



Newsletter 2010/2

2010 May

From the Director

NACAA and the FUTURE

Thomas Richards

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Variable star enthusiasts were well represented amongst the hundred-plus attendees at the NACAA conference at Canberra this Easter. Well organised and with high quality papers and posters, it was altogether an exhilarating few days. The theme was "Amateur Astronomy in the Online Age".

David Benn started things rolling with a workshop "Variable Star Data Visualisation and Analysis with Vstar". His Vstar software is being developed under contract to AAVSO for online use in the CitizenSky programme - and is already available there. The conference paper sessions kicked off on Saturday morning with the first John Perdrix Address (John founded NACAA) by myself. More of this below. Variable star papers in the conference were:

Tom Richards: Opportunities and Plans: the Directions of Southern Hemisphere Variable Star Research

Alan Plummer: Variable Stars: Observing Stellar Evolution

David O'Driscoll: Robotic Research for the Amateur Astronomer

Simon O'Toole: The Ubiquity of Exoplanets

Tom Richards: Round-table - Variable Stars Planning Session

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It's good to report that David O'Driscoll won the Astral Award for the best presentation. In addition I had a poster on the current results of the VSS Equatorial Eclipsing Binaries Project. I thought the round-table discussion would last half an hour before people wandered off to listen to occultation papers, but it bubbled along enthusiastically for its full hour and a half, with over 30 attendees.

Here are some of the impressions I came away with from the conference and particularly the round-table, about where VSS and variable star work should, or will, be going.

- VSS should run a special VS symposium at the next NACAA (Brisbane, Easter 2012) like the very successful Trans-Tasman Occultation Symposium. Not just for VSS members but for anybody interested.
- It was recognised that many prominent VSOs in Australia and New Zealand are not members of VSS and are not likely to join, as they are fully involved in projects of their own and VSS can offer them little. This poses questions about the role of VSS!
- VSS needs to take a stronger tutoring and mentoring role. It needs to put more effort into recruiting and training.
- Our Varstars website needs to have content upfront that will assist visitors to immediately do variable star observing. It was suggested we should have on the home page a list of a small number current variables to observe, and links to a brief introductory how-to document as well as briefs on each star. It was thought this should aim at new visual observers, but something similar could be done for CCD people. (I'm pleased to say we're working on this!)
- Club liaison needs to be developed, to assist VSOs at club level to recruit and set up local projects. (We have a proposal to assist in this role - and I'm hoping we can announce this soon.)
- A one-on-one mentoring scheme needs to be developed, both for visual and for CCD observing. (Who would like to organise this? Contact me.)
- The website needs to become more comprehensive and more interactive. (Again, I'm pleased to say we may be able to announce real progress on this soon.)
- The project-oriented approach of VSS seems right, but more opportunity for interaction amongst project members needs to be supplied.

I expressed the view that VSS is likely to settle down as a basically NZ-Australia organisation (if it survives) and is unlikely to attract significant membership from South America or southern Africa. I also said I thought that this calendar year would be likely to show whether VSS was a viable and useful organisation or not. That will depend on how well we can recruit and train VSOs, and how attractive our projects are. In the online age (theme of this conference!) there is a lot to keep southern VSOs busy and fruitful without what VSS can offer!

Another significant issue is that VSS is a lot of work. We have a fairly decentralised or-

ganisational model to spread the load, with project leaders, Newsletter editor and finance officer; but that still leaves me with a lot bigger workload than I have time for. And I'd like to do some astronomy of my own too!

We have another conference coming up in May - RASNZ in Dunedin - and it would be good to try to progress some of these issues. I'm hoping there will be a variable stars discussion session, but also I'd like to talk ideas with as many people as possible. And there's always the down-to-earth advice of: if you're suggesting something, are you willing to do it?

See you in Dunedin.

Tom

SOMETHING FROM THE EDITOR

We have a slightly larger Newsletter this time, due to some interesting articles. I wondered what I was getting with the ESP bug—the acronym is normally used in another area—but obviously Phil Evans is putting his time on his 'lonely rock in the Pacific' to good use astronomically. He's also scoring heavily in the EB area.

Bob Nelson has written a very interesting article about the use made of the EB light curves which he's mentioned in earlier parts of his series. We're now beginning to see where and how these light curves are used. I remember one of our members with a son who asked 'Well, Dad, it's a very nice light curve but what do you do with it?' Now we're really seeing this and in the concluding article in August we'll get past period changes into simple stellar modelling. From evolutionary changes into the real physical aspects.

Then I mentioned to Tom that we didn't have an EB report—could I have a page—and the result is a very interesting analysis of V1243 Aquilae—with strong observational support from Phil Evans and David O'Driscoll.

Nothing on CV measures this month —which is a disappointment as it seems that most CCD VSOs are working in that field. Can anyone out there help? Surely some of our members are measuring these stars. But Mati Morel has been doing some research into what is it, or which is it? on a couple of CVs.

Pulsating stars are well represented here. The Bright Cepheid project is going quite well and the results are encouraging—more about this at the RASNZ Conference in Dunedin. Then there is a rather puzzling star, EN Triangulum Aust. that was measured in Auckland as a Cepheid but is probably an SR star with some R CrB features. L2 Puppis—mentioned in Newsletters in 2009—shows some similar behaviour. So Stephen Hovell has produced a list of targets and together we've provided a bit of background. What are these stars?

STARS OF THE MONTH

Stan Walker

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Some of the rarer types of stellar objects have been in the news lately. One of our projects looks at some of these—the Dual Maxima Miras but there are a couple of other groups of interest—Recurrent Novae (to be in the August Newsletter) and R Coronae Borealis stars.

EN Triangulum Austrini

Let's start with a real puzzler, EN TrA. This is listed in the GCVS as **CEP**: with a period of 36.54 days. A note in that publication suggests it might be an RV Tauri type object. We measured it in Auckland for a month or two on two separate occasions using UBV filters and, whilst its colour was Cepheidlike, it wasn't excitingly regular. A more recent set of measures from ASAS3 is shown in Figure 1.

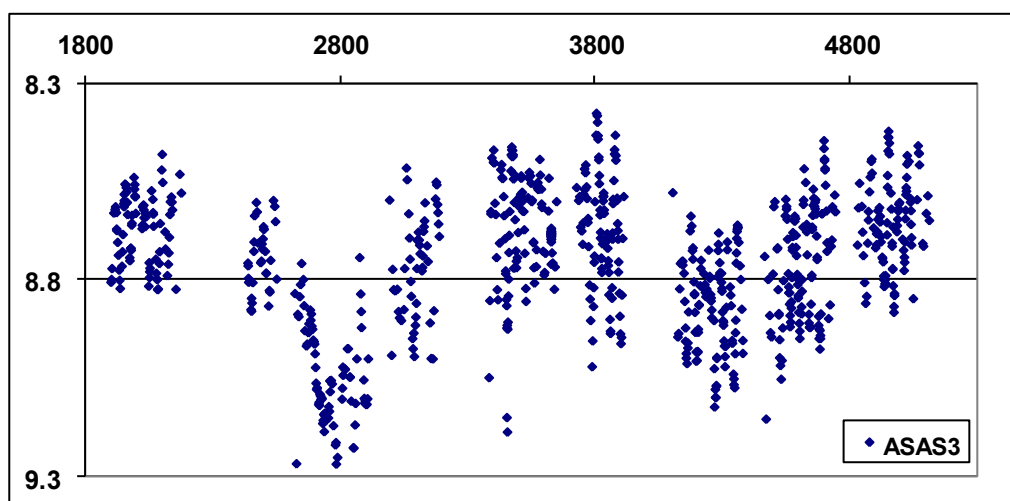
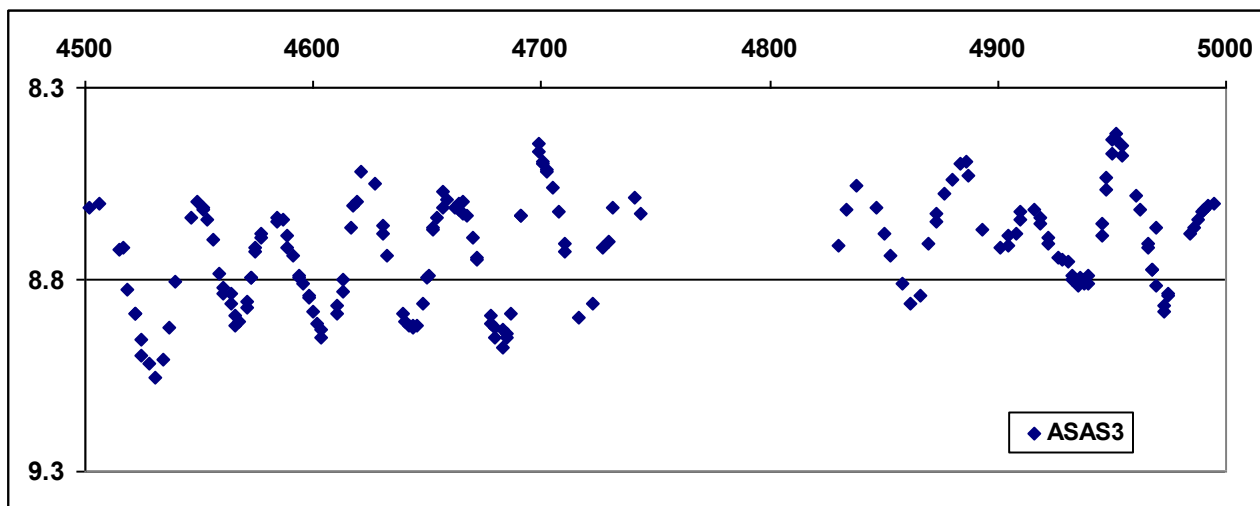


Figure 1

Measures from ASAS3 during the period JD 2451900 to date.

Figure 2—Below

This is a more detailed presentation showing the irregularity of the light curve



What is this star? It is obviously pulsating and with its colours of $B-V \sim 0.8$ and $U-B \sim 0.4$ might well be an SRd object. The period is at the bottom end of the scale. It's certainly not a Cepheid or an RV Tauri star which are both much more regular. The mean magnitude fluctuates like some SR stars but rather more quickly. There is an interesting event around JD 2452800 reminiscent of the R Coronae Borealis stars, although much less pronounced. The colours—and the period as well—are very similar to RY Sagittarii and the colours also resemble UW Centauri

STARS THAT GO OUT—R CORONAE BOREALIS OBJECTS

Stephen Hovell & Stan Walker

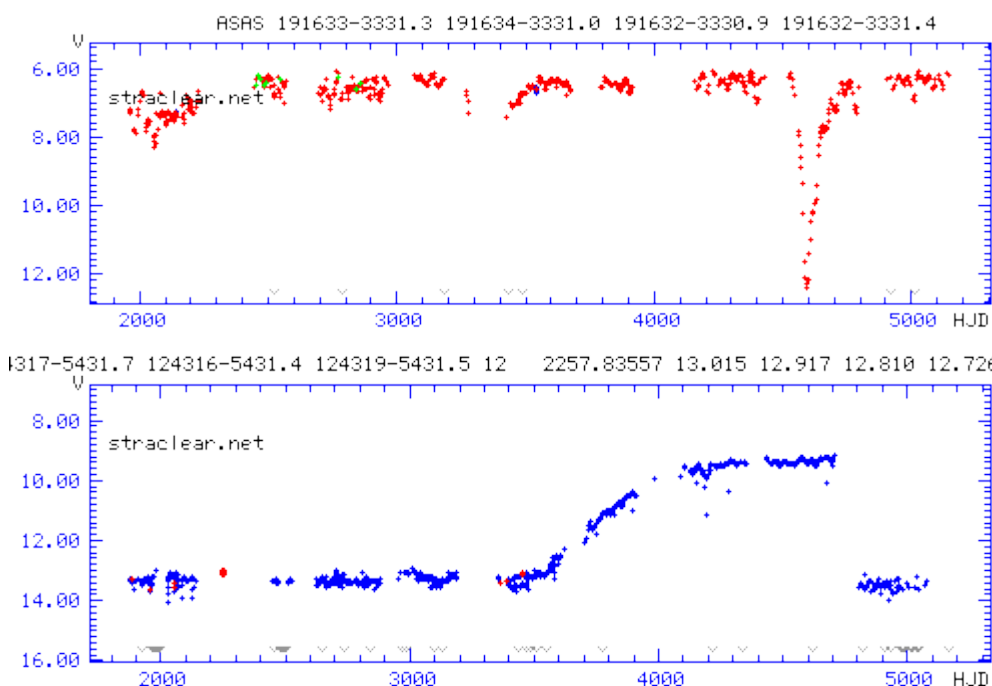
srh@xtra.co.nz astroman@paradise.net.nz

We have compiled a list of 26 reasonably bright R CrB stars south of the equator. This appears on the next page. EN TrA may well be one of these but let's look into the actual nature of these objects a little more. The fading mechanism is reasonably clear—at times a shell of cool material is ejected which obscures light at visible wavelengths. There is not much fading in the longer infra red region. Unlike Mira stars, however, in their normal states they are not particularly bright at J and H wavelengths.

Almost all these objects pulsate, but not regularly like Cepheids. Models show that they are structured more like the Mira stars with a dense central region and an extensive but very tenuous envelope. They are losing mass at a great rate driven by the pulsations. What exactly are they and at what state of evolution? There seem to be three main ideas:

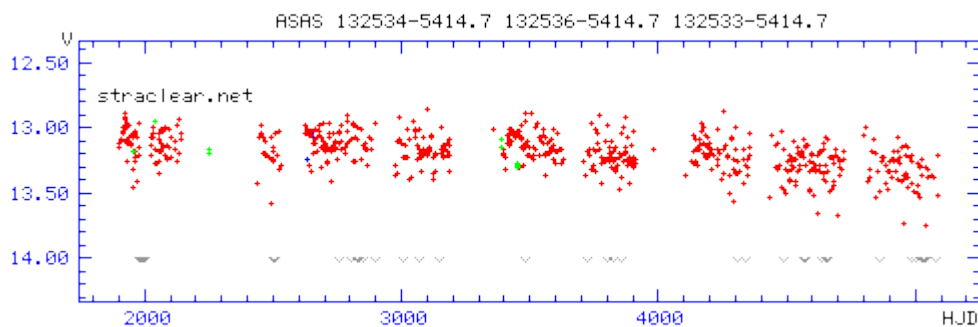
- The last thermal pulse (LTP) model suggests that they are in a very late stage of evolution and going through events which will see them collapse into a white dwarf. They may be related to planetary nebula stars.
- A more spectacular model suggest that they are the remains of a coalescence between two white dwarfs. This seems bizarre but may explain the great abundance of carbon and unusual isotopes of oxygen in the envelope.
- A third idea is that they do not represent any one group of objects but a short lived evolutionary state that a wide variety of stars go through—and that neither age nor mass is critical.

All of these models suggest links to other objects—planetary nebulae in the first, the final stage of CVs in the second and almost anything in the third. Which may well explain why they include such a range of stars from very hot to quite cool. What seems puzzling is that in spite of the abundance of carbon they do not have the deep red colour of carbon stars such as R Sculptoris or R Leporis. Let's see a few light curves, courtesy of ASAS3.

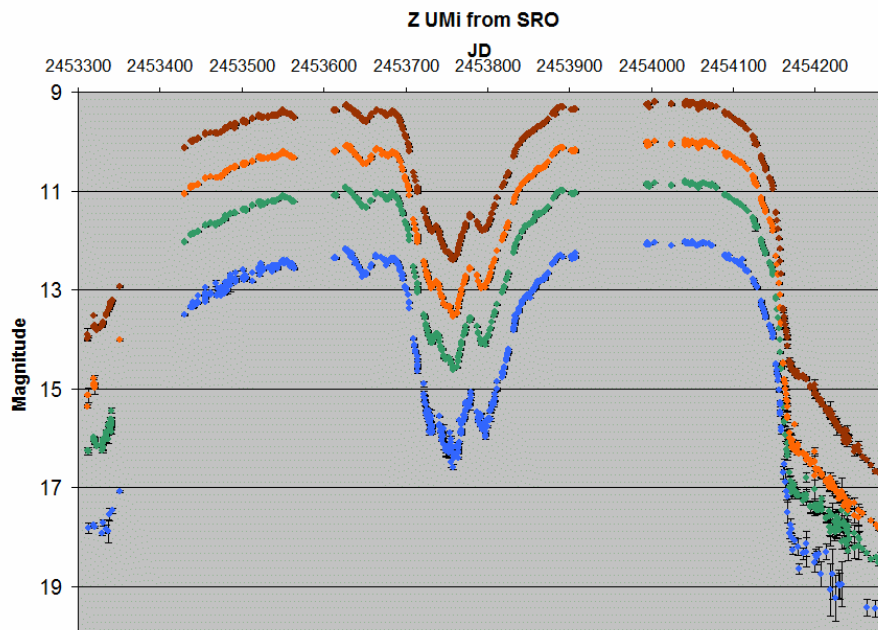


The top graph is the well known and observed RY Sagittarii which has a pulsation period of about 35 days – clearly visible here. It underwent an unusually short event in 2008

Below is UW Centauri which seems to have spent most of the last decade in an active state. When we observed this from Auckland in the 1970s and 80s it was much less active. It too shows pulsations but they are much less regular.



DY Centauri was a great disappointment— after hundreds of measures in Auckland over 20 years it still hadn't done anything. ASAS3 seems to depict the same type of behaviour. It is a very blue object.



Like many other objects Z Ursae Minoris is misdescribed in the GCVS as a Mira star with a period of 475 days. This graph comprises BVRI measures made at the AAVSO's Sonoita Research Observatory site by Dirk Terrell's group. From the top the colours represent I, R, V and B.

The light curve is rather unusual for such a star and there is little evidence of pulsation. It could almost be mistaken for a beta Lyrae star of incredibly long period!

Dirk Terrell's graph of Z Ursae Minoris. For other interesting objects see:

<http://www.boulder.swri.edu/~terrell/images>

RCBs south of Dec 0° and brighter than 14.0 at max

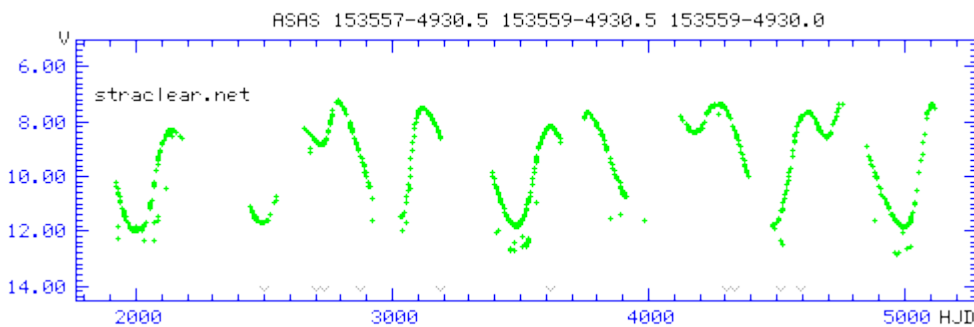
V1394 LMC	05h 16m 36s	−67° 51′ 53″	14.9 – ? (=HV 5637)
W Men	05h 26m 25s	−71° 11′ 12″	13.4 – <18.3p
V4263 LMC	05h 45m 03s	−64° 24′ 23″	14.9p–? (=HV 12842)
UX Ant	10h 57m 09s	−37° 23′ 55″	12.2 – 15.8p
UW Cen	12h 43m 17s	−54° 31′ 41″	9.1 – <14.5v
Y Mus	13h 05m 34s	−65° 30′ 47″	10.5 – 12.1p
V803 Cen	13h 23m 45s	−41° 44′ 30″	13.2 – 17.7v
DY Cen	13h 25m 34s	−53° 14′ 44″	12.0 – 16.4p
V504 Cen	14h 12m 49s	−40° 21′ 38″	12.0 – <18.0p
V854 Cen	14h 34m 50s	−39° 33′ 19″	6.84–14.94V
S Aps	15h 09m 25s	−72° 03′ 45″	9.6–15.2v
RT Nor	16h 24m 19s	−59° 20′ 39″	10.6 – 16.3p
RZ Nor	16h 32m 42s	−53° 15′ 34″	10.6 – <13.0v
WX CrA	18h 08m 51s	−37° 19′ 43″	11.0 – <16.5p
V517 Oph	17h 15m 20s	−29° 05′ 37″	12.6 – 20.3B
V532 Oph	17h 32m 43s	−21° 51′ 41″	12.6–<15.5p
V3795 Sgr	18h 13m 24s	−25° 46′ 41″	11.5 – <15.5p
V2552 Oph	17h 23′ 15″	−22° 52′ 06″	10.5 – 13.6V
VZ Sgr	18h 15m 09s	−29° 42′ 30″	10.8 – 15v
RS Tel	18h 18m 51s	−46° 32′ 53″	9 – <14.0v

GU Sgr	18h 24m 16s	-24° 15' 26"	11.33 – 15B
MV Sgr	18h 44m 32s	-20° 57' 13"	12 – 16.5B
V CrA	18h 47m 32s	-38° 09' 32"	8.3 – <16.5v
RY Sgr	19h 16m 33s	-33° 31' 20"	5.8 – 14v
ES Aql	19h 32m 22s	-00° 11' 31"	11.5 – <17.7V
U Aqr	22h 03m 19s	-16° 37' 35"	10.5 – <14.4p

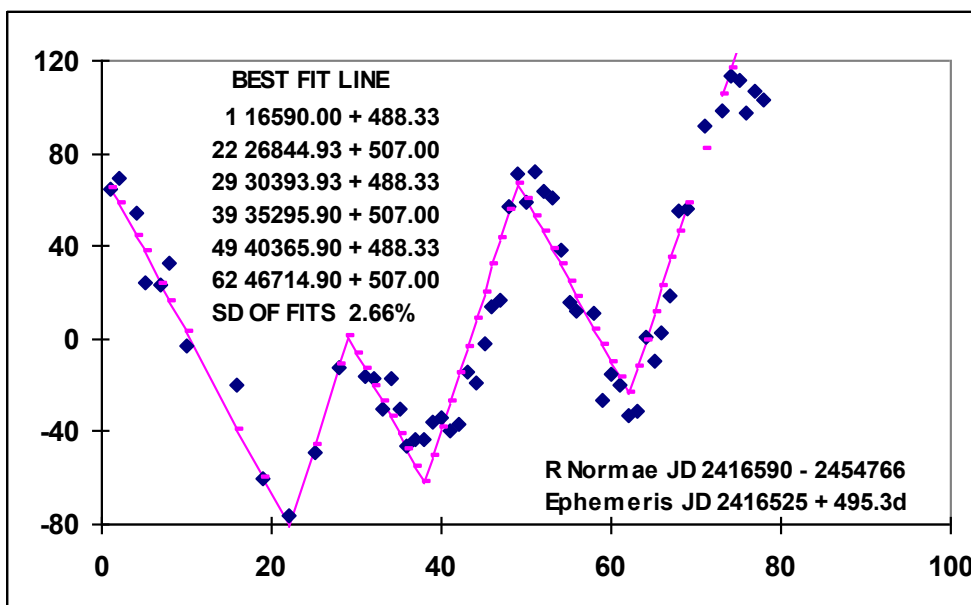
THE DUAL MAXIMA MIRA PROJECT

Not a lot to report on colour measures of these stars—probably because of the summer and the location of most of these. But it appears that some of those on our list are not similar to the four main members—R Centauri, BH Crucis (in the past—it's not now), R Normae and V415 Velorum (NSV 4715). TT Centauri and BX Carinae are probably DM stars, UZ Circini is possible and BN Scorpii looks rather like BH Crucis in the middle stages of its change to a single maximum Mira.

Recently the LPV Section of the AAVSO has published a list of 50 stars with humps and bumps compiled by Frank Schorr. The interesting part about this is that there are apparently no dual maxima Mira stars in the Northern Hemisphere. This lends extra credence to John Greaves' suggestion that these stars may have a common age and origin. Why are they different? It seems that element abundances in the envelope—and these are what make the Mira amplitudes so large—may have a more important role than was thought.



Shown here is first a recent light curve of R Normae which is now just past first maximum—and worth observing in BVRI. The lower graph shows O-C deviations of R Normae since 1904. As discussed at the 2009 Colloquium almost all Mira stars show alternating periods and this star is no exception. It appears likely that the longer period is coming to an end and the star will revert to the 488 day period.



THE ESP BUG

Phil Evans

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I've been bitten by a bug, but that's not so surprising since I live on the island of Rarotonga in the middle of the South Pacific. It itches and I want to scratch it. Usually I'd just put some anti-histamine cream on and forget about it but with this bug no amount of cream or potion is going to stop it bothering me. You see, it comes from outer space! It's the ESP bug, or, to give it its full name, the extra solar planet bug.

Yes, I've been chasing planets around distant stars.

It's not too difficult but you need to have a telescope and a CCD camera and, as with any variable star work, you must be able to properly calibrate your images with darks and flats. The telescope needs not be huge - even a small 4" refractor will do if the parent star is bright.

With my MI-250 mounted ten-year old 10" Meade LX200 classic scope and an SBIG ST9XE I've now detected five ESPs and I'm itching for more.

There are several techniques for detecting extra solar planets but only the transit method is a realistic approach for most amateurs, although at least one experienced amateur spectroscopist has made a detection using the radial velocity method (<http://www.astrosurf.com/~buil/tauboo/exoplanet.htm>). Thizy et al even followed up their detection by observing a transit of the same star with a 400mm Canon lens on a Canon 40D camera.

If you want to get started (beware of addiction) you first need to check if there is going to be a transit in your skies tonight and for that the best place to go is to the ETD web page <http://var2.astro.cz/ETD/>

Of the over 500 known exoplanets (at time of writing) about 80 are known transitters and all these are detailed on this site. To see what's visible tonight click on the Transit Predictions button and enter your



latitude and longitude. Be careful here as it's *ELONGITUDE* that's needed. That is the number of degrees east of zero longitude. My elon is 200 and my lat is -21. It's only necessary to give the figures to the nearest degree. In return you'll get a table of transits visible in your area for tonight. Here's a sample:

OBJECT		BEGIN (UT/h,A)	CENTER (DD.MM. UT/h,A)	END (UT/h,A)	D (min)	V (MAG)	DEPTH (MAG)	Elements Coords
<u>TrES-1 b</u>	Lyr	10:56 11°,NE	06.05. 12:11 23°,NE	13:26 30°,N	149.8	11.79	0.021	53898.87342+3.0300737 *E RA 19 04 09.844 DE +36 37 57.54
<u>OGLE-TR-56 b</u>	Sgr	11:37 62°,E	06.05. 12:31 74°,SE	13:25 83°,S	108.2	16.6	0.017	53936.598+1.211909 *E RA 17 56 35.51 DE -29 32 21.2
<u>WASP-15 b</u>	Cen	6:39 50°,SE	07.05. 8:31 72°,SE	10:22 75°,SW	222.9	11	0.011	54584.69823+3.7520656 *E RA 13 55 42.71 DE -32 09 34.6
<u>WASP-25 b</u>	Hya	9:8 82°,SW	07.05. 10:32 65°,W	11:57 45°,W	168.5	11.88	0.020	55259.93733+3.76483 *E RA 13 01 26.46 DE -27 31 18.9
<u>OGLE-TR-113 b</u>	Car	10:20 35°,SW	07.05. 11:16 28°,SW	12:12 21°,SW	112	14.42	0.024	52325.79823+1.4324757 *E RA 10 52 24 DE -61 26 48
<u>WASP-3 b</u>	Lyr	10:19 11°,NE	07.05. 11:28 22°,NE	12:36 30°,N	137	10.64	0.012	54143.8504+1.846835 *E RA 18 34 31.67 DE +35 39 41.9

Table 1 Sample transit predictions for Rarotonga. The times given are UT and when it says 9:8 it means 9:08. Also, h = altitude, A = azimuth direction.

TrES-1b (pronounced trace) is bright enough for me and a decent depth for the transit but it's too low in the sky. OGLE-TR-56b is high in the sky and a good depth but is a bit too dim for my rig. WASP 25b looks like my best bet tonight, but, oh dear, it's cloudy with thunderstorms predicted.

You can get transit predictions for many weeks ahead so change the date and see when your luck is in. Mark them down in your diary.

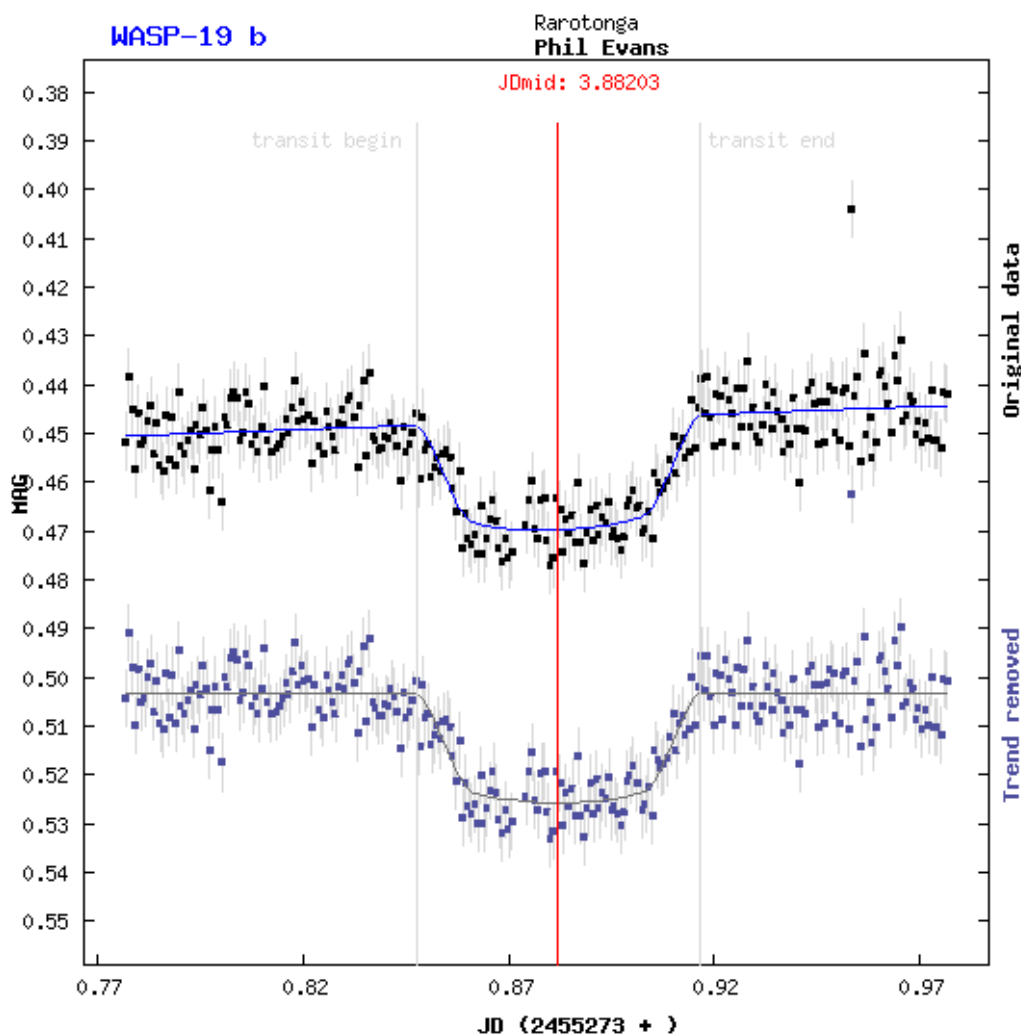
Having selected your star and noted the time the transit begins you need to begin observing about an hour before ingress in order to establish a good baseline magnitude. From now on it's just a variable star with a tiny variation, so you'll need to set your integration time to give you the best signal-to-noise ratio at the same time as keeping the cadence

high enough to spot the ingress and egress more precisely. For WASP-25b I'd probably do 2 minute integrations. I also defocus slightly so as not to run into problems with an appreciable percentage of light falling on the gaps between the pixels. If the star is very bright you may want to use a filter (either V or Rc) but all my work has been unfiltered differential photometry.

It's important to have good quality flats and darks (best taken at the same temperature as the lights), so plan your evening to include these if you don't already have high quality library calibration frames. If your darks are not at the same temperature as the lights and are scalable then you'll need to take bias frames as well.

If you can, keep imaging for some time after egress, half an hour at least. Starting well before ingress and finishing well after egress not only gives you a good baseline magnitude but also enables you to better check the published transit timing. I was caught out by one transit that lasted substantially longer than the published duration.

Once you've got your images properly calibrated and you've done your differential photometry it's now time to graph the data and the easiest way to do that is by going back to the ETD web site and clicking on "Model-fit-your data". Fill in the blanks, click the appropriate buttons, set a path to the data on your computer and submit it.



appropriate buttons, set a path to the data on your computer and submit it.

Here's a sample of what you'll get back if your data has no problems:

You'll also get some information on the duration, depth and time of mid-transit together with a table and graphic showing what geometry your data implies.

Figure 1 Returned model of uploaded photometry file

<i>Catalogue data</i>	<i>Measured data</i>
1.31 +/- 0.06 R_{Jup}	1.300 $^{-0.025}_{+0.025}$ R_{Jup}
0.93 +/- 0.04 R_{Earth}	<i>fixed, errors included in i</i>
0.0164 +/- 0.0005 AU	<i>fixed, errors included in i</i>
0.7888399 days	<i>fixed</i>
80.8 +/- 0.8 °	82.45 $^{-0.81215}_{+0.92521}$ °

Table 2 *Comparison of your implied geometry with catalogue geometry data*

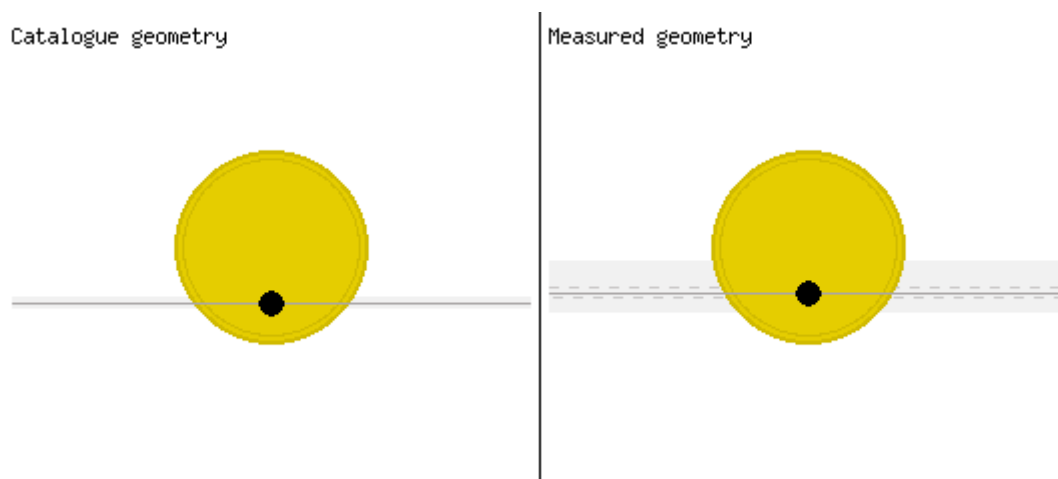


Figure 2 *Graphic showing the geometry implied by your data*

If others have observed the same planet you will be able to see how their light curves, transit durations and depths compare with yours. You'll probably notice that the quality of the submitted data is pretty ordinary – mostly 3 on a scale of 1 is best, 5 is worst. So far I've got a 2, two 3s, a 4 and a 5.

Some planets are easier than others to detect either because they are better positioned for my location or because their eclipse depths are large.

I was lucky with the first planet I tried – HD189733b – as it had a published eclipse depth of 28mmag and its parent star was bright. At a Vmag of 7.67 it was almost too bright and I had to take very short integrations of 2 secs and average groups of five.

So far I've only tackled planets where the eclipse depth has been 22mmag or larger but I think I ought to be capable of spotting an eclipse a bit shallower than those so far. Perhaps down to 12mmag but the opportunity hasn't yet arisen.

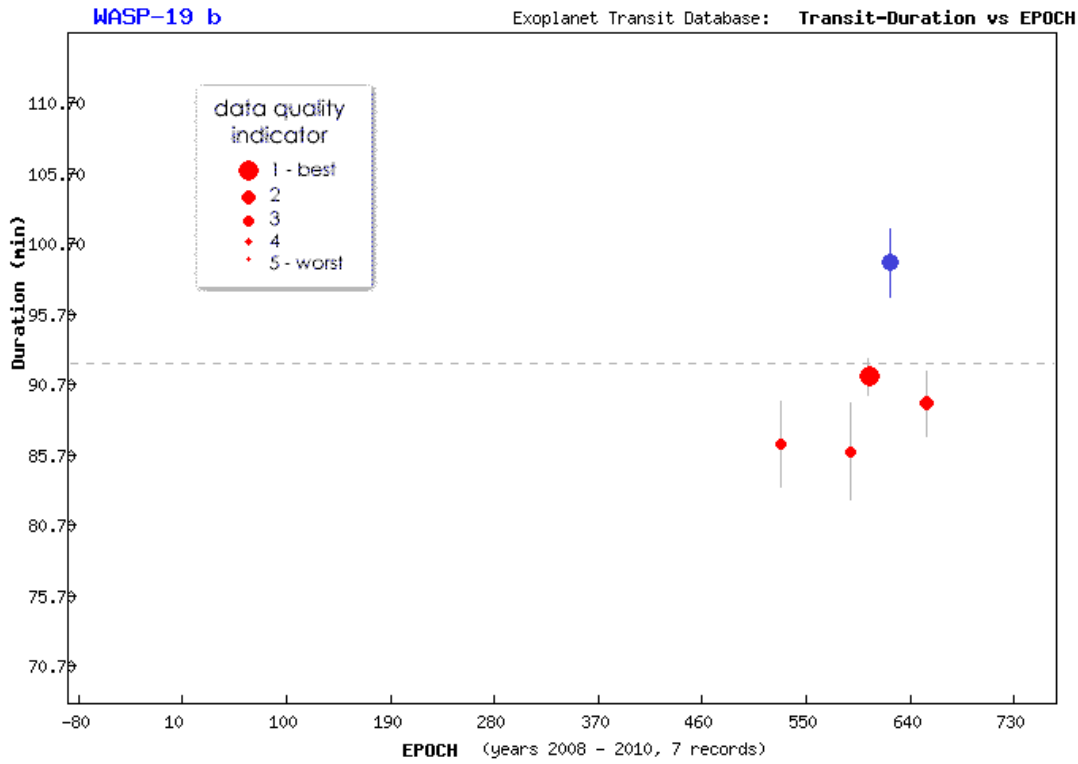


Figure 3 See how your results compare with other submissions

#	HJD mid (2400000 +)	Epoch	O- C (d)	D (min)	Depth (mmag)	band	DQ	LC	Author & REFERENCE	changed *
7	55329.90268 +/- 0.02073	703	0.0110	+/-	14.5 +/- 3.7	Clear	<u>5</u>		Milne G. TRESCA	*
6	55299.12689 +/- 0.00055	664	-	89.6 +/- 2.3	24 +/- 2	Clear	<u>2</u>		Curtis I. TRESCA	2010- 04-14
5	55273.88203 +/- 0.00062	632	-	99.6 +/- 2.4	22.5 +/- 0.9	Clear	<u>3</u>		Evans P. TRESCA	2010- 03-22
4	55259.68369 +/- 0.00033	614	-	91.5 +/- 1.3	22.7 +/- 0.5	Clear	<u>1</u>		Colque J. TRESCA	2010- 03-10
3	55247.06977 +/- 0.00087	598	0.0063	86.2 +/- 3.4	32.7 +/- 2.4	Clear	<u>3</u>		I. Curtis TRESCA	2010- 02-24
2	55199.73264 +/- 0.00083	538	-	86.7 +/- 3	19.6 +/- 1.4	Clear	<u>3</u>		Tifner F. TRESCA	2010- 01-03
1	54775.3372 +/- 0.0002	0	0.0000	+/-	+/-		1		Hebb L. et al, 2010 Hebb L. et al, 2010	* 2010- 01-05

Table 3. All the submissions to date on Wasp 19b

There's usually quite a big spread of results so don't be bashful about submitting yours if you disagree with the published timings and depths.

And don't worry if your data is incomplete. Here's my one attempt at CoRoT 2b

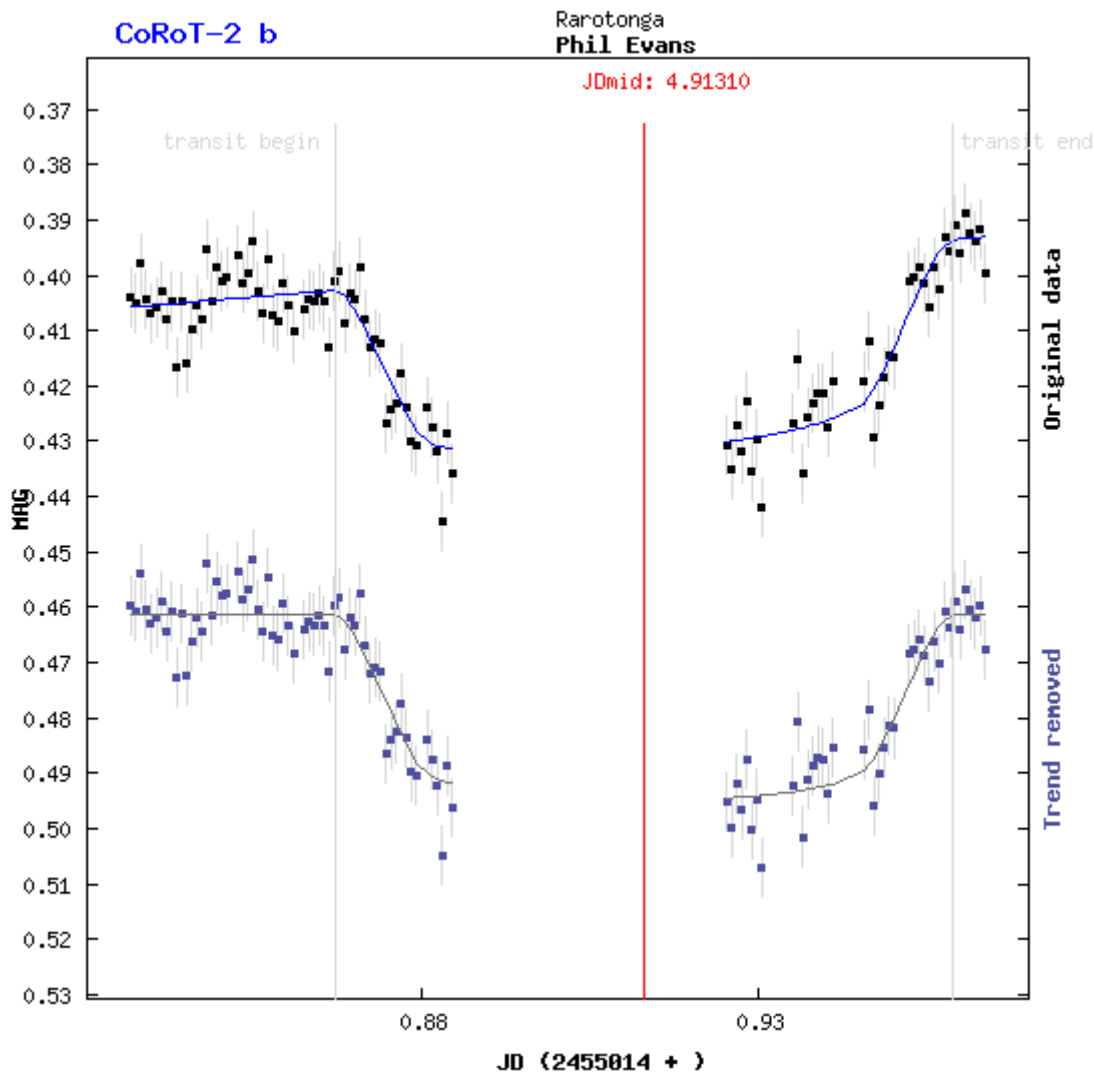


Fig 4 Even incomplete data is useful if it can show depth or start time. It was very cloudy the night I tackled CoRoT 2b and I was lucky to get the portions of the light curve that I did.

There's a lot more information available on the web but if you really want to delve deeper then I'd recommend reading Bruce L Gary's book "Exoplanet Observing For Amateurs". The second edition is for sale exclusively by Adirondack Astronomy <http://www.astrovid.com/>. But the first edition is available free of charge as a downloadable PDF file from his web site http://brucegary.net/book_EOA/x.htm

Of the about 80 confirmed transits some are only available to observers in the northern hemisphere but there's almost always at least one available to me most nights (weather permitting) and it's such a thrill to achieve a detection of something that was barely dreamt of by professional astronomers only 15 years ago that I'm frequently tempted to put away thoughts of the eclipsing binaries I've been working on.

REMARKS ON TWO POSSIBLE CATAclysmic VARIABLES

Mati Morel

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In the course of charting variable stars, one sometimes has to look deeper into the history of a variable to determine what is really being observed. Stars which are classified as CVs in the General Catalogue of Variable Stars are sometimes wrongly classified, due to inadequate data at discovery. I have made a careful study of one case (V601 Sco) which has been under watch by the VSS, and another star (V3642 Sgr) which has been put up as a likely target. I present my remarks on these stars.

V601 Scorpii = HV 10840.

Discovered by Swope (1943), as an irregular variable, range 15.0 -(16.5p. Suggested by her as a possible UG star of the SS Cyg type. Identification was unclear for a long time due to rough published coordinates, and a poor finder chart. It was identified with a "blue" star by Vogt and Bateson (1982), lying only 6" east of another star which has turned out to be red. Rod Stubbings has had V601 Sco on his program for several years without finding definite signs of CV activity. Rather he has found indications of variability in the neighbouring red star, at about 14 mag (vis). The coordinates for these two stars are given as follows:

- V601 Sco = HV 10840. "Blue" star identified by Vogt and Bateson (1982).
(2000) 17h04m05.32s -36°43'34.0" GCVS/GSC 2.2
- "Red star" = USNO-B1.0 0532-0505257, observed by Rod Stubbings.
(2000) 17h04m04.89s -36°43'31.5" B1.0. B-V = 1.54 (2MASS)

The investigation.

On red sensitive plates and images the Stubbings red star is clearly dominant at R ~13.0, while the blue star is dim, or very faint (R = 20.04 in the B1.0 catalogue).

On blue sensitive images the two stars are rather similar. Red star, B =15.41 (B1.0); blue star 16.81.

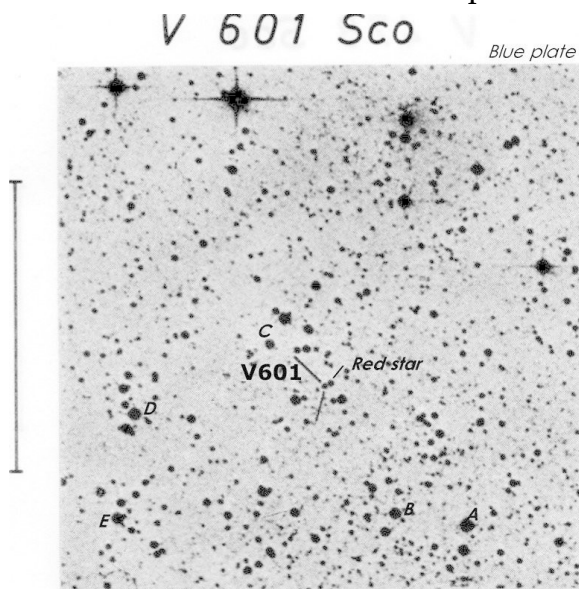
On Vogt and Bateson's photochart I estimate 16.5B and 16.6B respectively, on a blue ESS plate. The finder chart by Downes et al (1993) gives very similar results, on a Ila-D emulsion (blue sensitive).

At face value, the star identified by Vogt and Bateson is a star that shows up better on blue sensitive plates, and rather dimly on red plates. However, blueness (as B-V) is not in itself a defining characteristic of CVs. It is easy to show that the majority of CVs at quiescence do not have B-V that is particularly blue, as this index is a blend of two components, one hot and "blue" white dwarf, the other a main sequence K or M star. The blended B-V tends to be somewhere between the two



extremes, usually.

Having studied the problem for some time, I conclude that it is quite plausible that Swope has picked up the same “blue” star, of unknown type, on her blue sensitive plates while at the same time seeing nothing out of the ordinary with Rod’s red star, which would have been rather dim. However to posit that



Addendum:

Swope’s original 1943 finder chart marks the wrong star, UCAC2 16226806, $r = 13.10$ at (2000) $17^{\text{h}}04^{\text{m}}07.85^{\text{s}}$ $-36^{\circ}43'50.0''$. Swope’s finder chart only reaches 14.8B, so the red and blue stars discussed above are below the plate limit.

Conclusion.

The “blue” star identified as V601 Sco by Vogt and Bateson (1982) is most likely the same star (of Irregular variation) found by Swope in 1943 and named HV 10840. However, blueness is not, per se, a defining characteristic of CVs.

To say that V601 Sco is a CV (of the SS Cyg class) is premature. Typically an SS Cyg variable has $B-V \sim 0.62$ (average of 11 stars at quiescence), which doesn’t suit the descriptor of “blue”, and is redder than CVs in general, with $B-V \sim 0.42$ at quiescence. During outbursts the $B-V$ does shift blueward by 0.2 or 0.3. Swope wasn’t to know this as she had only blue plates to examine. The visual observer may find it much easier to observe Rod’s red star at $V \sim 14$, rather than V601 Sco (the “blue” star) which is $\sim 2\text{mag}$ fainter.

Other classes of stars may be blue, but not necessarily CVs. This could well be the case here, pending definite evidence of CV behaviour, which is currently lacking. I suggest that the present GCVS coordinates are correct. The finder chart (above) is adapted from Vogt & Bateson (1982).

V3462 Sgr: A suspected UG star at (2000) $18^{\text{h}}30^{\text{m}}19.99^{\text{s}}$ $-32^{\circ}37'58.5''$ GSC 2.3.

This star was actually first referenced more than 80 years ago by Zinner (1929). It was an entry, object number 1403, in his catalogue. I haven’t seen the actual catalogue, nor its title, as Zinner’s catalogue is virtually forgotten these days. It contains, as I understand, an early listing of suspected variables, especially in optical double star systems. I don’t know what observation lead to its being suspected of variability. Zi 1403 is the south-preceding component of a faint double star, $d = 6''$.

Zinner’s star was renamed CSV 4136 in the 1950s. The CSV catalogue is one of the predecessors to the NSV catalogue of suspected variables; “Zi 1403” lingers on as just another alias. Plaut (1971) rediscovered CSV 4136, as star no. 1047 in his survey of variables in a Sagittarius field. He gives a range of 14.07 - 18p, and suggests its type is UV: i.e. a flare star. Curiously, when the star was officially designated V3462 Sgr in 1974 the classification was changed to “UG?”. By tapping into SIMBAD it’s no problem to collect

colour information on V3462 Sgr, as follows :

R = 15.51 B = 17.12 V = 14.41 I = 10.10 All from GSC 2.3.

The B mag. is roughly consistent with Plaut's value of 18.0p, but the star appears to be too red for a UG star. Even flare stars are not supposed to be as red as this. The UG type appears doubtful.

References:

Plaut, L.	1971	Astron. Astrophys. Suppl. 4, No. 2, 75
Swope, H. H.	1943	Harvard Annals, 109, No. 9.
Vogt, N. and Bateson, F. M.	1982	Astron. Astrophys. Suppl. 48, 383-407.
Zinner, E.	1929	Erg. AN 8, No. 1.

CCD Notes

Tom Richards

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WHAT IS THE TIME ON THE SUN?

The importance of Heliocentric Julian Dates

If you look at an ecliptic star on your meridian at midnight, a signal from it reaches you about 500 seconds before it reaches the Sun, which lies opposite it on the celestial sphere and that much farther away. Six months later the star lies beyond the Sun, which intercepts a signal 500 seconds before reaching you.

This imposes a year-long sinusoidal cycle on the timing of any regular event on that star, such as an eclipse. The amplitude depends on the location of the star on the celestial sphere: 1000 seconds is the worst case but even a minute is intolerable for much work.

The solution to this problem is simply to calculate when the signal arrives at the Sun instead of the Earth. When expressed as a Julian Date, this is the Heliocentric Julian Date. To calculate this, you need to know the date and time of your observation, and the RA and Dec of the star at some equinox. Catalogues will give you that, usually to equinox J2000. The rest is just trigonometry, and the result is the "HJD Correction" which you add to the JD of the observation to give its HJD.

There are two online calculators you can use to find the HJD correction, Dan Bruton's at <http://www.physics.sfasu.edu/astro/javascript/hjd.html>, and Lew Cook's at <http://www.lewcook.com/SUNTime.htm>. Both require the J2000 coordinates of the star, and the observation time in UT or JD. If you try both of them, you may find they differ in the answer they give to the same data, but only at the fourth decimal place of a day - about 9 seconds. That is probably the result of rounding errors in the calculation.

Some photometry software such as Mira will output its photometry results in HJD rather than JD if you ask it to, and if it knows the celestial coordinates of the centre of the image.

Should you use HJD? If you can detect any change that happens in under an hour, then yes. And of course it is never wrong to use HJD - I have my software set to output it by default.

Do you have to calculate the HJD correction for each image in a night's time series? Well, the Earth moves through about 4.3 light-seconds a day in its orbit, so if you find the HJD correction for your middle observation of a star on a night, and apply that to all observations, you'll be a second out at worst, at either end. To get a handle on the error for a given star on a given night, calculate the corrections at the start and end of your run. They will very likely be just a fraction of a second different, which is no doubt well within your other uncertainties, so forget it.

It isn't too hard to write an HJD corrector in Excel. You'll find the equations Landolt & Blondeau, PASP 84:502, 784 (<http://adsabs.harvard.edu/abs/1972PASP...84..784L>). This also contains tables of light-time corrections for every hour of RA, ten degrees of declination, and tenth day of the year. Interpolation is easy.

Mind you, the ideal JD reference point is not the Sun's centre, but the solar system's barycentre (centre of gravity), which lies some 5 light-seconds from the Sun's centre. The Sun wobbles around this at varying distances in reaction to the orbiting planets, principally Jupiter of course, so the main modulation period is ~11 years. What this does mean is that you can't really expect HJD to give accurate time differences on time-scales of years to less than 5 seconds, for example if you are trying to get accurate eclipse times for a particular eclipsing binary over many years. At least it means that a couple of seconds' discrepancy between HJD calculators becomes tolerable.

STARS AT THE ECLIPTIC POLE

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I thought it would be interesting to find a few stars which didn't need HJD corrections. So I looked at the ecliptic pole in Guide 8—but was disappointed to find it fairly bare of stars up there in Dorado. The nearest I could find were VV Dor, a rather faint Mira with a 351 day period, AW Dor, a slightly brighter irregular object at around ninth magnitude and VW Dor, an eleventh magnitude RR Lyrae with a period of just over 12 hours. All at a distance of about two degrees. The northern ecliptic pole seems even more bereft of variables. So you really need these corrections—and I've been thinking about applying them to the shorter period Cepheid measures.

THE AAVSO CENTENARY

Next year, 2011, marks the centenary of the American Association of Variable Star Observers. At present they plan two meetings—the Spring meeting over 20-22 May in Boston, which is followed by an American Astronomical Society meeting on 22-26 May; and an autumn meeting on 5-9 October in Woburn, Maryland. Anyone who is interested might start planning for either or both of these.

HERE & THERE

YY Centauri and NSV 19431 (aka YYA Centauri) — Peter Williams

Looking around the various newsletters and journals there are several interesting articles. Starting with one of our own members, Peter Williams, we see in the JAAVSO a discussion of the behaviour of YY Centauri and NSV 19431, another rather similar Mira star nearby. Peter has been observing these stars since 1980—encouraged by an article in one of the old RASNZ VSS publications.

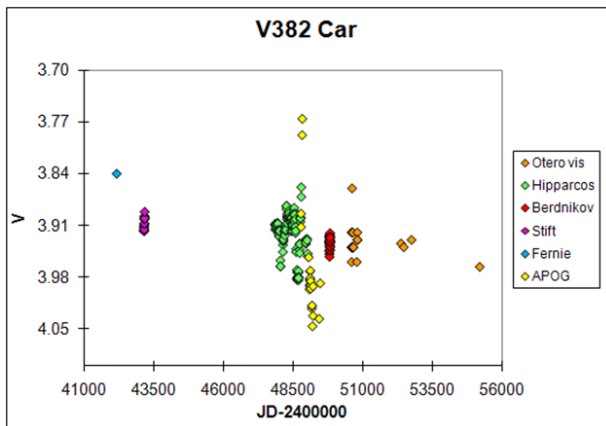
Whilst Peter mentions the cycles of NSV 19431 are a little erratic there is a suggestion from his Figure 1 that they have recently shortened by a few days since about 2003. His Figure 2, depicting YY Centauri, shows a definite alternation of cycle length.

These stars were observed at Auckland during the period 1971-84 when one of the members doubted the existence of YY Centauri. The GCVS coordinates were incorrect at the time and the period of close to a year—with maximum occurring near solar conjunction—didn't help much. In searching we noticed another variable star which we labelled YYa and this was plotted on the old VSS chart.

Peter's paper—JAAVSO Volume 38, 2010—is well worth reading and is a recommendation for not only making the measures but doing something with them. Incidentally, NSV 19431 is close to a ninth magnitude star and its light curve shows an amplitude of only ~0.1-2 in ASAS3 data so visual measures are needed.

Luminous Blue Variables — Sebastian Otero

Sebastian has written an article for the AAVSO Newsletter, 2010 April, describing some of these stars and the way in which they vary—somewhat erratically and usually on a long



time scale. Rather coincidentally Harry Williams and Stan Walker (APOG in the Graph) had measured this star for a time believing it to be a Cepheid—it was so described in the GCVS. But it wasn't particularly regular, in fact it didn't seem to do much at all. But Sebastian has put together various measures and produced the accompanying diagram showing one of the rare outbursts—also seen by Hipparcos.

T Ursae Minoris — Grant Foster

At the Variable Star Colloquium in 2009 one presentation questioned the way in which Mira stars might depart from being Miras. Grant Foster, in the 2010 January AAVSO Newsletter has written an interesting article about T Ursae Minoris, a Mira star which seems to have now changed into something resembling an SR Star. Originally the period was 310 days but is now about half that with a much lower amplitude of variation. The light curve is erratic, indicating the presence of multiple periodicities—another SR characteristic. This behaviour appears unique amongst Miras, so for those who observe these stars it would pay to have a look at the article.

ECLIPSING BINARIES FOR FUN AND PROFIT

Part IV - Determining Times of Minima

Bob Nelson, PhD

In this article, I shall lay out how to determine accurate times of minima suitable for publication, and some other things.

Introduction

What are we talking about here? Well, recall that eclipsing binaries (EBs) consist of two stars revolving about their centre of mass. In almost all cases, they are too distant even for a telescope of the highest resolution to separate them. Just by chance, their orbit is inclined enough for an eclipse to occur (otherwise they would not be observable as EBs). We know that they are eclipsing because there is a dip in the light intensity as one star passes in front of the other. This dip, or minimum, will occur twice each orbital period, except in the case of a detached system with a very faint secondary star when the secondary eclipse might be undetectable. (However, such cases are rare with today's sensitive detectors.) By convention, the deeper eclipse is called the primary one, and that occurs when the star of higher surface brightness -- read temperature -- is eclipsed.

Discovering the Period

When an eclipsing binary is discovered (and one can pretty quickly -- but not always -- tell its true identity from the shape of the light curve), the first task is to determine its orbital period. This is not always easy. First of all, the weather is often a factor. If, after discovering what you think is an EB, you might face several nights or a week of cloudy weather. Trying to piece together how many orbits or *cycles* have passed before your next observations may be problematic. The best remedy is to observe continuously for as long as you can when you can in order to get as much of the light curve as possible. With several nights' data, it should be possible to load it all onto a spreadsheet and test a number of trial periods (more later on that). With enough data spaced a few days apart, you should be able to nail the period.

There are often mistakes made. With Beta Lyrae (EB) and W UMa (EW) types, the light curves are continuously changing, so there should not be too much of a problem. Their periods are also usually short. However, with the longer-period Algol (EA) types (read detached or semi-detached), the light curve is pretty well flat between eclipses. If you detect only minima of moderate depth, are they all primary eclipses with a faint or undetectable secondary, or is the period double what you think it is, and the minima are both primary and secondary eclipses -- of equal depth? One clue is the depth of the eclipse. Recall the definition of stellar magnitude:

$$m = -2.5 \log (I) + \text{constant}.$$

Suppose that the two stars are of equal surface brightness and size, and the eclipse is total. Then the difference between the magnitude m_1 outside of eclipses and magnitude m_2 during an eclipse is:

$$m_2 - m_1 = -2.5 \log (I_2) + 2.5 \log (I_1) = 2.5 \log (I_1/I_2) = 2.5 \log 2 = 0.602.$$

Therefore (still assuming the same surface brightness on each star) the deepest the eclipse can ever be is 0.60 magnitudes. If one star is bigger than the other, the eclipses will be shallower (since less than one half the intensity is lost during an eclipse).

If one star is hotter than the other, the eclipse depths will be unequal, and there will be no ambiguity. It follows, then, that any eclipse deeper than 0.6 magnitudes must be a primary eclipse.

Another factor is the *shape* of the light curve during the eclipse. Let us define the *inclination* i of the orbit. Orbits in the plane of the sky have $i = 0$, while those completely edge-on have $i = 90^\circ$. *Total* eclipses will have inclinations close to 90° . (The inclination can be a little less -- say 88 or 89° -- as long as the disk of the smaller star passes completely in front of, or behind that of the larger. In the language of solar eclipses, there must be 1st, 2nd, 3rd and 4th contacts.) In the cases without 2nd and 3rd contacts, the eclipses are *partial*.

An *occultation* occurs when the smaller star passes behind the larger, while a *transit* occurs when the same, smaller star passes in front of the larger one. Occultations always create a flat portion of the light curve, whereas transits do not, owing to the varying intensity across the face of the larger star due to *limb darkening*. (Look in Wikipedia for a great explanation for the latter.)

The exceptions to the "flat bottom" rule during occultations would be at lower inclinations when the eclipse is threatening to become partial (times of 2nd and 3rd contact are identical); the length of the flat section will approach zero then.

As a rule, partial eclipses result in a "V-bottom" eclipse. However remember that limb-darkening is still in force, so there will always be some curvature to the light curve during the partial eclipses.

If a large number of ToMs is available (>10 , say), there are various pieces of period-search software to assist you. (See the author's website listed below for the program ToMcat.) These can often sniff out the period; however, for periods close to a day, or ToMs well spread out in time, there are many alias periods to confuse us.

Further Refinements of the Period

If the error in the determination of each time of minimum (ToM) is Δt , and the number of cycles that have elapsed between ToMs is E , then (following basic statistics) the error in your period will be

$$e = (2)^{1/2} \Delta t / E$$

Typically, error $\Delta t \sim 0.0002$ to 0.002 days. With $E = 10$, say, then the error in your value for the period will be 3×10^{-5} to 3×10^{-4} days. Within a year, the error in your ability to predict future eclipses (assuming that the period stays constant) will rise to $E = 365/P$ times error, e . In the case of a short period variable with, say, $P = 0.4$ days, the minimum error in the predicted time will be $365/0.4 \times (3 \times 10^{-5}) = 0.027$ days which is $0.027/0.4 = 0.068$ fraction of a period. That is not too bad. However, with the error at the upper range, the

fraction of a period rises to 0.68, and you really have lost track of the cycles. Whatever your error, this confusion will only get worse over time.

Initial period determinations therefore need to be followed up by subsequent ToM determinations to further refine the period. People have done that with many stars -- periods to 7-figure accuracy are common in the literature.

The O-C Diagram

In any case, it is desirable to keep track of any period changes that occur over time. The best way to do this is by the O-C diagram (Observed minus Calculated). To compute the data to plot, one starts with a set of elements HJDo and P (the period). HJDo is the initial time of minimum for a primary eclipse (expressed in terms of the Julian Date), corrected for light time to the centre of the Sun (that makes it "Heliocentric"). An example of a set of elements quoted in the literature (for the EW-type binary AC Boo from 1929 to 1982) is:

$$\text{JD Hel Min I} = 2\,455\,312.8409\,(1) + 0.3524320\,(1)\,E$$

Here, the period is multiplied by E = the cycle count since the initial ToM. (The uncertainty of each quantity is stated in brackets in the units of the last digit.)

Next, for your new ToM, the cycle number needs to be computed. (In order to avoid confusion below, I will substitute the letter n for E.) On a spreadsheet, one calculates

$$n' = (\text{HJD} - \text{HJDo}) / P.$$

Hopefully, this results in a value close to an integer or integer + 0.5. If, say, n is stored in cell E22, one can round to an integer or half integer by the formula

$$n = \text{ROUND}(2 * \text{E22}, 0) / 2.$$

The O-C value is then

$$\text{O-C} = \text{HJD} - (\text{HJDo} + P * n),$$

which is of course is the deviation from a strictly regular process of period P. You then plot the O-C values (y-axis) versus n (x-axis). The great value of this plot is that tiny changes in the period and trends show up clearly.

The way to interpret the O-C diagram is that if all your ToMs lie along a straight line of zero slope, you have the exact period, which is not changing. If, on the other hand, your points lie in a straight line of positive slope, that means the period is larger than you thought and you can calculate an improved period by adding the slope of your line to the original period.

Next, if the O-C plot results in a curve, and you can fit a parabola to that curve, that means you have a quadratic relation and the period is increasing at a constant rate. The relation then becomes something like:

$$\text{JD. Hel. min I} = 24\,55312.8409\,(1) + 0.3524304\,(1)\,E + 3.38 \times 10^{-10}\,E^2$$

The above relation has been fitted to the data for AC Boo after 1982. See Figure 1 below.

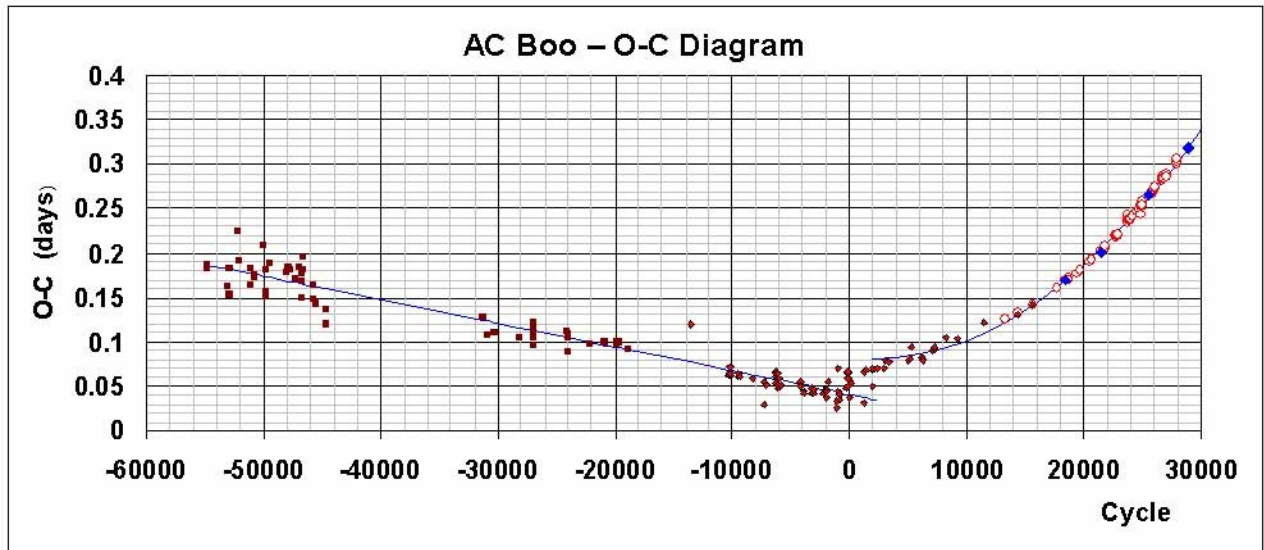


Figure 1. O-C Diagram for the 0.3524-day EW-type eclipsing binary AC Boo

At present, the author has a publication pending on this star and has no explanation for the "jog" in the relation around $E = 0$. The region of period increase is probably caused by mass transfer from the smaller to the larger star. The author has compiled a folder of O-C plots available on the AAVSO website. Some examples follow:

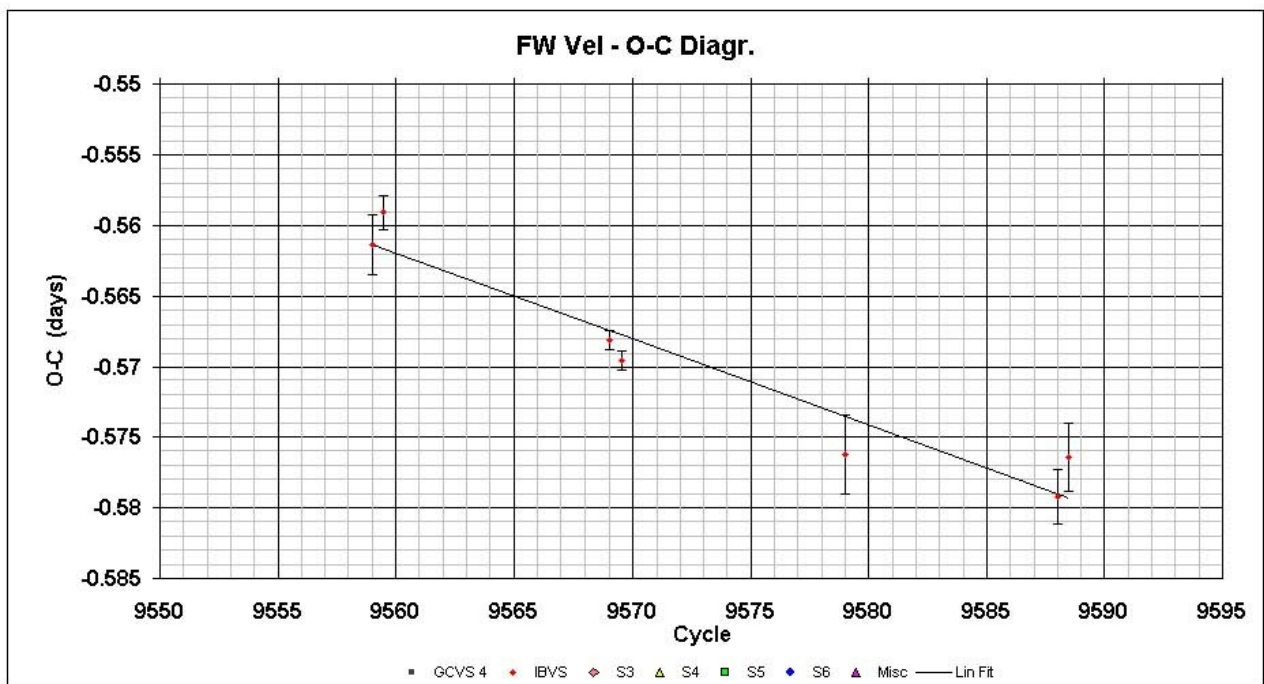


Figure 2. O-C Diagram for the 2.384-day EA-type eclipsing binary FW Vel.

This is quite a reasonable O-C relation. Within the error limits supplied by the observers, it appears to have a constant period, but further monitoring over time is required to rule out a possible positive curvature. (I would not want to publish using a parabola fitted to the above - I need better data than that!)

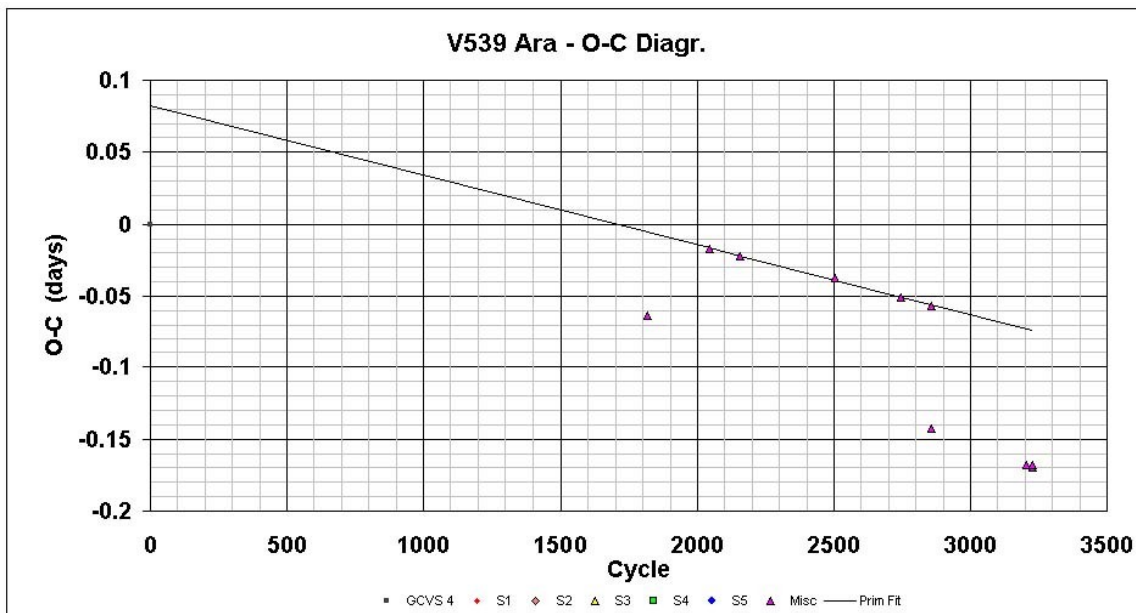


Fig. 3. O-C Diagram for the 3.169-day EA-type eclipsing binary V539 Ara

Something funny is going on in Figure 3. Why is there a second set of 4 points which lie on a straight line different from the others? It turns out that these points represent *secondary* eclipses. This system has an eccentric orbit, and the axis of the ellipse does *not* lie along the line of sight with the system. The secondary minima therefore do not occur at times halfway between the primary ones. We therefore need to set up a second set of elements for the secondary eclipses.

Relations like the above "stick up like a sore thumb", although the situation is not always as clear cut (owing to errors in timings). Note that short period binaries (especially the EW-types) will not have eccentric orbits. Tidal forces make the close orbits circular over relatively short time spans.

Figure 4 shows the behaviour of a popular and famous star. Depicted are times of minima go back to 1926, and SIMBAD reveals some 441 papers referring to it, going back to 1912! The relationship is complex, but clearly some mass transfer has taken place (and mostly from the more massive star to the less massive one, as can be shown).

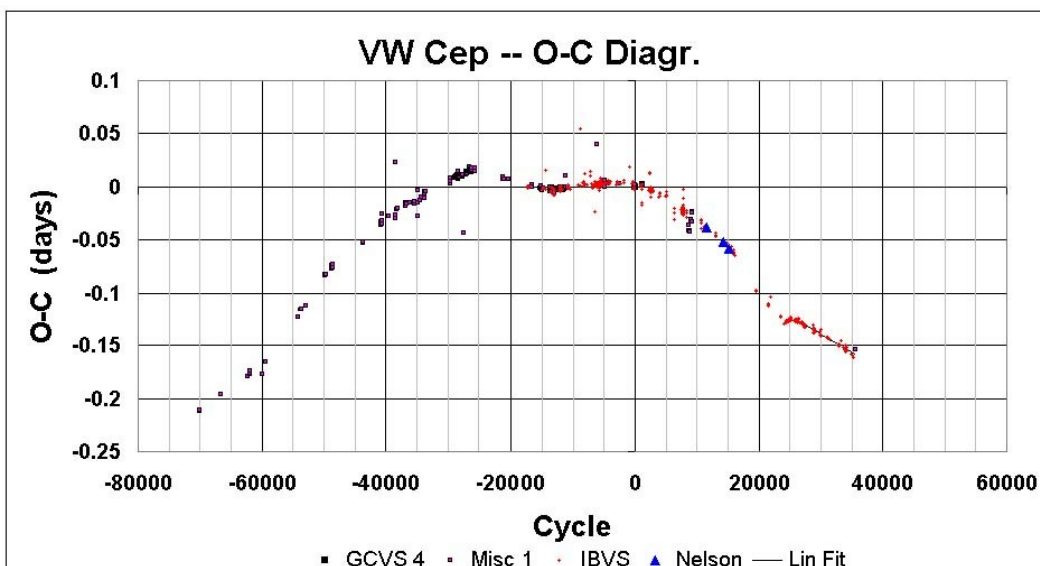


Figure 4.

O-C Diagram for the 0.278-day EW-type eclipsing binary VW Cep.

Anyway, this should give you a taste of the interesting world of eclipse timings and O-C diagrams. At time of writing there are, on the AAVSO database (Nelson 2010), some 2880 O-C files, of which 2076 are for the northern hemisphere and just 804 for the south. If one looks at the total number of points on these files, the totals are 84,023 times of minima for the north, and 10,147 for the south. Clearly the southern skies are underrepresented! (If, however, there are some databases for southern stars of which I am unaware, I would be glad to know about them.)

Well, all right: how does one go about determining times of minima? The quick answer is that it's quite easy, really; however, there are some things that must be borne in mind.

Selecting Your Targets

First of all, how do you go about selecting good targets? Help is at hand! The author has - over many years -- compiled a list (at time of writing) of 6164 systems (3218 in the north, 2946 in the south) and placed it in an Excel worksheet, EB_Elements5.xls. (This is available on my website listed below.) In it are listed 6164 systems (3218 in the north, 2946 in the south). On each line (one usually, two for eccentric orbiters) are given starname, alternate GSC designation, coordinates, HJD₀, Period, Eclipser type, magnitudes, spectral type (if available), and more.

You can then sort the worksheet to bring out a subset of suitable targets for your situation. First save under another filename and sort by declination. Then, for southern observers, delete all the declinations north of what you can comfortably observe. [For example, if you live in Christchurch, NZ (latitude 44°S), you will know that you can't see anything north of declination $90 - 44 = +46^\circ$. You might want to delete everything north of, say, $+30^\circ$ declination from the list (or perhaps all of the northern hemisphere).]

Next, sort by brightness and delete the unsuitable stars. What brightness range is best for you? It depends on your telescope's aperture and what detector you are going to use.

Taking the detector first, if you are going to use your eyeball (not recommended), you should visit the AAVSO website for specific suggestions. I do not recommend these visual eclipse timings because of their inherent inaccuracies, but if you do not have access to a CCD camera, you can still make useful contributions if you make the right target selection. That is, don't pick stars that have had recent photoelectric or CCD timings -- you are simply wasting your time, as you can't compete. On the other hand, if there have been no recent timings for that star, you can make useful contributions by helping to keep track of the cycles. For stars with unknown periods, your contribution will be more valuable still. Consult the EB O-C database for guidance.

Another detector is the single-channel photometer. This was discussed in Part III, so I will not deal with it again. Basically, it's not recommended.

The detector of choice is the CCD camera. There are many types available, and these also were discussed in Part III of this series.

Getting back to the brightness range, you do not want to pick stars for which the exposures are much longer than -- say -- 5 minutes. Much longer than that and things just get

too tedious. You will be better off selecting targets better suited to your equipment. You do not want to select stars that are too bright either. I don't like to do stars requiring exposures shorter than about 10 seconds. Scintillation noise builds up and, although I have been assured to the contrary by SBIG techs, I don't trust the shutter to give exactly uniform exposures across the field when really short exposures are used. Anyway, for really short exposures, you get thousands of files per hour, and who wants that?

The recommendation for a 13" (33 cm) f/4.5 telescope with a SBIG ST-7XME camera (my setup) is the range magnitude 8 to 13. For an 8" (20 cm) telescope, you should go a magnitude brighter, and for an 18" (47 cm), you should go a magnitude dimmer.

Now the list should be narrowed considerably. The next step (possibly) is the period. Call me lazy, but for times of minima determinations, I don't like to work on stars with periods longer than about 12 days. (For light curve determinations, I shy away after 2 days. It just gets too tedious. While we are here, light curve determinations of stars with periods close to an integral or half integral multiple of a day are REALLY tedious.) Some eclipses just go on and on. With a large selection of targets, you might want to stick with periods 1 day or less. On the other hand, you can be a big hero and work on the long-period stars, but be prepared for the tedium!

Once you have a target list of 1000-2000 stars, you can now use another piece of software, *EB_Min*, written by the author (and available on his website). You first create a text file from *EB_Elements.xls* (full instructions are supplied with the *EB_Min* package). *EB_Min* reads the file, inputs the date, your time zone, your observatory coordinates, and computes a list of stars predicted to eclipse that night. You can even create a second file (hour angle, declination) of your local restrictions, like trees, rooftops, so that obstructed stars will be excluded from the list. The list can then be printed out, saved, loaded into Excel, etc.

In selecting a target, it is *strongly* recommended that you start taking data no less than 90 minutes before the predicted time of minimum. First of all, the elements are not perfectly accurate (or why are you going through all this?), and secondly, you want to get a sufficient part of the descending part and the ascending part to define the ToM well. Ideally, for best accuracy, you'd like to include the points of inflection (or points where the curvature changes), as they are the steepest parts of the curve. At the very least, you want to capture a depth of at least 0.2 magnitudes, and hopefully more.

Another consideration is the availability of suitable comparison stars. There are a number of planetarium programs (Guide 8, The Sky) that add a CCD outline frame to the plot, based on your CCD type and primary mirror focal length so you can plan the field of view. As for selecting a comparison star, you want a star as close in magnitude to the target star as possible, and perhaps a bit brighter. You also need a check (K) star (and perhaps two) to guard against variability in the comparison. For light curve determination, the comparison star should ideally be close in spectral type to the program star, but this is often not possible.

Another consideration is proximity of the comparison star. It is very nice when the com-

parison and program star are close on the chip, as the program (V) and comparison (C) magnitudes will be highly correlated as thin clouds pass over. Then V-C will be virtually unchanged from the clear-sky value.

You also need a suitable guide star. All SBIG cameras are available with a co-mounted guide chip, so the planetarium programs show that frame as well, allowing you to see what guide stars are available. (Some software also indicates what is available if you rotate the camera in the focuser, but I do not like to do this, not the least of which because you need to recalibrate the autoguider.) For a guide star I can, but do not like to, go as faint as 12th magnitude, because of the necessary long guide star exposures, and there is always the possibility of losing the guide star should a thin cloud pass over. Bright guide stars -- when you can get them -- are a joy, as the telescope will keep tracking reliably through thin clouds.

Before you start, you need to check your computer's clock. There are many pieces of software around, including those that set your clock daily; however, you should check anyway, and make a note in your logbook that you have done so. In my logbook (I have a template to draw the CCD frame) I sketch the main stars in the field (labelling V, C, K), complete with orientation. That way, I can always go back to check things. I also write down as much other information as possible -- including aperture sizes in data reduction, sky conditions, etc. I also write down at least one start time - see below.

The Observations

When you have found a suitable target, and it's about one and a half hours before the predicted time of minimum, you acquire the star, get it centred on the chip the way you want it, and set the autoguider running on the guide star. If you have an automated filter wheel, you will need to decide on which filter to use. Except for the faintest stars (when a clear filter is called for), you should try to use a filter. The reason for this is that if you later want to go for a light curve, you can use data from this run. Also, the data from other observers can be compared and combined with yours. My preference is R, because I get the greatest throughput at those wavelengths, but for the brightest stars, V or even B is appropriate.

You should take a short, full-frame exposure without saving to disk in order to check the focus. That done, you can note the maximum count in the program, comparison and check star images. This is automatically displayed by the camera software unless there is a brighter star in the field. You do not want to exceed the non-linear limit of the CCD chip. In my camera, the SBIG ST-7XME, this is believed to be half maximum (32,700 counts). Set an exposure to create the maximum count in V, C, K without violating the above. In the case of faint stars, where the exposure times are long (5 minutes or more), you can relax this requirement and go as few as, say, 5000 counts above background, especially if the star images are large. The count times will be long, and that helps average out the variations.

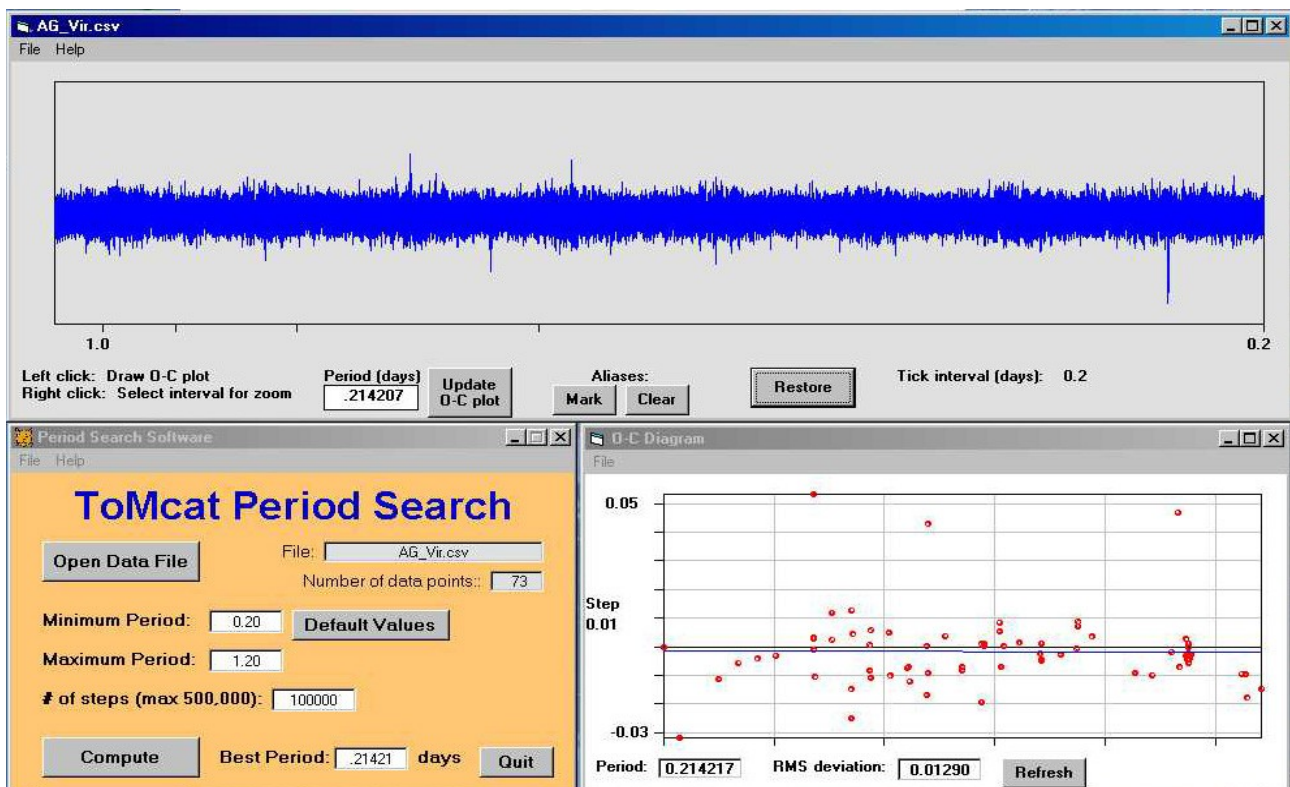
You can then set the camera to make multiple images in your run (say 1000), relax and do something else while you are waiting for the images to come in. I like to process the images (bias and dark removal, flat-fielding) after a few (3-5) images to see if the variable is

going into eclipse. [Software and image processing were discussed at length in Part III.] Many analysis software (I use MIRA, from Mirametrics, Inc.) allow you to load a stack of images, set the apertures, and do the photometry of the whole bunch. The data appear in a text screen whereupon they are to be saved to a text file.

Next, the data are imported into Excel. You can have Excel load the text file directly into a worksheet (but pay attention to 'parsing', mentioned below). However, I prefer to first load the data into a word processor (WRITE works fine) and then clipboard-copy the data only (no headers) over to an Excel template file. This template file (a copy of which can be found on my web page) has a chart already open so that when I drop in the data, a graph appears instantaneously. Note that the parse settings in [Alt]-D-E > 'Delimited' need to be set appropriately for the data to be put in the correct columns. (You may have to mess with this a bit for your text output, but 'Tab' only works for me.) Set the parse settings in a test column of numbers *before* dropping the data, as Excel may give you some ugly results otherwise. Excel will use these settings for all subsequent parses.

Is the system going into an eclipse? The rapid descent in an Algol primary eclipse will usually be very unambiguous, but for other types, some judgement is often required. Sometimes there can appear to be a trend, but random noise is just playing tricks on you. Sometimes you could be just after maximum with a long slow descent to follow. You might be at the bottom of an eclipse. It may take, say, 10 minutes or more of data to be sure. But persist -- a few minutes of useless data is better than missing an eclipse.

Once you are sure that the system is going into eclipse, all you need to do is watch the monitor once in a while to make sure that the camera does not lose the guide star. Most important: using an online clock (available at www.time.gov), you should write down



One of the software packages available

manually the start time of at least one exposure. The reason for this is that, should there be a question about the validity of a ToM, you have some way to go back and check. (A very common mistake can occur due to daylight savings time changes when your computer gets it wrong.). Record the time from time.gov in UTC to avoid any confusion. Your data acquisition software should do the same, by the way.

It is good to reduce blocks of images periodically to watch the eclipse's progress. Once you have passed minimum (yeah!), you are in the home stretch, and it might be good to look for the next target.

Determining the Time of Minimum

Now that you have reduced all the frames, done all the photometry, and inserted all the data into Excel, you should end up with a portion of the light curve that looks like Figure 5.

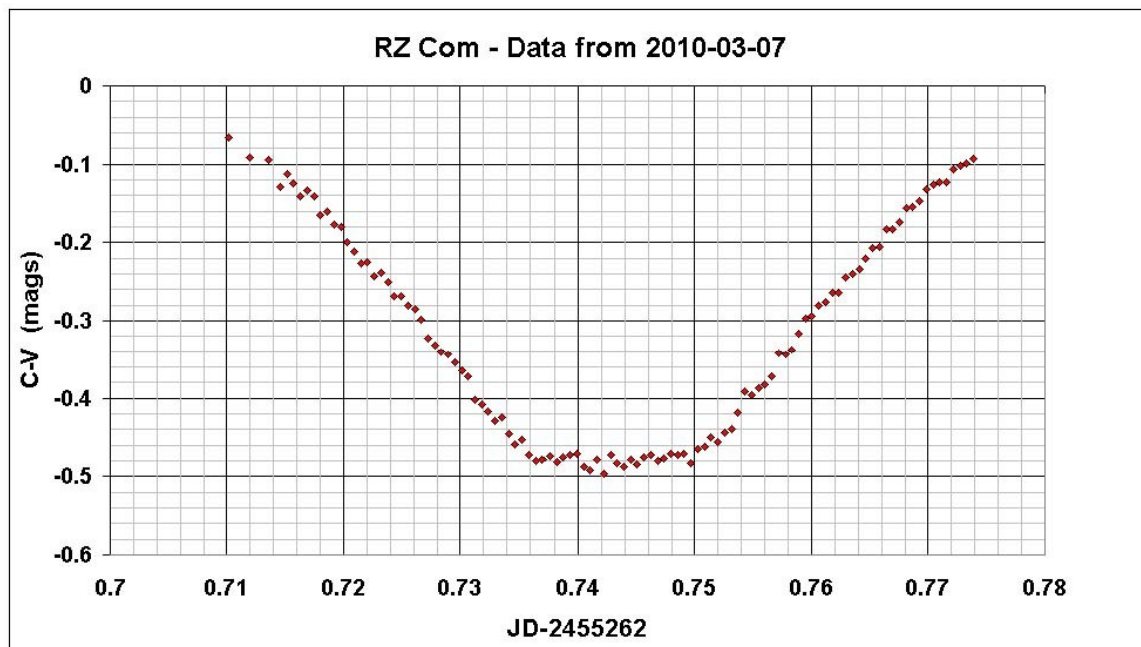


Figure 5. The secondary minimum of RZ Com (0.339-day EW/KW) of 2010-03-07

How does one determine the time of minimum accurately? Well, there are many methods. In the olden days, observers used to plot their data onto translucent graph paper and fold it over in such a way to make the descending part of the curve line up with the ascending part. This is known as the 'tracing paper method' and it works quite well, although the precision one gets is limited.

There are at least five methods in existence:

- 1) Curve fitting: parabolic and low-pass Fourier fitting,
- 2) Tracing paper -- digital form,
- 3) Bisector of chords,
- 4) Kwee and van Woerden, and
- 5) Sliding integrations.

Space is too limited to go into any detail. Suffice to say that they are all integrated into the software *Minima*, written by the author and available on his website. In passing, it is noted that while method 4 (K&vW) seems to be the industry standard, I find Fourier fitting to be the best overall. Both it and the 'tracing paper' method are incorporated into my Excel templates so that I can quickly find the time of minimum without going to *Minima*.

The bisector of chord method is not very good, and I seldom use it. While sliding integrations can be good, it sometimes can have problems.

You need to add the *heliocentric correction* to your time of minimum. This is to correct the light-time from the centre of the Sun to wherever the Earth is in its orbit, relative to the line of sight to the star. Calculations are complex, but the heliocentric correction is calculated in another piece of software written by the author, *Astrotime*. It does many conversions (e.g., from 1950.0 coordinates to 2000.0), Julian dates, horizon coordinates, galactic coordinates as well as heliocentric corrections.

Lastly, you need to determine an error estimate. Many authors wildly overestimate their accuracy, sometimes going to 5 decimal points(!). Typically what I do is determine the ToM by several methods, take the standard deviation of the different ToMs and double this figure. Kwee and van Woerden provides an error estimate which I have found to be quite reliable; however, I always double this figure too.

The reason doubling these figures is that there are all kinds of systematic sources of error that do not show up in any statistics. For example, the differential air mass of comparison and variable could change significantly over long runs, skewing your data (it does not take much). While we are here, for folks having German equatorial mounts requiring a meridian flip, don't even think of using data from opposite sides of the meridian. It just doesn't work. All you need is a 0.01 or 0.02 magnitude shift and the accuracy of the ToM is shot to heck.

Anyway, my errors are usually in the range of 0.0002 to 0.0005. With truly exceptional data, I will go to a 0.0001 day error estimate. (You know it's good when all the methods give ToMs agreeing to 4 figures!) With raunchy data, I go to 0.001 or 0.002 or worse.

Be conservative with your error estimates! All my experience with O-C plots tells me that most researchers (including me!) have often overestimated their accuracy by a factors of 2 or 3 or more. Also, if you are not sure of the ToM, don't report it.

Where to publish? There are many suitable publications, but I find the best to be the *Information Bulletin on Variable Stars* (IBVS). It's supported by the *International Astronomical Union* (IAU), it is refereed, it's free of page charges, it's available online, (www.konkoly.hu/IBVS/issues.html), and it is the journal of choice for times of minima data and new variable discoveries. It's also published in Hungary, a hotbed of variable star research.

Parting Remarks

Anyway, there you have it -- how to determine accurate, professional times of minima.

I find eclipsing binaries to be a fascinating field of research. There are many targets you

can observe with a modest (8-14" aperture) telescope and a CCD camera and yet make meaningful contributions to astronomy. The thing I like about EBs is that there is always something going on, and -- in the cloudy locales in which many of us live -- one can take advantage of breaks in the cloud lasting only a few hours.

For periods of sustained clear weather, one can do light curves using several filters. Data from light curves can be analyzed to yield fundamental stellar parameters like stellar masses, temperature and stellar sizes. In the next and concluding article in this series, I will give an introduction to stellar modelling -- enough to get you started.

And lastly, remember that the southern skies are grossly understudied -- at least at the stellar level. There are many, many southern systems that need observing!

Useful URLs

ADS: http://adsabs.harvard.edu/article_service.html?nosetcookie=1

BBSAG: <http://www.astroinfo.org/calsky/Deep-Sky/index.html/8/3>

BAV: <http://www.bav-astro.de/LkDB/index.php?lang=en>

CALEB: <http://ebola.eastern.edu/>

Crakow Atlas of EBs: <http://www.as.ap.krakow.pl/o-c/cont.html>

EB Minima dB: http://www.oa.uj.edu.pl/ktt/krttk_dn.html

Eclipsing Binary O-C Files, www.aavso.org/observing/programs/eclipser/omc

GCVS: <http://www.sai.msu.su/groups/cluster/gcvs/cgi-bin/search.htm>

IBVS: <http://www.konkoly.hu/IBVS/issues.html>

International Variable Star Index: <http://www.aavso.org/vsx/>

Nelson, R.H. website: members.shaw.ca/bob.nelson

OEJV: <http://var.astro.cz/oejv/>

SIMBAD (Harvard): <http://simbad.harvard.edu/simbad/sim-fid>

SIMBAD (Strasbourg): <http://simbad.u-strasbg.fr/simbad/sim-fid>

Up-To-Date Linear Elements of EBs: <http://www.as.up.krakow.pl/ephem/>

Variable Stars South: <http://www.varstars.org/>

Some more of Bob's software packages -- sorry about the small size but visit his site for the actual screen displays.

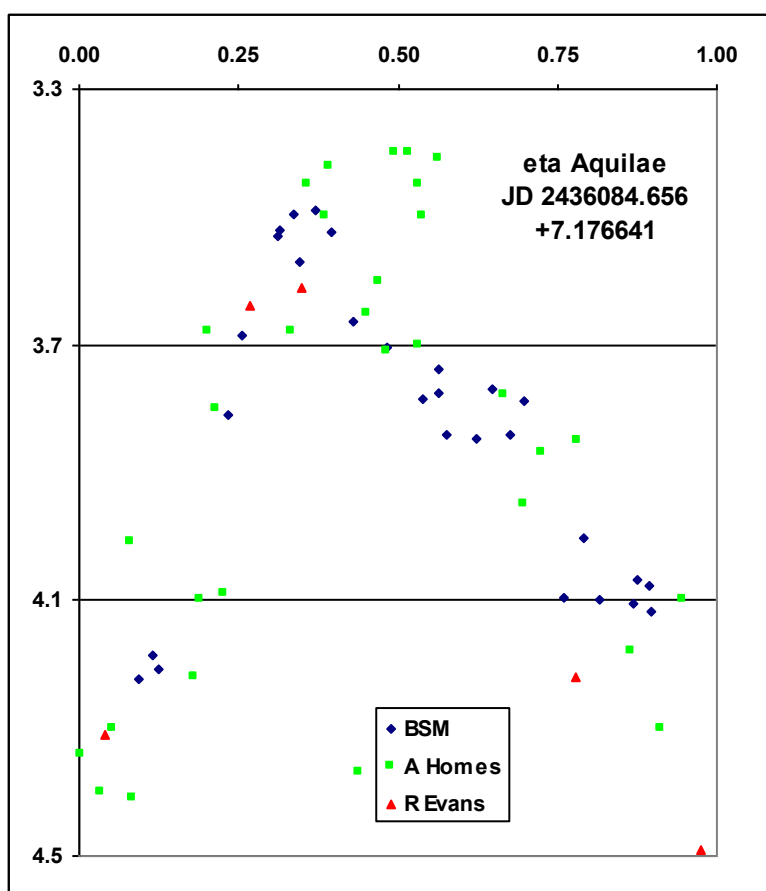
THE BRIGHT CEPHEID PROJECT

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Seems I've been concentrating on this to the exclusion of other projects but this one has the advantage that it is done with binoculars and the eye alone, so accurate transformations to the standard system aren't needed. We're now getting measures from Aline and John Homes, Glen Schrader and Bob Evans—but we'd like several more observers.

The accuracy of measures using the special charts is markedly better than previously—there are several reasons for this, which we'll discuss in more detail at Dunedin in a week or so. Glen Schrader has analysed measures of two stars, I Carinae and U Carinae, and has some encouraging numbers related to the quality of these measures. There are a few



problems, however, some of which can be attributed to bright stars in the field affecting the estimates of Cepheids such as R and S Muscae—and perhaps the over-enthusiasm of some observers getting out there whenever there's a tiny gap in the clouds.

Maybe this is related to our original concept of trying to obtain 50 or more measures of each programme star by each observer in a season. It now appears that 15-25 will be adequate.

One thing which seemed to be a concern was the setting up of the AAVSO Bright Star Monitor South. If this can measure these stars more effectively then why should we? Measures by the original BSM of eta Aquilae are

shown in the composite graph above. Here we can see that the visual measures are almost as good as the CCD V measures—and they're much easier to make. The International Database of the AAVSO publishes error estimates and from these it is easy to determine a standard deviation of 0.033 magnitudes for their dataset. Apart from a little flurry amongst the brighter visual measures they are almost of a similar standard.

One thing in favour of the visual measures is that the small CCD field—area is ~three square degrees—requires close comparison stars. Most of our targets do not afford that luxury. So if you want a simple project which you can do from the deck chair on the verandah then this one may be to your liking.

Equatorial Eclipsing Binaries Project

V1243 AQL - A REMARKABLE ALIGNMENT

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V1243 Aql is listed in the GCVS as EA - an eclipser with an Algol-like light curve - with a period of 0.703048 d. Its J2000 coordinates are 19h 29m 29.60s +05° 37' 13.0". At magnitude 13.3 with a 0.9 mag primary eclipse it is bright enough for CCD time series work with small telescopes.

We have now collected data as follows, covering August through April:

Phil Evans (Rarotonga)	20 nights
David O'Driscoll (Brisbane)	3 nights
Tom Richards (Melbourne)	1 night

In the November Newsletter (see <http://www.varstars.org/Newsletters.html>) I reported on my doubts about the official period. Our data now confirms that the period is twice the GCVS period: 1.4061(7) d; and epoch HJD 2455064.781255(79). Compare our phase plot in Figure 1 with the plot in the November Newsletter and you'll see a messy minimum is now neatly resolved into two minima of different depths. The earlier phase plot also showed no secondary minimum, which can only happen if the orbit is elliptical with the axis in our line of sight and the apoastron on the far side of the system. The new phasing in Figure 1 shows also that the orbit is almost certainly circular, since the secondary minimum lies at exactly phase 0.5.

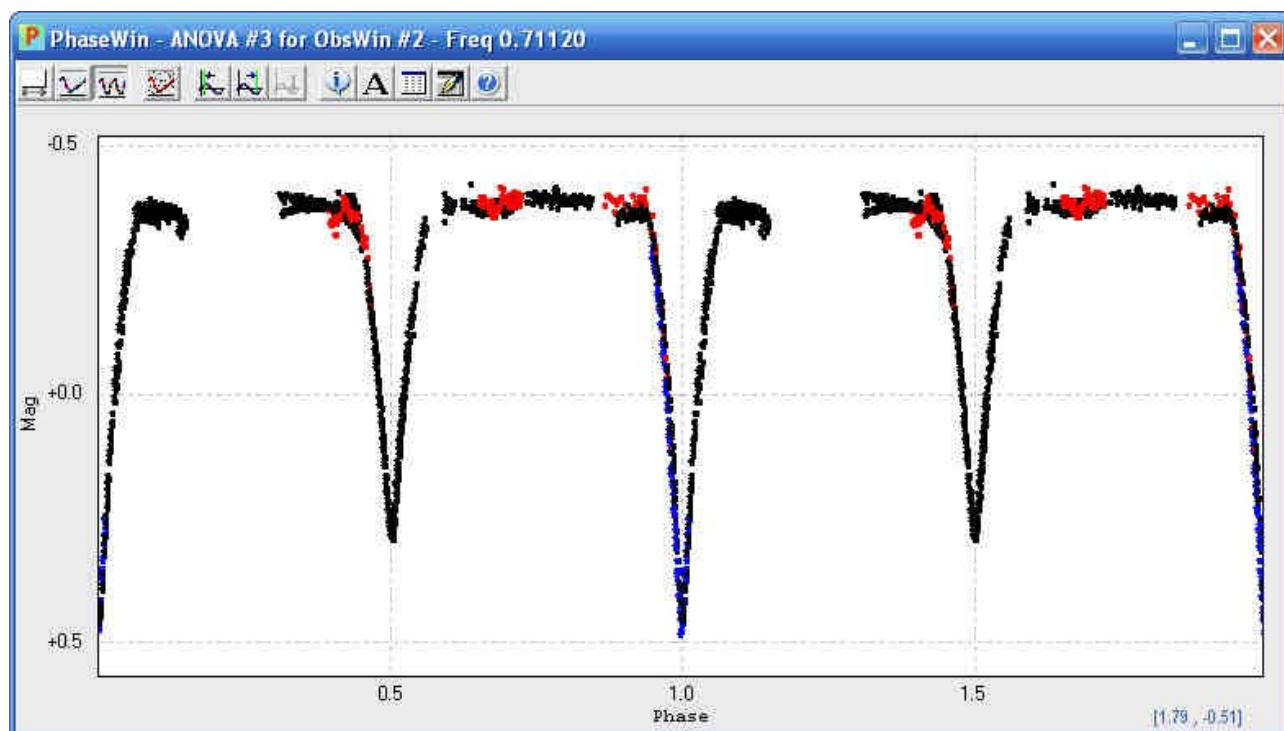


FIGURE 1 Light curve of V1243 Aql folded on a period of 1.4061 d. Data from Phil Evans (black), David O'Driscoll (red) and Tom Richards (blue). Vertical scale is magnitude difference from the comparison star, GSC1 0477:2970.

The light curve looks very much like that of two fully detached stars - but then so does Algol and it's semi-detached. The out-of-eclipse parts show a slight hump, though data there is poor. The hump could be due to the "reflection effect" - the wrongly-named phenomenon of a hotter star heating the nearside of the cooler star giving rise to a more luminous "hot-spot", which we see best as the cooler star swings behind the hotter one. None of this can be confirmed on present data.

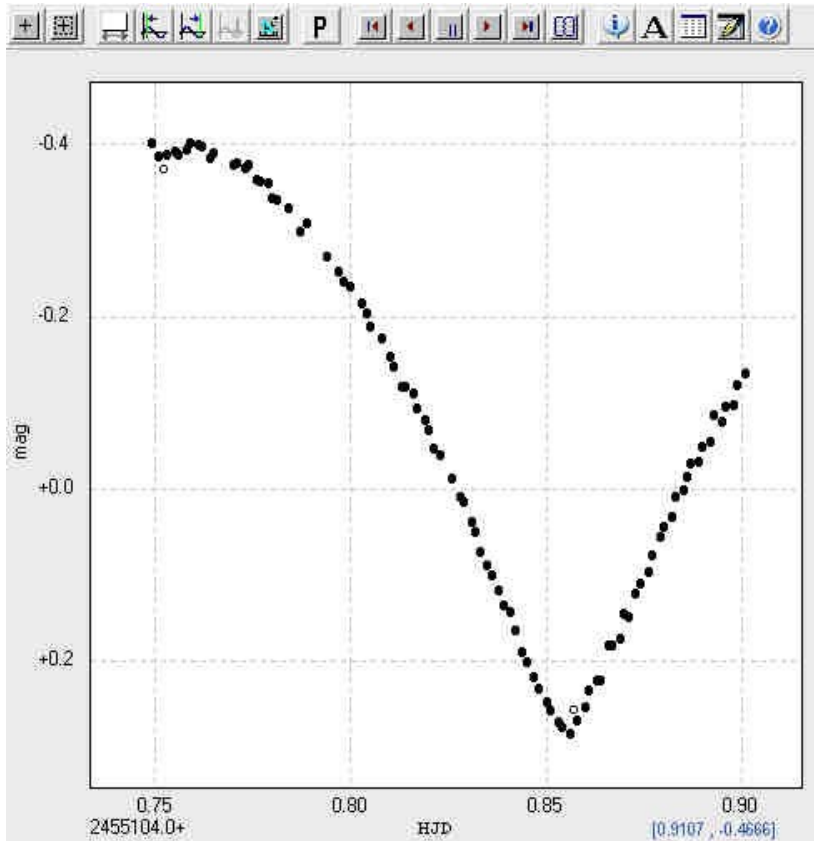


FIGURE 2

A secondary eclipse recorded by Phil Evans. The open circles were ignored in minima calculations.

Judging by the sharp-pointed minima, both eclipses are partial, as shown in Figure 2. The explanation for this lies in Figure 3, showing the positions of a pair of stars at their two partial mid-eclipses. Plainly, the maximum occulting of the rearward star happens at exactly mid-eclipse. With a total eclipse on the other hand, the totally eclipsed smaller rearward star takes some time to pass behind the front star, so

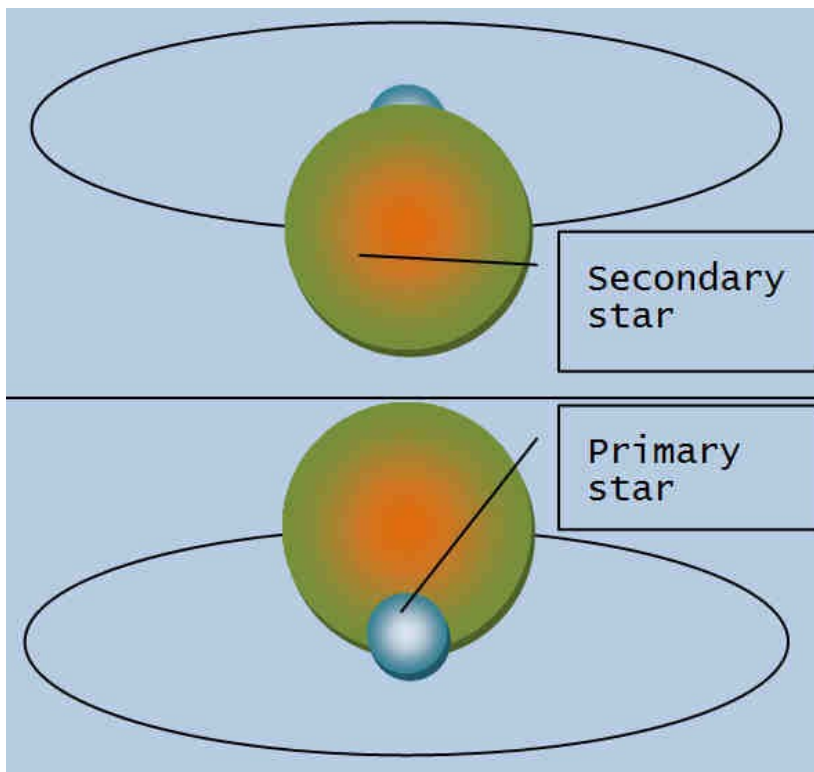


FIGURE 3

Partial eclipse configuration of two stars in circular orbits. The diagram shows the smaller star as more massive than the larger star, so nearer to the system's centre. Only the orbit of the secondary is shown. This is not a representation of V1243 Aql.

for that period the eclipse curve must be flat. Correspondingly, when the smaller star passes in front of the larger, once it is fully on the disk, there will be no change in light till it reaches the other side, so the annular eclipse is also flat-bottomed. (Sometimes there

can be a slight dish shape to the flat part indicating the limb of the rearward star is darker than the rest of it.) Finally, if the orbits are circular then our view is left-right and front-back symmetrical, so the system must present either two partial eclipses or a total plus an annular.

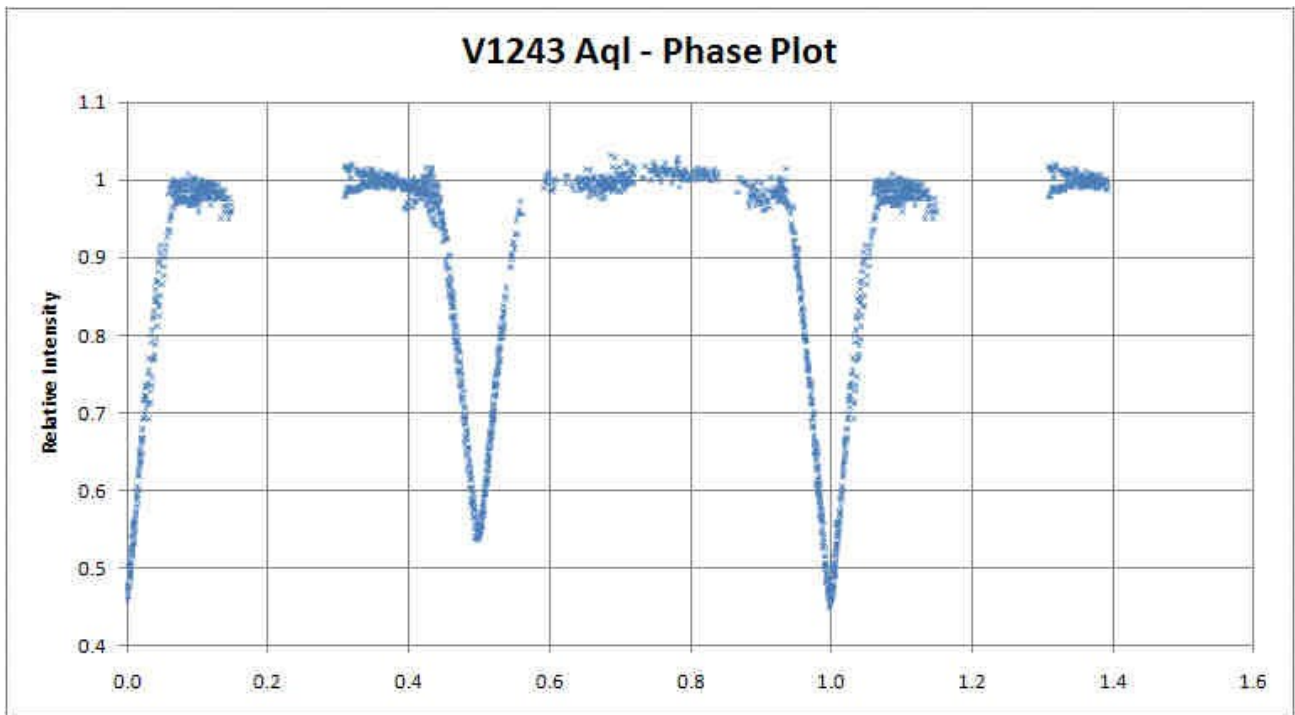


FIGURE 4 Phase plot of V1243 Aql folded on 1.4061 d. The vertical axis is relative brightness, with out-of eclipse brightness set to 1.0.

What's remarkable about the new phase plot is the depths of those two eclipses. How much light is lost in each eclipse? This is better seen in the plot of flux (aka brightness or intensity) in Figure 4. That's an arithmetic scale with a real zero unlike the magnitude scale. Careful measurements of the two minima show:

	Minimum Relative Depth	Relative Brightness
Primary	0.54	0.46
Secondary	0.46	0.54

In other words, the depth of one eclipse is the brightness of the other. Now out of eclipse, the fluxes of the two stars sum to 1.00:

$$f(A) + f(B) = 1.00$$

Also the data shows that at the two minima

$$f(\text{min-I}) + f(\text{min-II}) = 1.00$$

In each minimum we get all the flux of one star plus a bit of the flux of the other:

$$\text{flux}(\text{Min-I}) = f(A) + k(f(B))$$

$$\text{flux}(\text{Min-I+}) = f(B) + k'(f(A))$$

where k and k' are the fractions of the two rearward stars showing.

Hence $k = k' = 0$

That is to say, both the eclipses are total! That can only happen if

- (a) the stars are same size, and
- (b) the orbital inclination is 90d (line-of-sight).

Another consequence is that totality must be momentary, which explains why there are no flat bottoms to the minima, as is characteristic of totality.

This is a rare phenomenon, needless to say, and needs to be checked carefully. Now that V1243 Aql is well placed for a few months (at my latitude it rises on 15th May at 10:30 pm) we can resume intensive observation.

What we need this season is transformed colour data. Last season most data was unfiltered (RE) or untransformed R_c (DO and TR). All members with CCDs and Johnson-Cousins filters are invited to take part! You will need to know the transformation coefficients for your instrumentation. In particular we want:

1/ All-sky photometry to get B , V and R magnitudes for field stars. GSC1 0477:2970, 0473:0637 and :0028 are possibly the best candidates; but initially we need photometry on all field stars of about that magnitude, then we can choose which to use and how. See Figure 5.

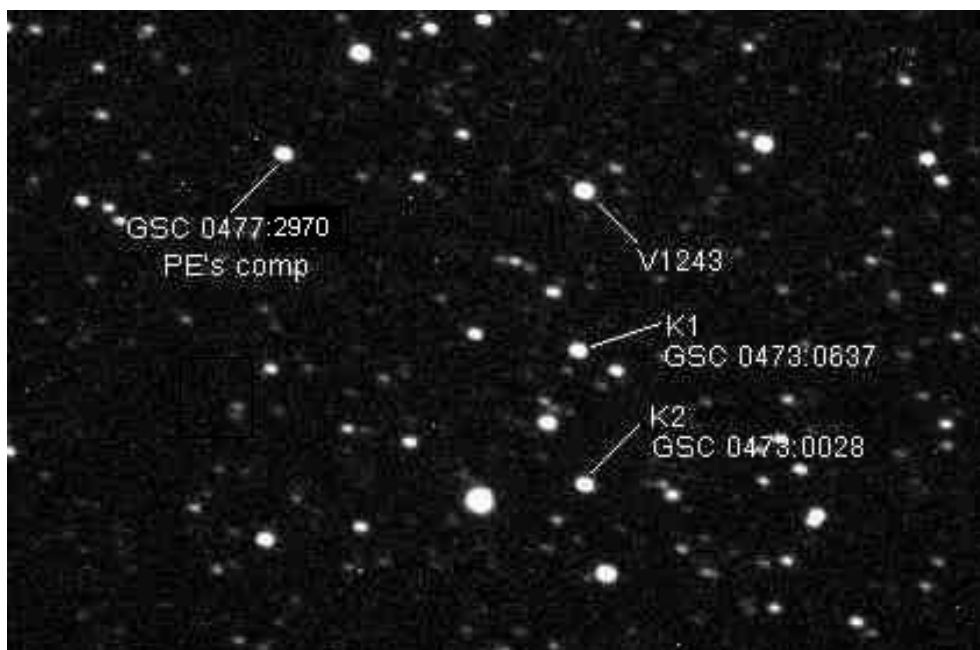


FIGURE 5

Field of V1243 Aql, showing the comparison star C and check stars K1 K2 we have used so far.

2/ Careful B and V (or V and R) photometry of all phases. Ensure your computer's clock is accurately set. Pay special attention to shoulders and minima,

where changes are fastest. Obtain as long a run as you can on each night. A run containing a shoulder and a minimum is more valuable than either by itself. Times of minima will be published on the website, or use Bob Nelson's EBmin program to see what's happening on any night (download from <http://members.shaw.ca/bob.nelson/software1.htm>, but update the data entry for the star with the period and epoch above).

With that data we will try to determine:

- (a) the exact depths of the two minima,
- (b) the colour of each star individually from the colour data at the two minima,
- (c) the exact shape of eclipses and the important out-of-eclipse phases.

Please email all data to me. Preferred format is CSV or tab-separated text with columns for HJD (or JD if you must), magnitude (or mag difference from the comp star), mag error if obtainable, and airmass if obtainable. In the covering email please state if the data are transformed, the comp you used and what magnitude if any it was set to. If you have any questions about any of this, please email me.

Go to it!

MORE ABOUT ARTICLES

Thanks for the extra contributions this quarter. They will arouse a lot of interest and it's good to see what people are doing. Apart from this, I've looked more carefully into what form the material should be in and some thoughts appear below.

The compatibility problems mainly arise with tables. For simple tables tabs and spaces produce good results and are easy to modify if necessary. If you want to use a Word table format then produce this as a separate document then convert it into an image file of some type—jpg or gif are easy. Don't put the table description in this.

For pictures and graphs do the same but ensure that there are no links to their origin remaining or embedded. These internal links can cause them to be less clear. Unfortunately there are several in this NL which I can't remove and don't have time before the deadline to contact people. These are not the hyperlinks in the text which are no problem.

I can easily use versions of Word up to 2000 but Word 2007, even when saved as Word 2003, is more difficult. It has a lot of hidden formatting which I have to remove.

So keep the text unformatted but indicate where you would like graphs and tables placed, e.g.

Table 1

Figure 2

Captions should be placed at the end of the text, '**Figure 1: This shows**' or '**Table 1 This**' Try to follow these guidelines but we'd sooner you submitted it in any form than not at all—we do want to hear what you're doing! Thanks.

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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, although if you wish a particular layout send a formatted version as well and we'll ensure that this is followed. Publication dates are February, May, August and November—the twentieth of each of these months and the copy deadline is the first of each of these months.