is vary all the parameters as we did above, run the program and look at the correlations, listed on the [menu] 'Display DCO' > 'Correlations' page. Then, from this matrix, set up subsets of the set of all parameters whose bilateral correlations are less than 0.5 in absolute value. You then vary the parameters, rotating from one subset to the next. [For this case, $i-T_2-\Omega_1$, $i-T_2-L_1$, and $i-T_2-q$ would be those subsets. Note that there can be other parameters to be included if one has radial velocity (RV) data or spots. CV Boo used RV data.

	Inclin.	T2	Pot'l 1	M2 / M1	L1
Inclin.	1.00000	.30785	.16838	-.05587	-.17794
T2	.30785	1.00000	-.06123	.00108	-.25098
Pot'l 1	.16838	-.06123	1.00000	.65478	-.91999
M2 / M1	-.05587	.00108	.65478	1.00000	-.78613
L1	-.17794	-.25098	-.91999	-.78613	1.00000

Fig. 6. The Correlation page for WDWint with the basic five parameters. (The RV parms are absent.)

The process can be complicated and long, but you should be able to zero in on a solution. (A solution is reached when, for each subset, the suggested corrections are less than the estimated errors by some percentage (like 50% or 10%, etc.). It is recommended that you try the sample files that come with the WDwint package. One of these is for the relatively simple detached system, CV Boo which has had a solution published (Nelson, 2004).

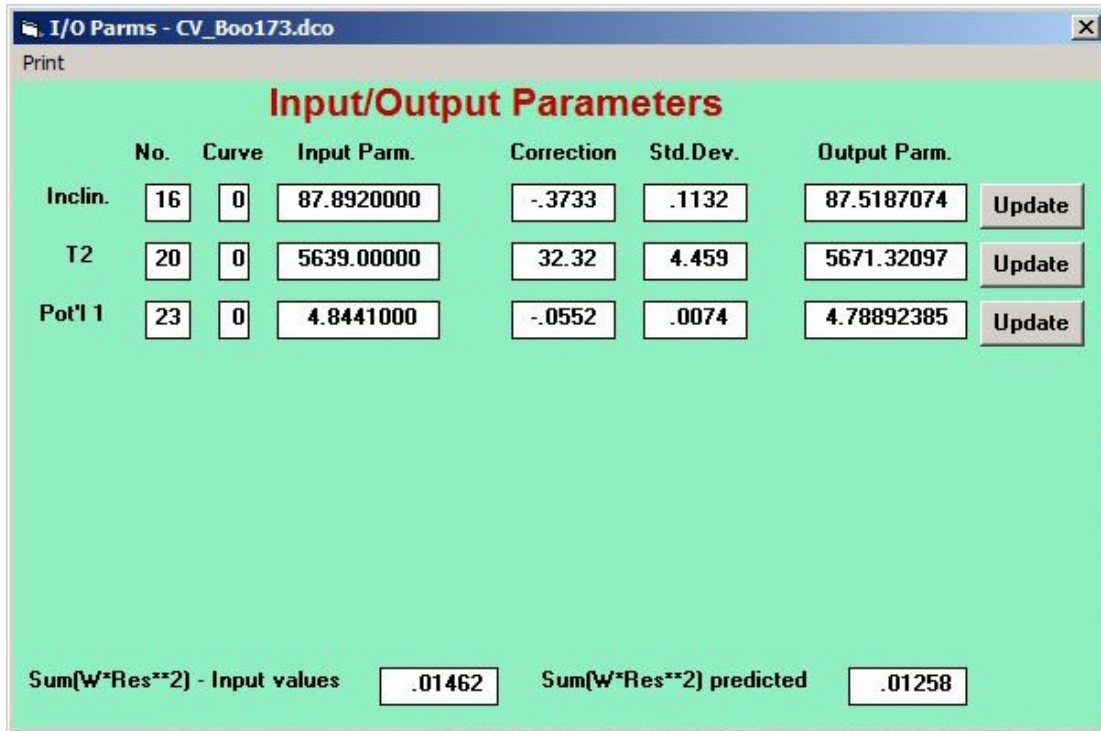


Figure 7.

One subset of the basic parameters for CV Boo

Fig. 7 shows the screen shot for the input-output parameters for CV Boo. Note that the standard deviations of the suggested corrections are less than one third of the actual corrections in each case. If this condition applies to all the parameters (which it does), we are therefore at solution.

The preceding was, for sure, a brief explanation of WD modelling. There will undoubtedly be glitches and setbacks in your modelling attempts. Feel free to email me for help. Be assured, however, that the results are worth it!

References

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CATACLYSMIC VARIABLES IN QUIESCENCE

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All of you are familiar with the work previously carried out by the RASNZ VSS in measuring cataclysmic variable stars. Due to their efforts we were able to determine types of CV, intervals between outbursts, types of outbursts and a large amount of useful information.

Whilst a couple of dozen stars were visible during outbursts the number observable during quiescence is much smaller - hence our knowledge of the fainter parts of the light curves was restricted to a few bright objects like VW Hydri, BV Centauri and some others.

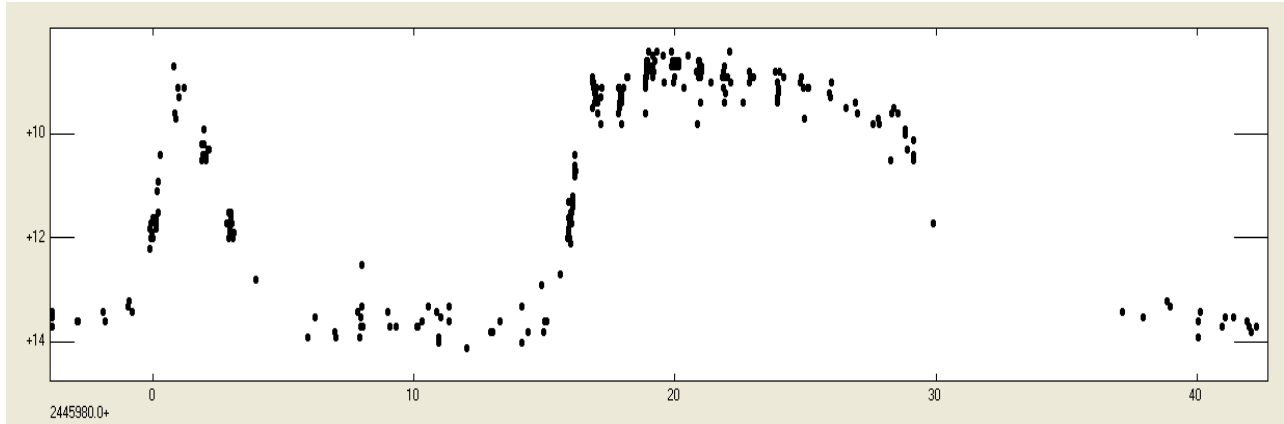


Figure 1: This image shows 50 days of visual measures of VW Hydri in 1984. Contrast it with Figure 2!

In recent times the advent of CCDs has seen intensive study of the outbursts and orbital and superhump periods have been found for most stars brighter than magnitude 20. Not all CVs are suitably inclined to our line of sight to show orbital humps - and superhumps have only been recognised in the SU UMa stars with periods of ~2 hours and less.

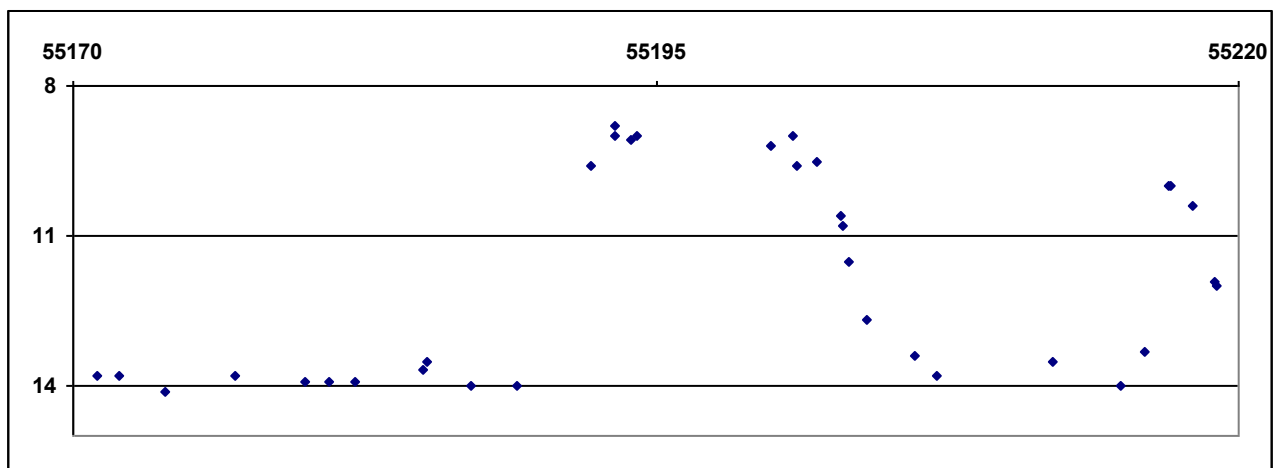


Figure 2: A similar 50 day period including the January 2010 superoutburst showing the decline in observations of this, the brightest and most popular of the southern CVs.

At this stage it would probably be useful to find out more about these stars in the non-outburst states. Observing these can reveal something about the structure of the systems which, in turn, determines the frequency and nature of the eruptive outbursts. Because of the sensitivity of the CCD as compared to the eyeball - and its ability to make long exposure images - the number of targets is extended dramatically.

The proposed project involves monitoring the stars in range, but with only one or two images a night. Since there are less than a hundred of these stars brighter than $V = 17$ this is not an onerous task. So how do we go about it? We want to observe in the V range, similar to that of the eye. These days almost every group has access to a 'go to' telescope and a CCD camera, usually with standard RGB filters. A few may have BVRI or some combination of these. The goto telescope removes one of the problems, locating the star with a pointing precision of several arcminutes, as it should be somewhere on the frame. The filters remove most of the atmospheric effects - but sacrifice a little light at the faint limits. Unfiltered photometry suffers in accuracy and may introduce spurious effects when the time scale we're looking at is considered—but this could be experimented with as it adds another magnitude—and the CBA has something similar in mind with the infrequent outbursters.

All participants will be provided with access to free professional data reduction software for those without this. A review of one of the best appears on page 25. As well, mentors are available to take you through some of the necessary incidentals such as flat fielding and dark frames where necessary. Some of this will be familiar if you have been making images of deep sky objects. The reduction software produces a compact numeric datafile file which can easily be emailed. You would have between 10-100 of these a night. You don't even need to identify the target star on the image frame but we will determine which one for your information. After that, it's a simple task, if you wish, to keep track yourself of what's happening.

We suggest that in each field you take two or three exposures, say 40 to 60 seconds dependent upon the size of your telescope. If we can build up a team of people willing to spend an hour or two a night on a regular basis then the object of the exercise, to provide one or two datapoints a night, will be achieved. What will we find out? These features should be resolvable:

- What is the frequency of outbursts?
- Are there different types of outburst - shape and duration tell us this?
- The shape and duration are themselves important.
- Some stars with superoutbursts show normal outburst precursors.
- There are conflicting reports of almost flarelike outburst. Are these real?

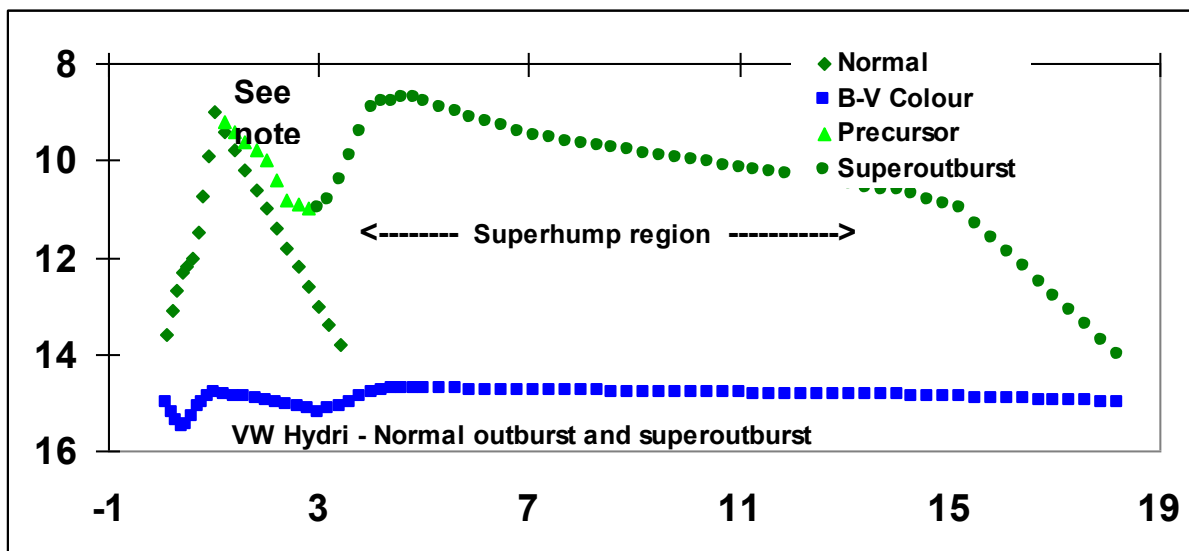
Previously unknown orbital periods may be noticed in a few cases.

The stars are obviously seasonal, due to the Sun's presence at times, but even a year will provide a lot of information. We do not see this as an exclusive project, rather as something a little different from whatever you're doing at present and when you feel you need a change. And if you're part of a group, either locally or through this project, we've found in the past that this makes astronomy much more enjoyable.

All measures will go to the International Database, operated by the AAVSO, where they will be attributed to you as the observer. First, however, they need to go to the project coordinators for translation into magnitudes as they appear in the sky - a process which

may need a few more observations - simple to make but which allow transformation into the standard system. About 20 minutes work spread over a month or two for each star. As with all such cooperative projects all participants with a reasonable number of measures will be co-authors of any papers published. This won't be immediate but within the next 12 months there should be suitable material in the case of the best objects. Some suggested targets will appear on the website in the next few days.

One of the most studied southern objects is VW Hydri. The November, 2008, Newsletter contained some thoughts about this star on pp 8-10. The phenomena described are probably quite common but as comprehensive measures of only a few stars are available who can make any definite comments? For those not familiar with the CV mechanism a brief summary appears on page 24. The overall mechanism is very simple but the ways in which this is seen are very complex. So, if you're feeling a little bored with whatever you're using the CCD camera for at the moment try this idea out. Contact me initially if you're interested and I'll provide the necessary backup



This figure was originally published in the November, 2008, newsletter but illustrates some of the points mentioned. The normal outburst begins as a 'single shot event' with part of the overfull disc being dumped onto the white dwarf primary. But the primary is partially obscured as this happens and the system becomes redder—as shown by the dip in the B-V colour—with the light coming from the hot disc and the cooling infalling material. There is a noticeable slowing at $V = 12$ but then the accretion heating on the primary begins to dominate the system. Once maximum brightness is reached the star begins to get dimmer and cooler. A simple story.

But when conditions are right—about every 180 days for VW Hydri—the normal outburst appear to trigger a continued and enhanced flow of material from the secondary star. This can be found in the brighter green triangles of the plot as enhanced orbital (obeying the orbital period of the system) humps. Normally the orbital humps are drowned out by the light from accretion onto the primary during outburst but if they are visible it shows that mass flow has increased by 30-40 times and this is what drives the superoutburst. The disc becomes distorted, it precesses and the apparent period becomes different from the orbital period by a few percent. When we first noticed this in Auckland about 1970—before the superoutbursts were modelled—we were completely bemused by how the orbital period could change like this. Our original paper on the system provided the correct period—but we had to admit that the similar appearing superhumps were something different!

So the type of measures proposed in this article may reveal similar unknown information about CVs—and the vast majority have not been studied in any depth at quiescence.

WHAT DRIVES THE CATAclysmic VARIABLE PHENOMENA?

A study of the literature relating to CVs reveals a bewildering array of types of CV and a similar variety of phenomena. The field has become exceedingly complex at first glance and the amateur wishing to make contributions in this field is often overawed by what is read. But it's not as complex as it seems. Like all stars the events depend upon a simple energy source and how it reacts with its surroundings.

It is often forgotten that, except for the rare nova outbursts, all the energy is being provided by the cooler, mass losing star (normally called the secondary) and it is only the variations in the rate of mass loss and flow that produce the almost bewildering variety of CV types. The energy being released is heat from the kinetic energy of material falling into the deep gravitational well of the compact primary white dwarf star—but the series of stages can appear confusing and complex. We can liken the whole process to a series of waterfalls in a river where the various stages on the way to accretion by the primary star resemble a series of ledges at different altitudes—and with multiple branches in each fall—and with interlacing water streams. Sounds complex, but then so are the observed phenomena!

The initial event is the formation of a disc resulting from the mix of gravitational attraction by the primary and the angular momentum of the material peeled off the secondary star through the L1 point. The material falls toward the white dwarf but it's no longer in that precise direction—so the gas stream becomes curved, links up with itself in the chase and eventually forms a disc. Without this material and the resulting disc the system would be a simple binary star of rather short period. We see this type of thing in the low states of some CVs when mass transfer ceases, usually because the cool star shrinks away from the L1 point. This is often a consequence of prolonged mass transfer.

During quiescence, which is the state of the CV when mass is being transferred, but outbursts are not in progress, the disc is the main source of luminosity. Since it cannot exist without the stream of material from the secondary there will be a gas stream where flickering seems to occur, and a collisional point which is hotter than the rest of the disc. We see this as the orbital frequency humps in these systems when the inclination is greater than about 50-60 degrees.

The normal outbursts of a star like VW Hydri result from material being lost from the disc onto the surface of the white dwarf. Once again kinetic energy is transformed into heat. The outburst shows the shape of a single event—a sharp rise in brightness and a slower fall—and the UBV colours support this idea. It is even possible to see the initial obscuration of the WD star before the infalling material reaches it as a temporary slowing in the rate of brightening and a reddening of the system overall.

The superoutbursts are a more prolonged event with continuous mass transfer providing an ongoing source of energy for a period. This has been observed in greatly enhanced orbital humps—clearly a sign of greater and ongoing mass transfer.

So far all of this is simple but once we move away from the single-shot events of the normal outbursts of the SU UMa stars the scene becomes much more complex. Various parts of the systems become luminous, the disc is distorted and revolves at a slightly different rate and in many systems there is a variety of outburst types, many of which are hard to categorise. Thus we have SS Cyg types, Z Cams where there is a 'hung up' state and a good number of CVs which don't appear to fit anywhere such as TU Mensae. But all of these can be explained—if the observations are adequate—by the facts mentioned in the second paragraph above.

In a few rare cases the secondary is itself a white dwarf star, often peeled down so much that all the hydrogen has been lost and the system is now a helium CV. Such objects cannot become novae as the temperatures in the accreting star will never be hot enough to cause a surface ignition of helium. In other stars—polars and intermediate polars—magnetism has a strong role, usually by inhibiting the formation of a disc and also, in time, producing synchronised rotation of the white dwarf primary.

And, of course, the systems of each type will lie anywhere between the two extremes. Returning to the waterfall analogy, think of the CV phenomena as similar to a waterfall with multiple parallel paths, with perhaps only the polars—where magnetism inhibits disc formation—showing a single event along each path.

SOFTWARE REVIEW—MUNIWIN V1.1.27

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Good things are often said to come in small packages and with a download size of just 2.3MB Muniwin v1 is a classic example. If you are doing CCD photometry then this little package is one that ought to be in your software toolkit, and you can't complain about the price as it is freeware distributed under the GNU General Public License.

Muniwin won't control your CCD camera nor will it control your telescope or your focuser, it is not ASCOM-compatible because it doesn't need to be. Its sole function is to take your raw FITS or SBIG files, reduce those using bias, dark and flat frames then report back either the instrumental magnitudes of selected stars or differential magnitudes for selected variable and comparison stars. The report can be text or graphical.

MuniWin was written using the C language by David Motl of the Czech Republic as an update to an earlier version called Munipack written by Filip Hroch. The package is based on Peter Stetson's DAOPHOT (Dominion Astrophysical Observatory PHOTometry) package. The program, source code and documentation are all freely available from <http://sourceforge.net/projects/c-munipack/files/>

There are two versions available at the time of writing. Version 1 is Windows specific and I have used it without problem on W2K, XP (all SPs) and Win 7. Version 2 is functionally identical to version 1 but has been re-written to be platform-independent and is still a work-in-progress. I've used it only on my Win 7 computer and found no problems but I do miss the right-click functionality of the native Windows version. In what follows I will only refer to version 1.1.27 which is the latest stable release.

When you first run Muniwin you are presented with a clean spreadsheet-like interface onto which you load your CCD images. You can import either FITS or SBIG's special compressed format.

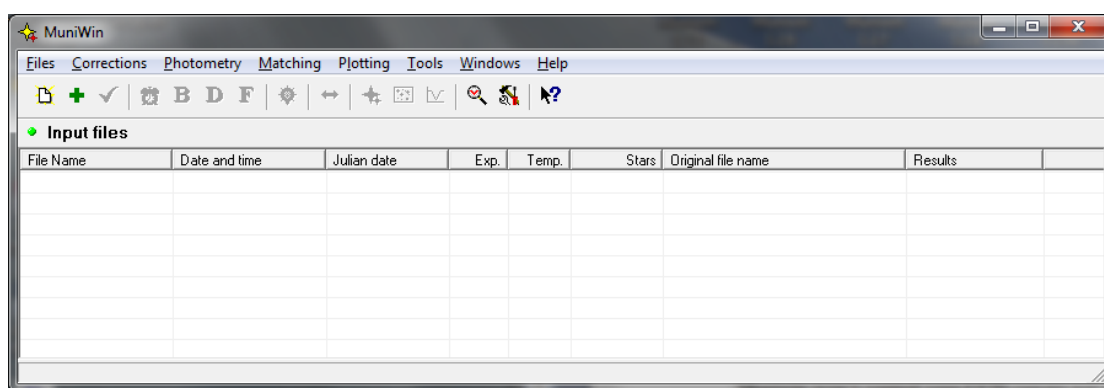


Figure 1. Muniwin's opening screen showing its spreadsheet-like interface

You can add your files through the () button or by dragging and dropping from an Explorer window. If you opt to use the button you can filter the filenames from a Windows folder or add all at once. The filtering function is able to distinguish between science images and calibration images (bias, darks and flats).

You can switch at any time between the spreadsheet interface and a preview or slide show interface by right-clicking and selecting “Window Style”. Once I’ve got my images into Muniwin I usually switch to the slide show and check each image carefully. If there is a problem then I’ll delete that image from the set by right-clicking and selecting “Remove files”.

Also from the right click menu you can opt to see the original image and view the FITS header information. When viewing the image you can have it fit the viewing window or scale it up to 2000% and there are options to have Muniwin automatically adjust the contrast and to invert the image. Both of which I find useful. When you select a star on the frame with your cursor you can see more information including the intensity in ADU, the sky value, the FWHM and the SNR (but in magnitudes, not as a simple ratio).

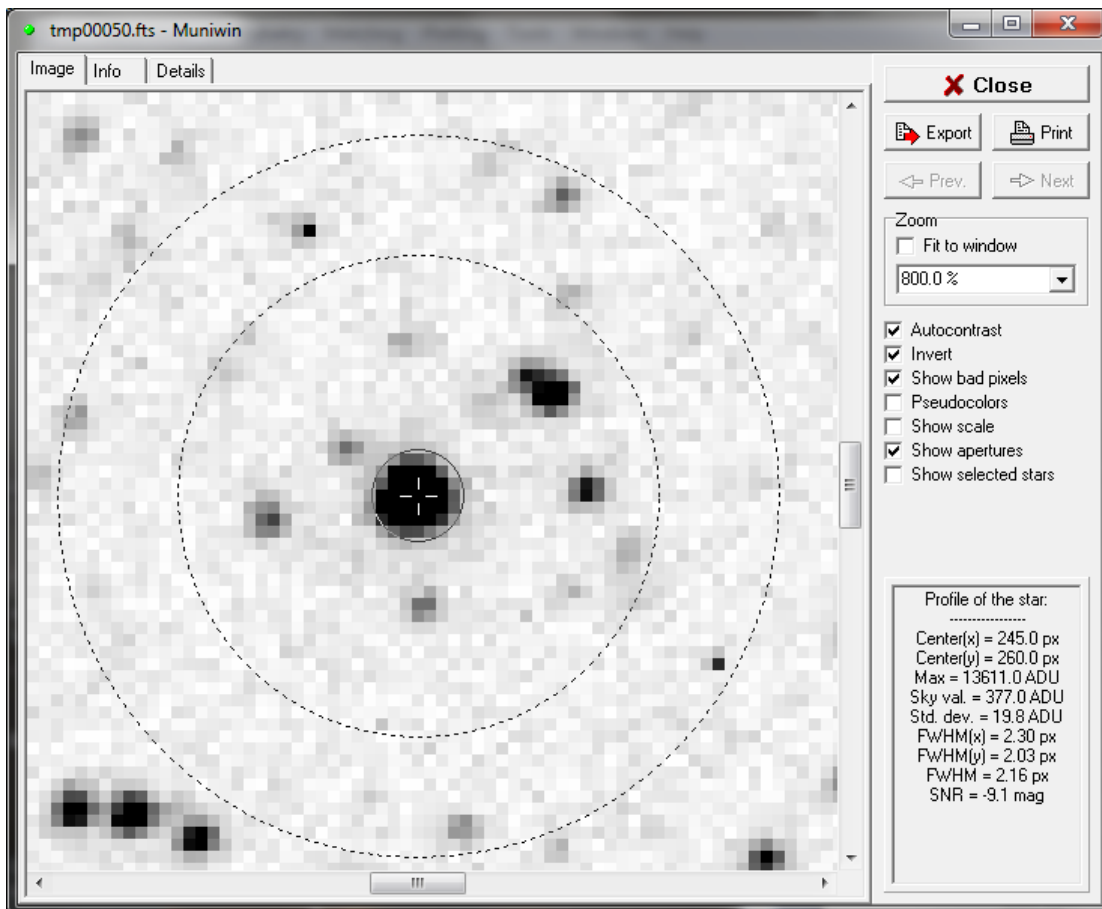


Figure 2.

**Original
image
data
from the
right-
click |
Open
menu**

Once you have added your CCD images the next step is to ‘convert’ them using the (✓) button (in the spreadsheet view). If they were SBIG format they are converted to FITS and stored in a temporary folder. If they were already FITS then they are just copied to a temporary folder. Information is read from the FITS header and used to populate the rows on screen. Doing this conversion means that your precious original files remain untouched. From now on the program only uses the temporary files.

The function buttons along the top of the screen are designed to be used in succession from left to right and next after the convert button is the time correction button (🕒) which is useful if your computer clock is off by a known amount. This button will add or

subtract time in seconds or days and you can apply it to all or a selection (using standard Windows selection keys) of your images. Repeated use of the time button is cumulative.

The next three buttons are for the reduction process – bias removal (**B**), dark subtraction (**D**) and flat-fielding (**F**). Of course, if you are using darks at the same temperature and exposure as your lights, then you do not need to subtract the bias. If you haven't already got master calibration frames for these Muniwin will make them for you.

To make a master dark or flat-dark frame, add your individual darks, convert them then go to the Tools menu and select 'Make Master Dark Frame'. You'll be asked if this is to be a scalable dark for use at different temperatures or exposures and for this you'll need a master bias frame.

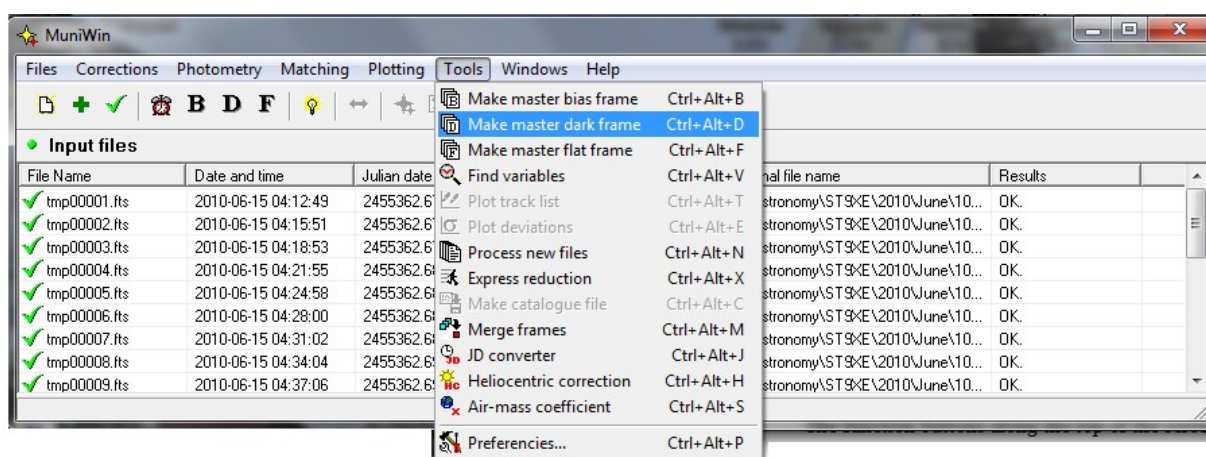


Figure 3. Making a master dark frame

Master flats are made in a similar fashion but the individual flats are normalised to a value you specify in the preferences. The default normalisation value is 10,000 ADU.

Muniwin uses a 'robust mean' algorithm for making master bias and darks. Robust statistics largely follows classical statistics but is very tolerant of outliers and "small departures from modal assumptions". (It's over 40 years since I did my maths/physics degree and I had to check this out on Wikipedia). In private correspondence with David Motl he tells me that the algorithms are "based on M-estimators" and produce a value "very close to the median. Pixels are processed one-by-one independently."

Once you have your files properly calibrated the next step is to click the photometry button (💡). This brings into play two of the original routines from DAOPHOT to firstly find stars on the frame and secondly perform aperture photometry on them. When finding stars the program relies on the preferences you set under the Tools menu.

The max and min pixel values are set to bound the linear portion of your CCD's response. For my ST9XE I set my upper bound to be 55,000 ADU (I've previously tested my camera for linearity) and lower bound to the bias level of 100 ADU. You would generally set these once then forget all about them unless you change your detector. The read noise and gain I have previously got from another program (which may have been MaximDL but I can't remember now). The FWHM should be set to approximately that of the stars in

your frame as this sets the width of the Gaussian used to find stars. For the image shown in Fig 2 this would be 2.16. The detection threshold is the level above the lower bound below which the program should not claim a bright spot to be a star. This is set in units of the standard deviation of the sky value and the default value for this is 4 but you can see I've set 5. In the figure 2 example the sky standard deviation is shown as 19.8 so this would mean that anything between 199 ADU ($5 \times 19.8 + 100$) and my lower bound of 100 ADU would not be classified as a star and would be ignored.

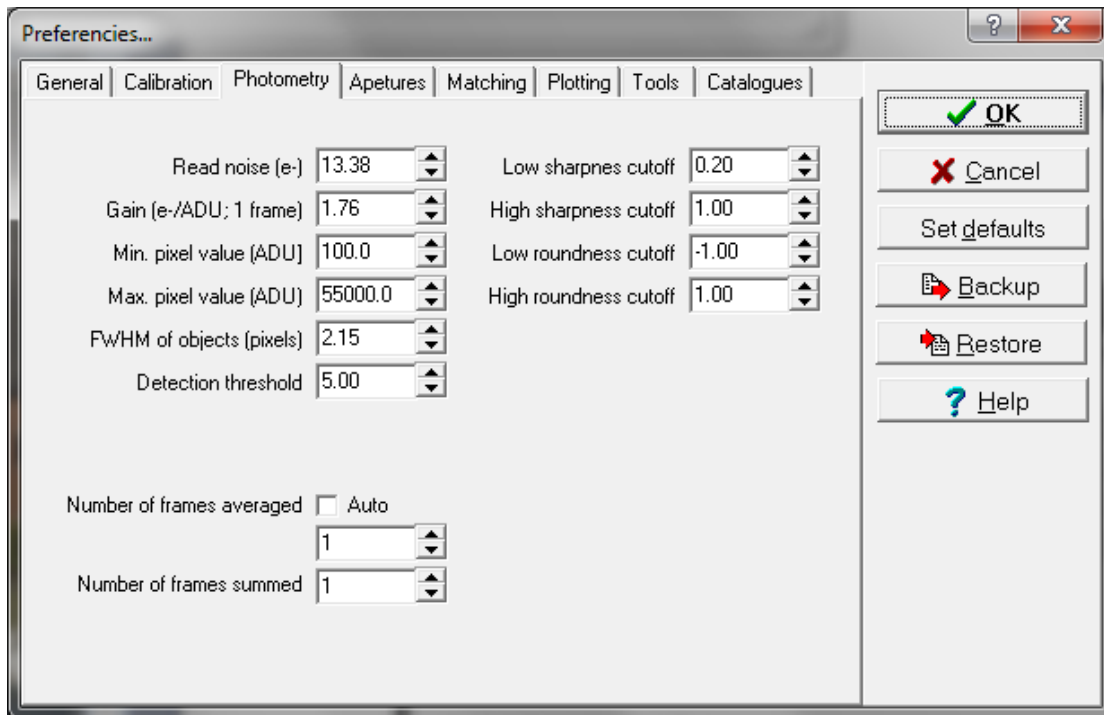


Figure 4.

Setting the photometry parameters in the preferences menu

The low and high sharpness cut-offs are minimum and maximum values for the sharpness of a bright spot and are intended to help the program decide whether the bright spot (or dark spot) is a pixel belonging to a real star or a bad (hot or cold) pixel. It will also eliminate low surface brightness galaxies. These values should be left at their defaults.

Similarly the low and high roundness cut-offs are minimum and maximum values for the roundness of a bright spot and are for the program to use in deciding whether the spot is a star or a bad column or row. It will also eliminate edge-on galaxies. Again leave these values at their default settings. FWHM, Threshold, Sharpness and Roundness are parameters used in the FIND routine of DAOPHOT.

Your image may be the result of summing or averaging several frames and if so you need to tell Muniwin how many frames are summed or averaged. But the figure you enter for the gain must be the gain for a single frame not for the sum of frames.

Moving on to the aperture preferences you can enter up to 12 different inner apertures but only one value each for the inner and outer sky radii.

That's not generally a problem but look at those four-decimal-place default values (in Fig 5). With a little bit of arithmetic and the help of Excel I found that they lay on a portion of a parabola $y = 0.1818x^2 + 0.1818x + 1.636$ and to be blunt I have no idea why. More sur-

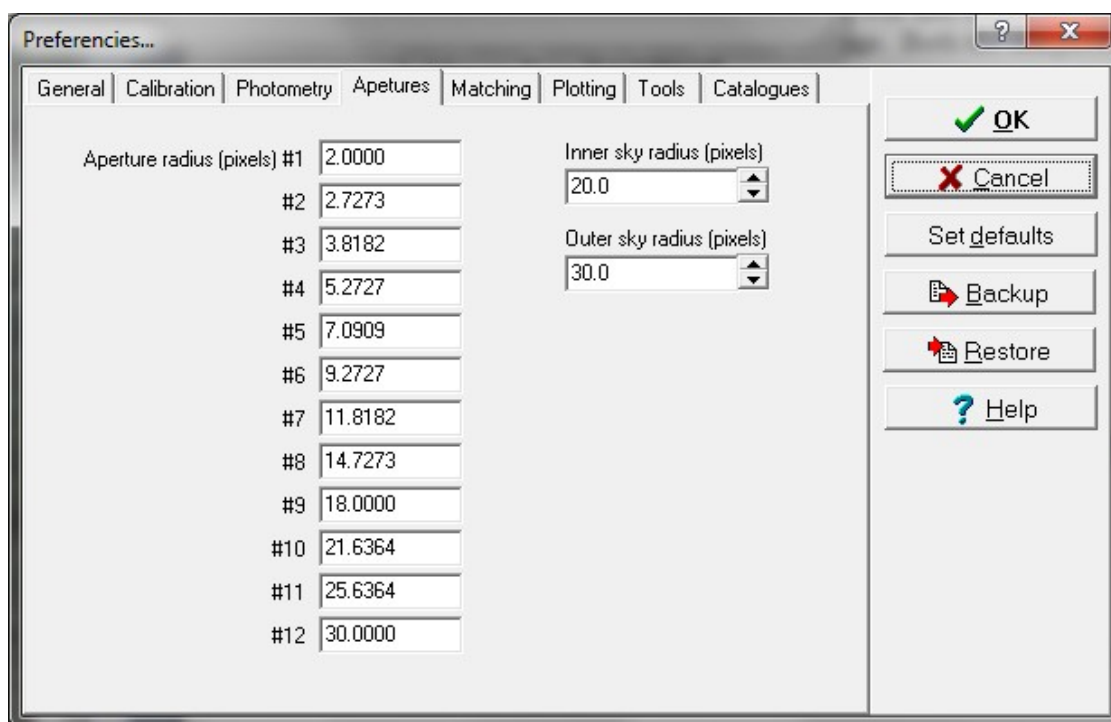


Figure 5. Setting the aperture radii for photometry

prising is that the author David Motl does not know either!

In response to my query he writes: *“These values originate from the original Munipack, which was written by Filip Hroch from Masaryk University in Brno, and I believe that in turn they originate from the P B Stetson’s DAOPHOT software. Originally, the Muniwin was started as a fork from this project and I left the default values the same - why change something that works?”* Why indeed! Of course you can enter your own values for the inner star radii and I sometimes do.

The program is quite fast taking only a few minutes to scan and measure intensities of several hundred stars in each of 12 apertures on several hundred frames. In a timed test it took 1m50secs to find and measure the instrumental magnitudes of up to 1600 stars on 133 frames. The computer was a 2.6GHz Core 2 duo with 2GB ram.

Next you need to match up the stars on each frame – just press the Match button (↔) and after choosing one of your frames as a reference frame sit back and watch the log flash by. It took just 12 seconds to match the stars on the 133 frames used in the photometry test above but I’ve known it to take several minutes if the star field is dense

Although the log flashes by as it is working, you can inspect it once the routine has finished from the Windows | Show message log menu item.

With your photometry complete and stars matched on all your frames you can now plot the results. Select the variable, comp and check stars using the Stars button (★) and after clicking OK you get an immediate graph of your data. You can save the data and your export file will be a plain text document with JD (or HJD), diff mag (or instr mag), std deviation, heliocentric correction and air-mass (if you’ve set your location in preferences). You can set what data you want in the preferences.

When you plot your graph you can choose which aperture to use for the photometry and optionally show error bars. But it pays to first look at the Tools | Plot Deviations menu item which will show you the best aperture to use. It plots the deviations between the comp and check star for each aperture (see Figure 6) with the assumption being that the aperture with the smallest deviation will be the ideal one. In Figure 6 this is aperture #3.

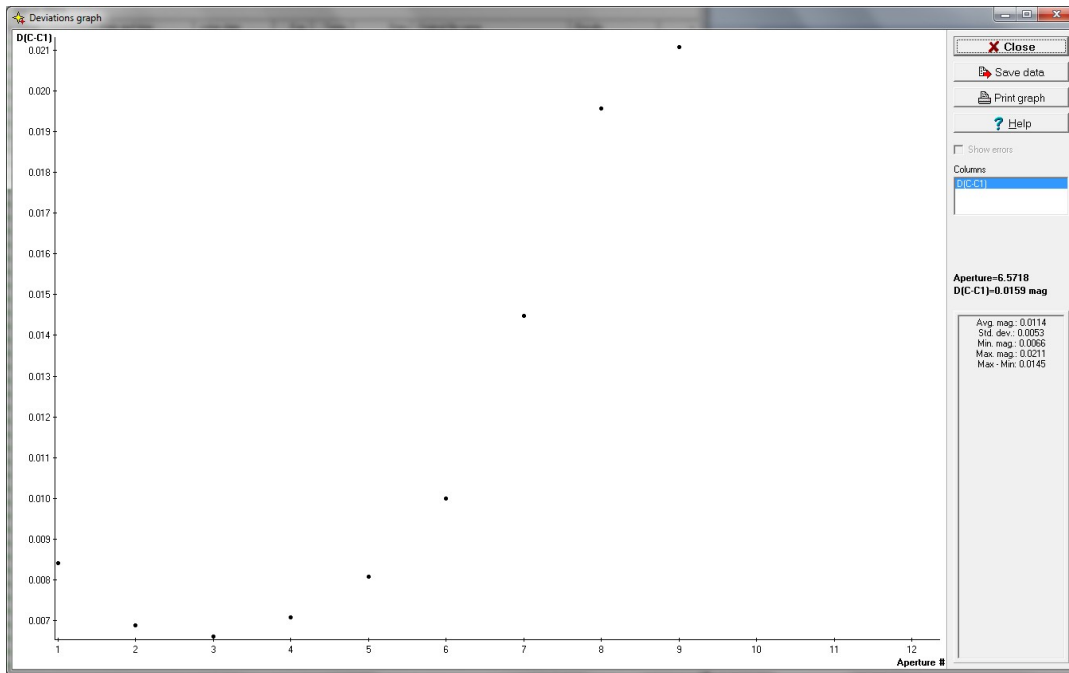


Figure 6:

The Plot Deviations function from the Tools menu will show you the best aperture to choose. Here it is aperture #3 which shows the minimum deviation between comp and check stars and is arguably the best one to choose.

Now comes the fun part and one of the best features of Muniwin. If you recall it stores instrumental magnitudes for all stars on all frames so you can check you frames for other variables using the Tools | Find variables menu item. Here's what you see:

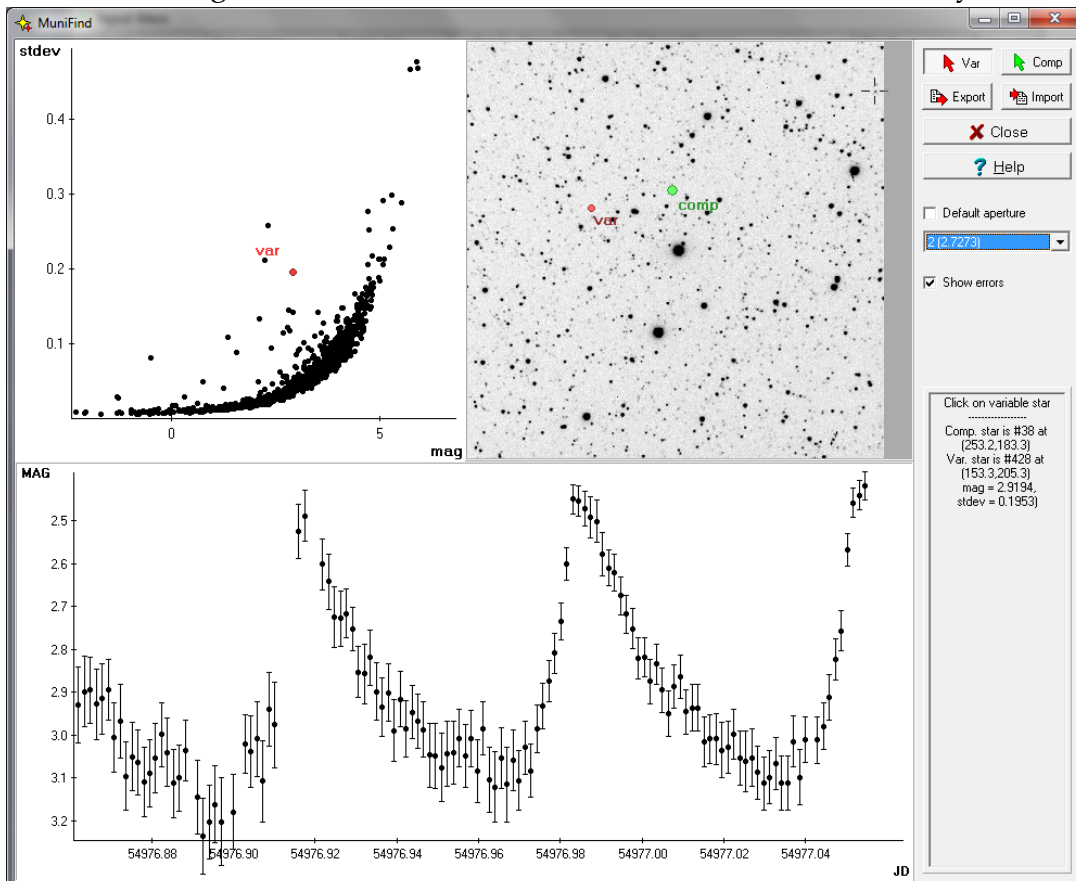


Figure 7.

The Find Variables function lets you see other variable stars on your frame besides your target. Here I've found a new variable and it looks very much like a delta Scuti variable. It certainly wasn't my target for the evening.

The program will scan its photometry listing and compute the mean brightness of each star and its standard deviation then plot these on a graph of std dev *vs* magnitude.

The program will choose a comp star and you click on any point on the graph and see an immediate light curve. Of course you can change the comp star at will. I've found several new variables this way and I'll get around to publishing them one day.

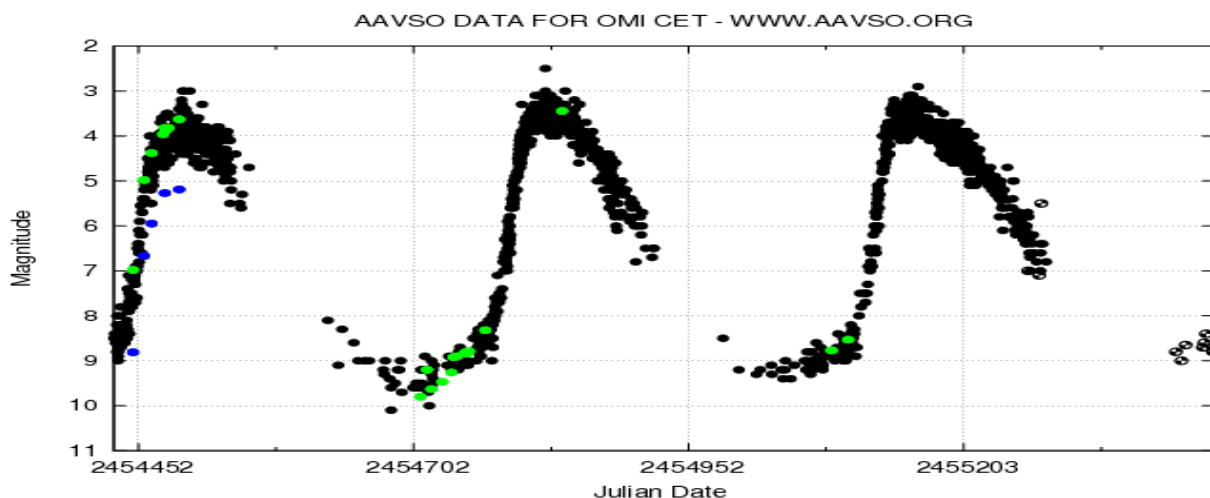
There are a number of other useful features on the Tools menu including plotting a tracking list so you can check on your mount's performance. The program will look up an object's coordinates from one of several catalogues if you provide paths to them. This is useful for calculating the heliocentric correction or to compute the air-mass coefficient. When you set up the program to make a light curve with heliocentric JDs or to include air-mass coefficients to the output file, you have to enter the object's equatorial coordinates. You can either enter them manually or you can look them up in the GCVS, NSV, NSVS or BRKA catalogues. You can also use your own images to make a catalogue file which is useful if you plan on re-imaging the same area again in the future.

For programmers all the functions and commands of Muniwin are available to you as a reference library that you can link to but I have not tested this as I'm not a programmer. This library is detailed in the user's manual which is available as a PDF file.

All in all it is a marvellous program with very little in it to complain about. I think my biggest gripe is that I can't set the sizes of the apertures interactively with an image and circles on screen to guide me in my decision. Perhaps I'll suggest that as a feature for David Motl to add. If there are any existing users in VSS who have likes or dislikes about Muniwin (either version) please let me know so I can pass on your comments to him.

AN OBSERVING EXTRA

Mira time is coming round again—not only is Cetus visible about supertime but Mira is ready to begin its rise through six magnitudes or so. Visual measures are always welcomed on the International Database but some of our CCD observers might like to try their hands at BVRI measures each week or so. Another star of interest is R Hydrae but this is a bit late in the season for it.



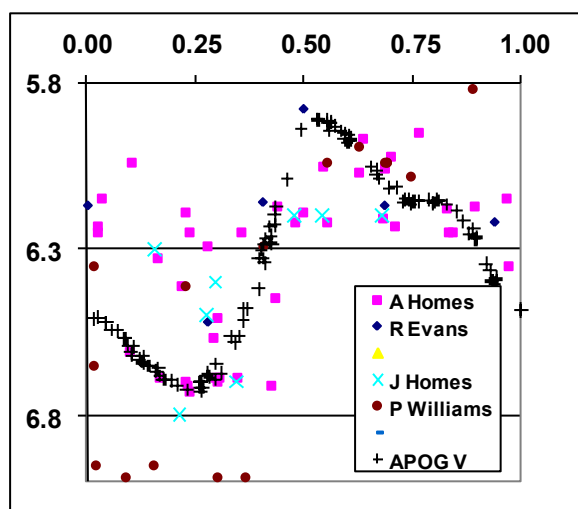
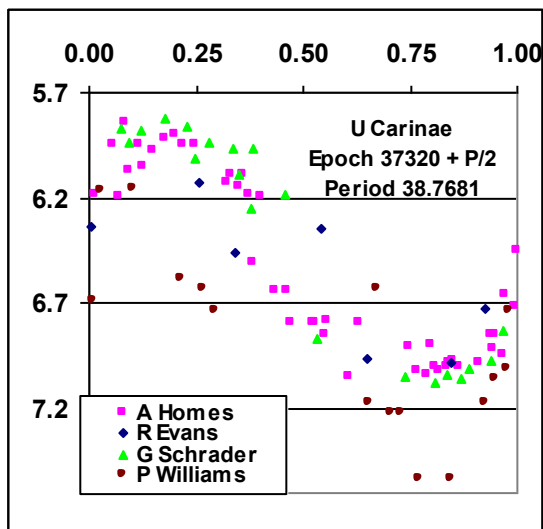
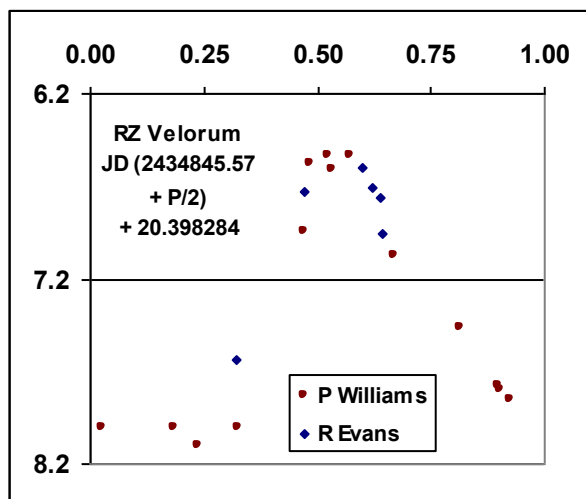
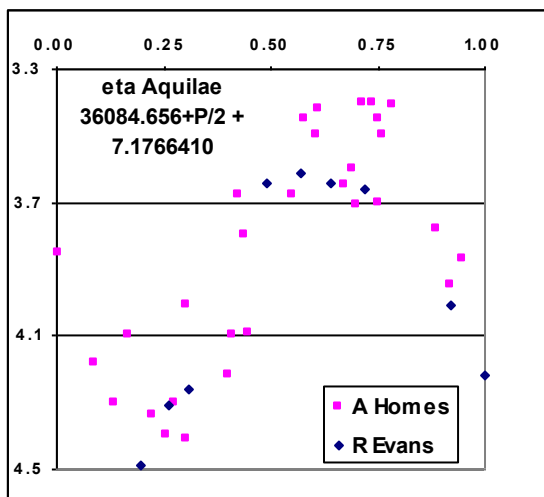
With some room to spare on pages 38 and 39 some light curves of Miras visible at this time are shown—either rising to or near maximum, or with short periods so they are quick movers. These 100-200 day Miras are interesting as they often show multiple periods and they're certainly fun to measure and plot.

BRIGHT CEPHEID PROJECT

Stan Walker

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This project has been running for almost a year and we now have five regular observers, Aline Homes, Bob Evans, Glen Schrader, John Homes and Peter Williams. Several more would be appreciated. Some of the measures in 2010 are shown below. Some fit very nicely, others, like R Muscae, are not as good. It's possible that there has been a period change with this last star but we do not yet have enough measures to comment. This

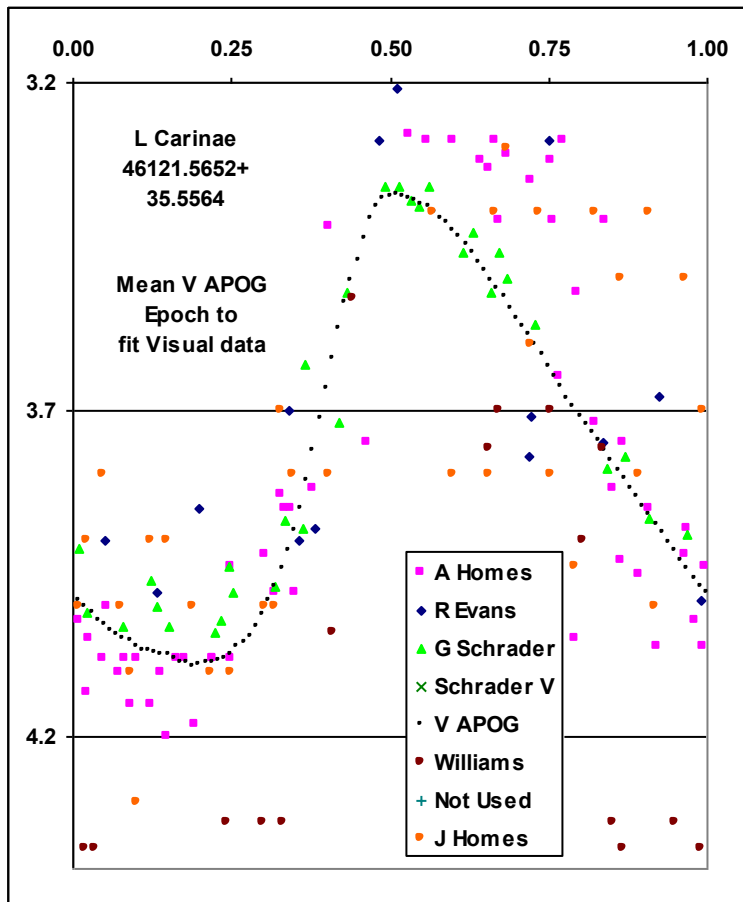


fourth plot shows the Auckland Photoelectric Observers' Group (APOG) measures superimposed on the visual estimates.

From the measures we have so far a number of things are clear. Firstly, it takes a while for new observers to build up the skill and confidence to reach the standard demanded by the low amplitude targets. But all the observers are producing valuable measures—for reasons which are explained on the next page. Secondly, not everyone sees the stars the same way so we get light curves more or less in parallel but displaced in magnitude.

Note also that the epochs have been offset in all cases so that the maxima don't appear at phase 0.00 (they're hard to visualise that way). One lesson learnt was to give all observers a similar shape and colour symbol which is used on every star to make things clearer.

We have selected 1 Carinae to do a case study to illustrate how these measures will be used. To the left are shown the measures to date in 2010. There may be a few more to come and there are no V measures by Glen Schrader of this star in 2010.

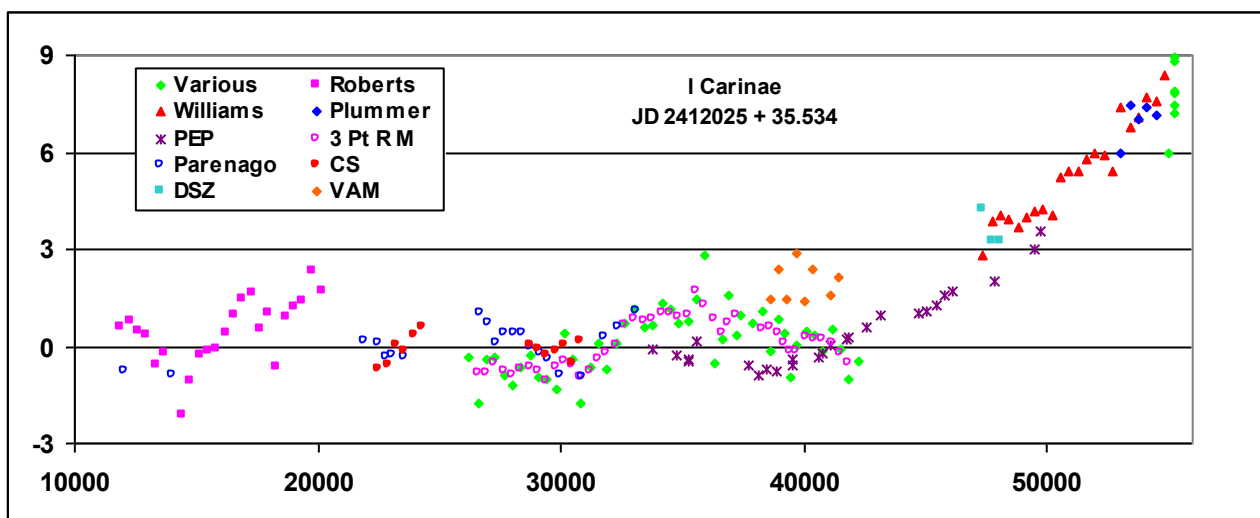


Overall the plot looks fairly messy but what we're seeing here is largely the different eye responses. As well, the period has changed slightly—and then, the V of the UBV system does not exactly match the eye's visual response.

The object is to determine very accurate epochs of maximum of these stars and to plot them on an O-C diagram to follow changes in the pulsation period.

Such a diagram for 1 Carinae is shown below. We can see one major period change in the 1960s but there is also the suggestion that there are short term variations on the scale of decades. But the measures are not good enough to be certain.

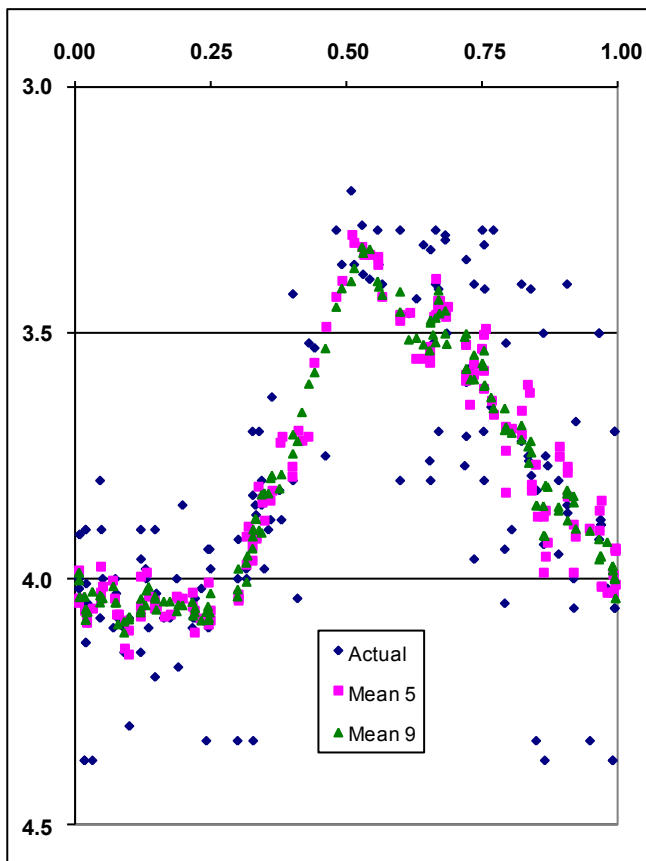
The epochs shown have been determined using a variety of comparison sequences and detectors—mainly visual, but a few photographic and some photoelectric V measures from Auckland. The original diagram was very con-



fused but this was redrawn using only epochs determined from observers who had made more than 100 measures in total. This removed most of the measures by beginners' groups as this is a favourite target for such projects. A preliminary set of epochs from this

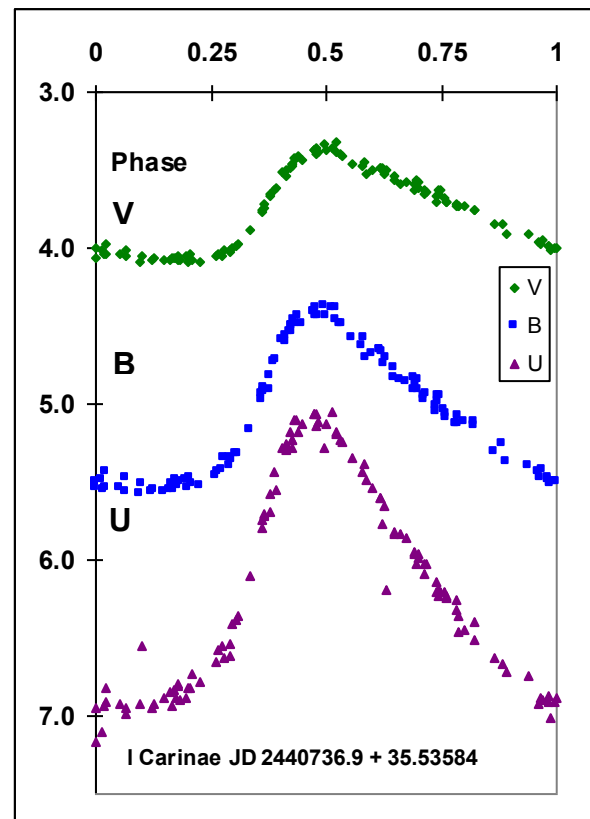
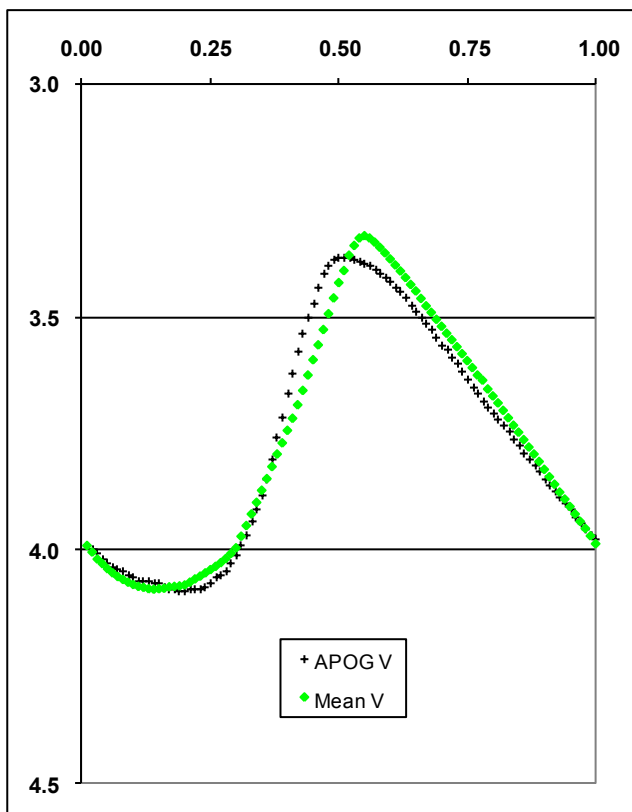
project is also shown at the end of this diagram. These were determined using the APOG mean curve as current visual measures then were too few for a good ‘visual’ mean curve.

The next step was to determine this visual mean curve. The first stage is shown to the left.



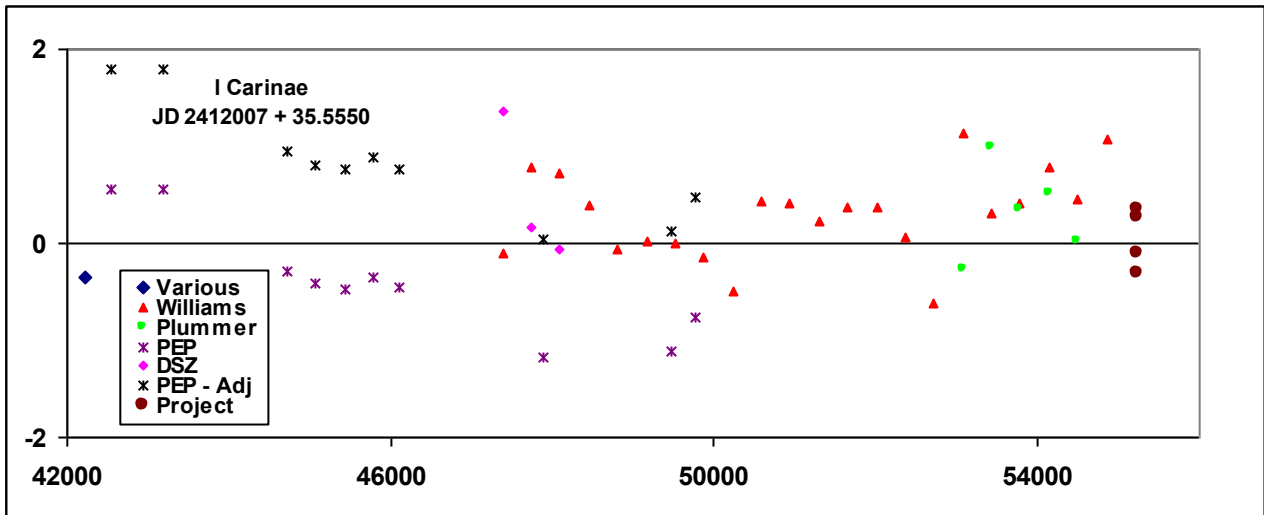
Two levels of running mean were applied to the data. Since even the 9 point running mean was too noisy a second stage—with a fair curve drawn through the individual points in this and values taken at 0.01 phase intervals—was necessary. This second step is shown in the lower illustration.

In this second illustration we have also included the mean peV light curve for comparison. It is clear by using the bisected chords method that the visual maximum is later in phase than the V maximum. This has been noticed in Mira stars as well where the maximum at J and H wavelengths is very much displaced from the V maximum. From the lower two illustrations we can come to some conclusions about the different wavelength measures.



Feature	U	B	V	visual
Amplitude	1.9	1.2	0.77	0.79
Phase offset	-2.17 days	-1.70 days	-1.23 days	0.00 days

If this correction was made in the O-C diagram of page 33 by moving the V epochs up by 1.23 days the fit would be far better. This has been done in our final figure and is shown by the black crosses. There are indications of a slight period change about JD 2448000, or 1990. But as was noted in the original project proposal this will take time to determine. Incidentally, the V range at Auckland is less than the catalogued value of 0.90 (3.28-4.18). As well, the phase offsets show that care must be taken when using datasets with different detectors—and the correction to the PEP data may be too large. Beverly Smith of the East Tennessee State University has been measuring phase lags on Miras and Semi-regular stars with somewhat confusing results. There are many papers on this phenomenon, first mentioned in 1933, and we had to apply corrections between the U, B and V



maxima determined at Auckland. This last graph shows uncorrected PEP in purple, corrected PEP in black. The corrected epochs do tend to support the idea of a small period change but the determination of the correction value is open to some question given the comparatively small number of visual measures, the mix of observers with different eye response and the time elapsed between the datasets. The AAVSO's BSM measures of Cepheids in the north may provide some answers.

At this stage it is not clear what the exact present period of I Carinae is, but the use of several slightly different periods in the illustrations has no effect on the epoch determinations—except in the O-C diagrams which are much more precise methods of determining periods. The value used in our last figure is the best fit to the visual measures of Peter Williams and Alan Plummer but these were made with a slightly different sequence. With modern measures we now know that this comparison sequence will need no further changes!

Later this year we will be updating the results on some of the main stars in the project and submitting this to a refereed journal. Keep the measures coming!

CCD COLUMN

Conducted by Tom Richards

HOW GOOD IS YOUR TIMING?

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Much astronomical observational data has time as one dimension – we are interested in how the stars change. Photometry is like that – its data are given as magnitude (or flux) against time. Most CCD observers pay great attention to getting the magnitude as accurate as possible, but pay less attention to the other half of the equation. Yet there are many applications of photometry where getting the time accurate is at least as important as doing a good job on the vertical axis. Consider times of minima of eclipsing binaries, as one example. An even more demanding requirement for good timing is the upcoming SPADES Project, where we need accuracy down to a few seconds. (See "From the Director" in this issue about SPADES.). You will find a practical example in the report on VSS work on CU Hya in this *Newsletter*. Figure 1 shows one set of eclipse observations from that campaign.

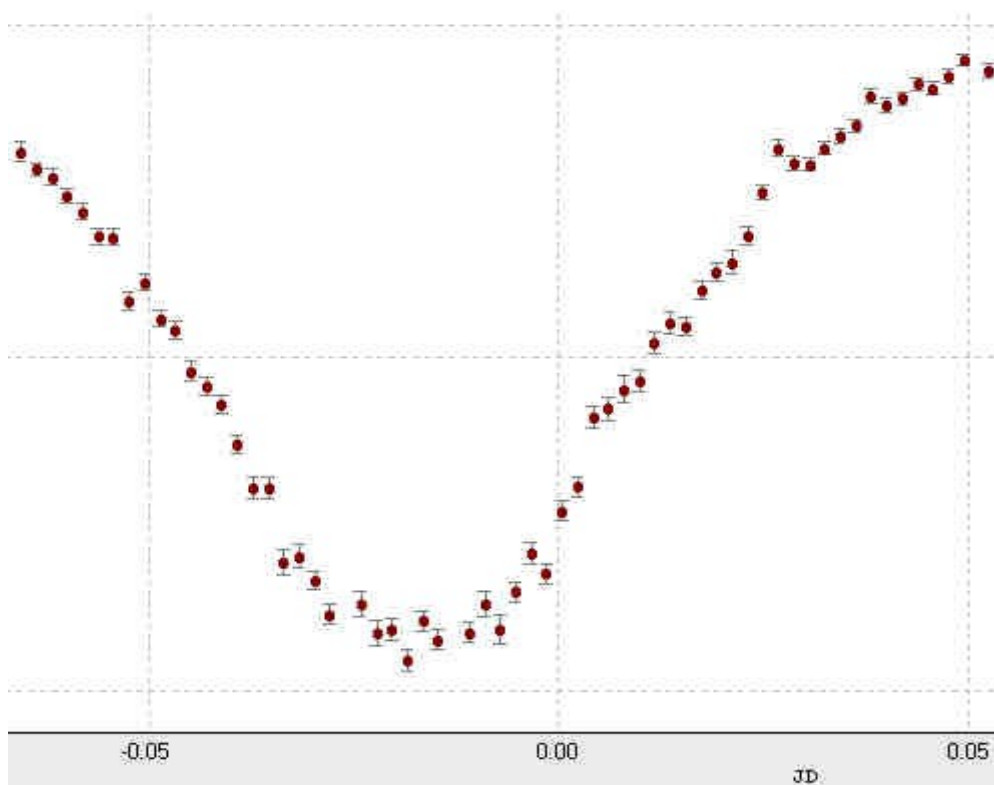


Figure 1.

Data points of an eclipse of CU Hya (mag against HJD -2455521.0). Data from Tom Richards.

Careful measurement of the 61 data points in the eclipse yield a time of minimum precise to 6×10^{-5} day or 5 seconds – even though the exposure time was 90 s. (For details of the measurement see the CU Hya report.) If a batch of data can yield a time measurement of this precision, we want the timing of the data points themselves to be known even better. Two factors influence the precision and accuracy of the timestamp in the FITS header of an image you make: the time on your computer's clock and delays in stamping that time onto the header.

For CCD work your telescope is run by your computer – any clock you have in your mount's firmware should not be operational. Computer clocks are not very accurate – they can drift quite fast. So they need to be synchronised to a very reliable external source. There is a worldwide system of Internet time servers obeying a protocol called

Network Time Protocol, keeping time extremely close to UTC. These can be accessed by any NTP client application you install on your computer, thereby updating your computer clock. Two are widely used, tested and recommended by Australia/NZ asteroid and occultation observers (whose time demands are critical) for their excellent performance, and we should use these too. They are:

Dimension4 - <http://www.thinkman.com/dimension4/>

BeeperSync - <http://hristopavlov.net/BeeperSync/> The website has a very good discussion of the issues.

I use Dimension4. When you set it up it will show you a list of NTP servers you can connect to. Choose a few closest to you to minimise round-trip time delay errors. I have Melbourne University at the top of my list. If you use a server within 1000 km or so of you, you can expect accuracy of 20 ms or better – ignorable compared to your other problems. You should set your client to update your clock on starting the computer, and thereafter maybe every half-hour, or every 10 minutes at the most if you have an old computer. Do not update more frequently, as the updating can interrupt timestamping an image in progress.

The bigger problem though is that your clock's output – the time it gives to other applications such as your screen clock or to timestamp a CCD image – is run by your computer's CPU. It can suspend clock output for a noticeable time while processing higher-priority interrupts, which happen all the time. Have you ever seen your screen clock jump a couple of seconds? Blame interruptions to the display, not your clock. What happens is that your imaging software queries the clock when it starts an exposure, but that query may be delayed getting to the clock, so the time returned is late.

We just have to live with these interrupts, so the only game in town is to try to see how much they can affect the timestamp of a CCD image. A FITS header will timestamp the start of an exposure, which you can hear as a shutter click from your camera.

So here's a good experiment. Set your watch or a wall clock as accurately as you can. Check its agreement with your computer clock's on-screen clockface. This in itself is not trivial. Once satisfied, close your on-screen clockface and commence a series of exposures. Listen for the shutter click and note the time of each as accurately as you can against your wall clock. With practice you should feel comfortable that you are within 1 second. Do that at least a hundred times.

Now write it up in Excel. For each exposure (row) you record the wall-clock time it started, the FITS time-stamp, and the difference in seconds (FITS time minus time of shutter click). Find the standard deviation of the entries in the difference column (Excel **stdev()**). That is the measure of how *precise* your individual timings are.

What about the mean of the entries in the difference column? In Excel that's **average()**. If it's around a second that may reflect just a systematic error on your part in reading the wall clock – maybe you usually read a second late, or anticipate by half a second. People do – it's called their Personal Equation. But if you have a mean difference that you think is outside your PE, start to worry, for now you have a systematic error in the clock tim-

ing. Maybe, if positive, it indicates a systematic delay in querying the computer clock. Worse still, if you find evidence of a significant periodic error in those difference figures – the difference trends up and down – then really worry, for that is very hard to allow for. You just get a big precision error.

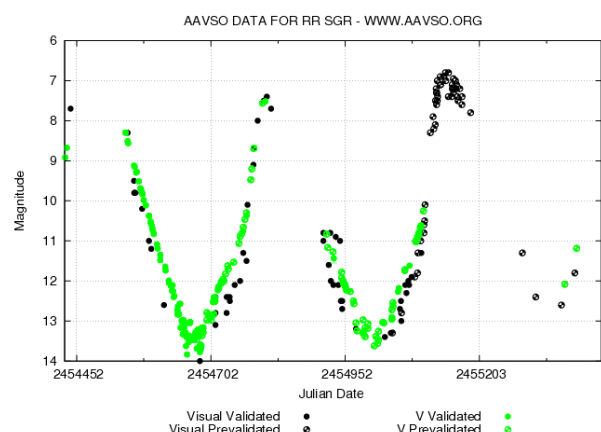
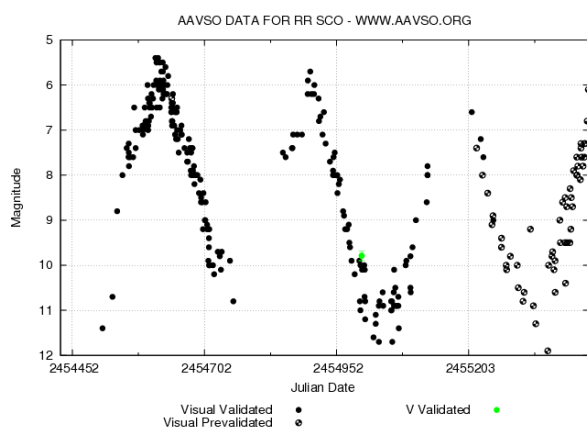
Hristo Pavlov's BeeperSync is designed primarily to control timestamp insertion into video frames, and Dave Herald reports (private communication) that tests show that using auditory timing of shutter clicks agrees remarkably well with the video timestamps; so don't feel your auditory PE must be to blame for a systematic error. But there are some obvious ways of pinning down the time of the shutter click more accurately:

- Use continuous shortwave radio time signals plus a sound recorder that can also hear the shutter. There is no such service in Australia or New Zealand. The least worst from distant parts is WWVH from Hawaii, broadcasting at 2.5, 5, 10, and 15 MHz. Of course there's a reception delay time. For more information go to http://tufi.alphalink.com.au/time/time_hf.html. Preparing an Excel worksheet of a hundred entries from the sound recording will be tedious, to say the least.
- Use the sound recorder and get a friend to tap the seconds from the wall clock, calling out every minute and every ten seconds. This should reduce the PE to a small fraction of a second.

So, by one of these methods you find the average delay (FITS time minus time of shutter click). If it is significant compared to the precision error (standard deviation) of those figures, you need to subtract it from the FITS timestamp to obtain a more accurate time reading for each image. This is best done when you port your photometry output file to Excel. Remember that photometry software usually lists the time as the exposure midpoint, so that's what you need to correct.

Finally, when reporting your data in a campaign that requires really accurate time information, such as our upcoming SPADES project, you should correct the time of mid-exposure if warranted, and always quote your timing precision error.

If you carry out the above experiment, it would be good to report on your experiences to the vss-members egroup, so we can learn from each other. (I haven't carried out this experiment yet since my telescope has been down for several months.)



CAMERAS FOR LOAN

VSS has two Meade DSI Pro cameras available for 12-month renewable loan to members. These are suitable for entry-level CCD imaging - a good way to learn about CCD variable star observing. Or of course as a guide camera. They come with the Autostar software suite.

The Pro is a superseded model so you won't find out about it from Meade's website. Try <http://www.cloudynights.com/documents/dsi2.pdf>. The following specs are an excerpt from that site

Take in DSI specs.jpg here

If you are interested please email me with a brief account of what you plan to do with it - which may be as simple as "learning CCD photometry".

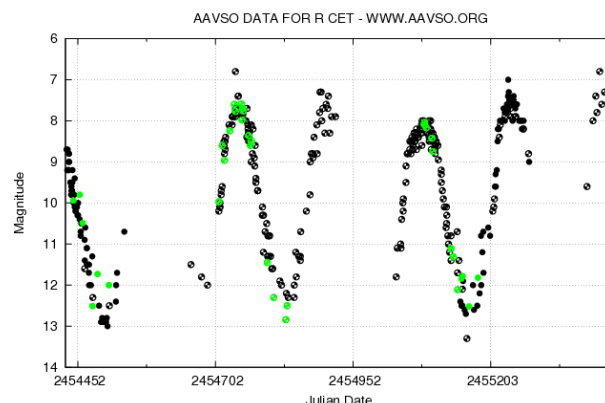
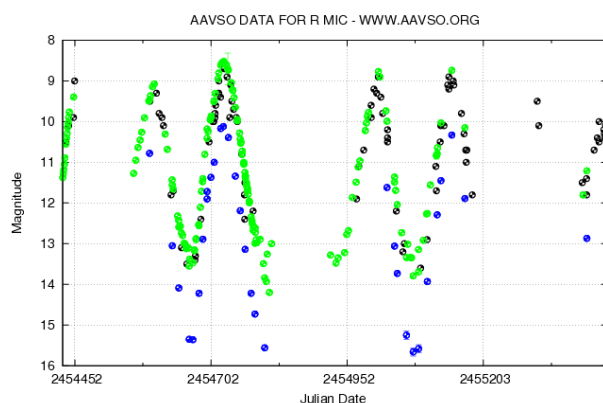
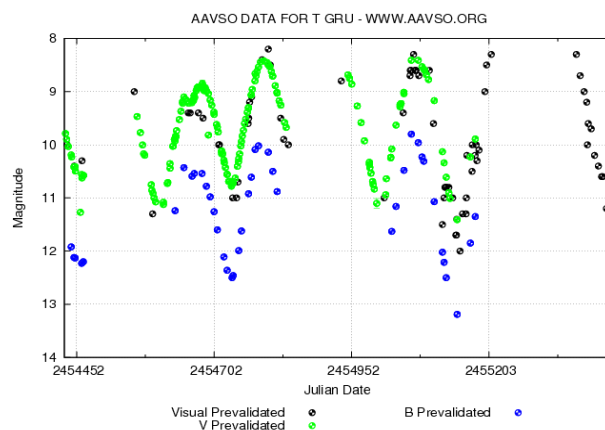
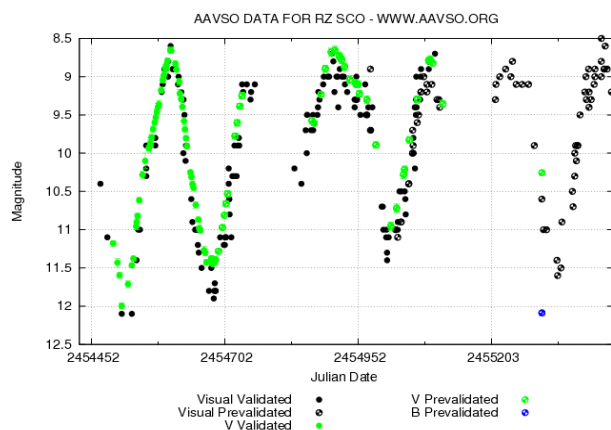
Tom Richards

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SPECIFICATIONS

CCD Sensor	High Sensitivity Sony® ExView HAD™ Monochrome CCD Sensor
Pixels	510 x 492 pixels (250,000 pixels)
Pixel Size (in microns)	9.6 microns (W) x 7.5 microns (H)
A/D Conversion	16-bit (greater image depth and contrast)
Min. - Max. Exposure Time	1/10,000 of a second to one hour
Housing	Anodized die-cast aluminum
USB Compatibility	High Speed 2.0 and 1.1
Size / Weight of product	3.25" x 3.25" x 1.25" / 10 oz.

The CCD used is the Sony IXC254AL. The image area size as given by Sony is a 6mm diagonal (type 1/3 size CCD). The horizontal by vertical imaging area is approximately 4.8 mm x 3.6 mm. This is the size that along with focal length will determine the field of view of the image taken. There are FOV calculators available on the internet.



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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. It needs to be expanded a lot more however, and suggestions should be sent to the webmaster.

All VSS members should belong to the VSS-members egroup, as that is the main channel of fast communication between members. If you're a VSS member and still haven't signed up to it, please go to its home page (above) and apply.

MEMBERSHIP

New members are welcome. The annual subscription is \$20NZ, and the membership year expires on April 30th. Find out how to join by visiting the VSS website at <http://www.varstars.org/Join-VSS.html>. There you will find out how to join by post, email, or directly online. If you join by email or online you will get a link to pay by PayPal's secure online payment system, from your credit card or bank account.

After you've joined and received your membership certificate, do please sign up to the VSS-members egroup (see above). In its personal information section, it would help everyone if you added information about your telescope and equipment, your astronomical interests and anything else you consider appropriate.

NEWSLETTER ITEMS

These are welcomed and should be sent to the Editor. I'd appreciate them unformatted, with figures and tables separate, although if you wish a particular layout send a formatted version *as well* and we'll ensure that this is followed as closely as possible. The main problem occurs when figures or tables run over into the next page but this is not usually too difficult to overcome. Publication dates are February, May, August and November—the twentieth day of these months—copy deadline is the first of each of these months.