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Variable Star Section Circular

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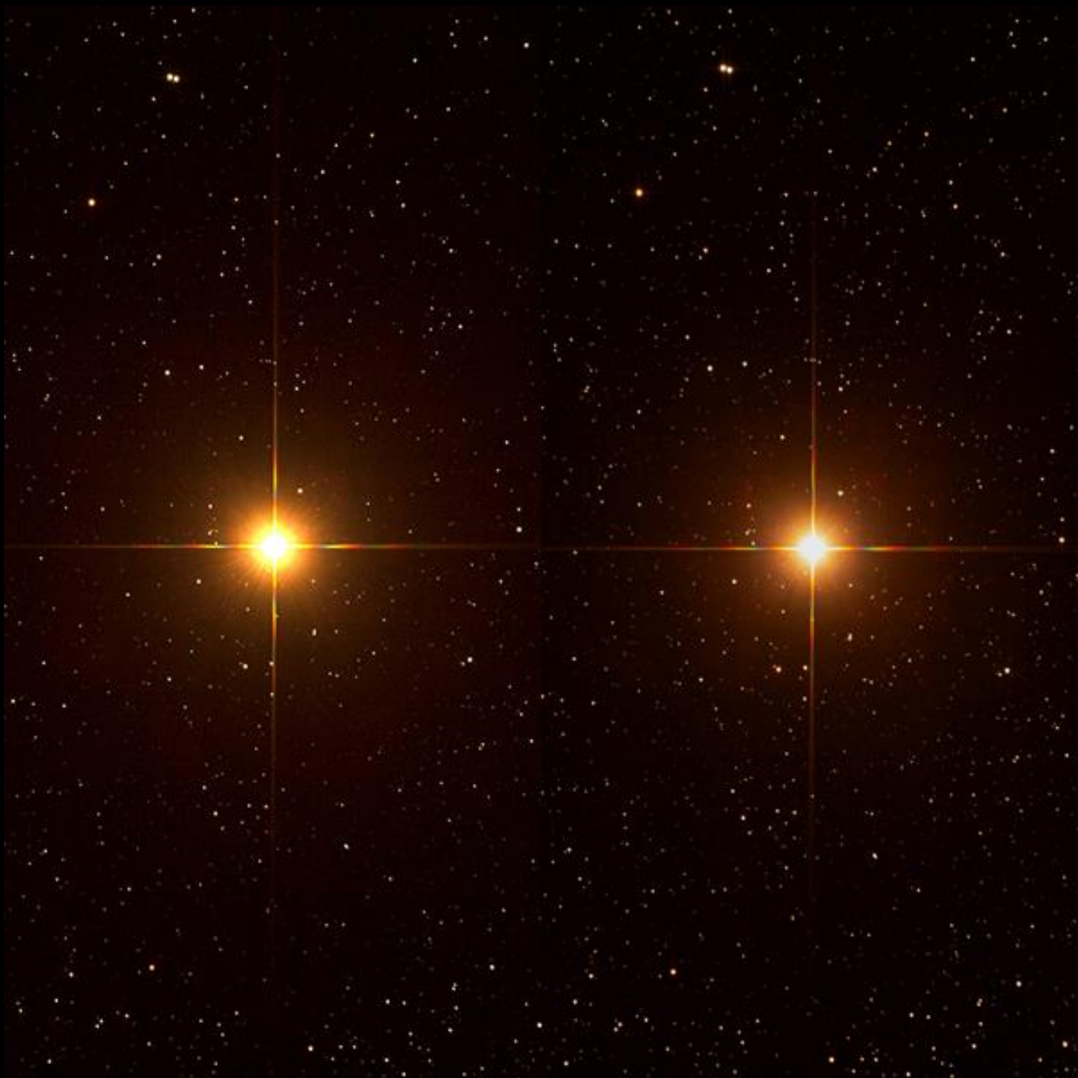

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Cover Picture

Variation in brightness of Betelgeuse
. *Left*: February 2016 and *Right*: December 2019
Canon 5DmkIII (IR modified), 250mm f5 reflector with Baader flattener
Taken remotely from Animas, New Mexico
© Brian Ottum, Michigan USA

From the Director *Jeremy Shears*

Section Meeting, May 9

Our VSS meeting, on **Saturday May 9 in Northampton**, is coming around quickly. Further details are provided elsewhere in this Circular. Prof. Boris Gänsicke (University of Warwick) has kindly agreed to give the keynote talk and the rest of the day will focus on contributions to variable star astronomy by section members, covering some of the projects they are working on.

SPRING MIRAS

M = Max, m = min.

R And	m=May
W And	M=Apr/May
RW And	M=May
UV Aur	m=Apr/May
X Cam	m=Apr
SU Cnc	M=Feb/Mar
RT CVn	m=Mar
T Cas	m=Apr
o Cet	m=May/Jun
R Com	m=Mar
S CrB	m=Mar/Apr
V CrB	m=Apr/May
W CrB	m=Feb/Mar
R Cyg	m=May/Jun
S Cyg	M=May
T Dra	m=May/Jun
RU Her	M=May
SS Her	M=Feb/Mar
	m=Apr
R Hya	m=Apr/May
SU Lac	m=Feb/Mar
RS Leo	M=Mar
W Lyn	m=May/Jun
X Lyn	M=Mar/Apr
X Oph	m=May/Jun
U Ori	M=Apr/May
R Ser	M=May/Jun
T UMa	M=Mar/Apr

Source BAA Handbook

It promises to be a great day out. Even better: there is no entry fee and a light lunch & refreshments will be provided! As well as listening to the talks and getting ideas for observing programmes, it's a great opportunity to meet up with fellow variable star enthusiasts. Not yet a variable star observer? Then come along anyway to find out what section members get up to! You will be most welcome.

I do hope to see many of you in Northampton.

Two variable stars in the news

It's not often that variable stars make the mainstream news, let alone the popular press! But the fading of **Betelgeuse** has certainly featured strongly in the last few months, even making it to the main BBC 10 o'clock news and the *Today* programme on BBC Radio 4. Much of the coverage focused on whether it was about to go supernova: some of it was a little sensationalist, but at least the BBC coverage was balanced. We were certainly lucky that the dimming coincided with Orion being well-placed for observation and it was a stimulus for people who are not normally interested in astronomy to go outside and look at Orion for themselves. Getting the public to look up at the night sky is always a good thing.

According to a recent paper by Prof. Constantino Sigismondi (ICRA/Sapienza), his analyses of its light curve variously predict minimum sometime between Jan 22 and Feb 1. Time will tell whether reality bears this out. At the time of writing, the fade appears to have stopped and the star is brightening again.

A widefield chart for making estimates of Betelgeuse has been prepared by John Toone and is available from the Charts section of the VSS website, and at the back of this Circular, and look out for Mark Kidger's article on page 10.

Another variable star to gain press coverage recently (at least in the scientific press like New Scientist, but with some spill-over into the broadsheets) is **V Sge**. This followed an announcement by

Prof. Bradley Schaefer from Louisiana State University and his colleagues at the 235th meeting of the American Astronomical Society in Honolulu in early January. The team had examined images and photometry of V Sge from 1890 to the present which led them to conclude that the binary system has been getting brighter. It's now 2.5 mag brighter than in 1890. They suggest that the two stars in the binary system could merge spectacularly, resulting in a nova in 2083 (plus or minus 11 years). Put the date in your diaries now!

Brad's announcement prompted David Boyd to contact him to let him know that he had a series of eclipse timings for V Sge which he had measured between 2012 to 2018. David's email found Brad hard at work deep inside the Harvard plate stack where he was looking for pre-1930 eclipse times for V Sge. It turns out that David's eclipse timings neatly fill a gap between older published data and recent results from TESS. This is another excellent example which shows how valuable our observations can become at a future date, even though it may not always be apparent at the time we are making them!

VSS campaigns on U Leo and HR Lyr

The 2019 December BAA *Journal* and the Variable Star Section Circular 182 contains an article about the curious variable star, **U Leo**. Although U Leo has been linked to a possible nova in 1885, this is by no means certain and its identity remains something of a mystery.

The VSS has launched a CCD photometry campaign on U Leo during the current observing season with the aim of shedding light on this enigmatic star.

I have recently been alerted by Boris Gänsicke that he hopes to obtain some spectroscopy on U Leo during February 2020 using the Isaac Newton Telescope. This might allow measurement of the radial velocity of the F-type star in the system. It would therefore be helpful to obtain ground-based photometry in support of his observing run from now onwards (not limited to Boris's INT run, which might have been completed by the time you read this)

Given this star is rather faint, at mag 17.3, it is a target for CCD observers. It will require long and unfiltered exposures to get a reasonable signal-to-noise ratio. Richard Sabo reports a ~0.1 amplitude sinusoidal variation consistent with the 3.2 h period measured by Boris from CRTS data. Many thanks to others who have been observing U Leo during the campaign so far: Ken Menzies, Richard Sabo, Roger Pickard, Ian Miller, Paul Leyland, Dave Smith, Sjoerd Dufoer, Michael Linnolt, Carlo Gualdoni and myself. Others are of course most welcome to join in as Leo will be with us for a while longer this season.

An update on the VSS **HR Lyr** campaign which took place during the 2019/20 observing season is provided elsewhere in this Circular. Although the campaign is officially over, I hope observers will keep this star on their observing list.

LISA Spectroscope available for loan and VSS mentors in spectroscopy

In the December VSSC, number 182, I announced that there is a LISA spectroscope available for loan. Thus far, I have not received any applications to borrow it, so it is still available. If you are interested, have a look at the loan guidelines in the December VSSC and get in touch with me. Surely somebody would like the opportunity of trying out spectroscopy?

The VSS offers mentorship to members who are starting out in visual, DSLR or CCD observations of variable stars, as well as in data analysis. We are extending this mentorship scheme to spectroscopy. Andy Wilson, Robin Leadbeater and David Boyd have kindly offered to be mentors. Further details about spectroscopy mentoring are provided in Andy's article later in this Circular. If you'd like a mentor, do get in touch with me. Also, if you'd like to become a mentor yourself, in spectroscopy or one of the other areas, please do let me know.

SU Tau

We are aiming to raise the profile of variable star astronomy and the VSS in the *Journal* by placing an article on a VS theme in each edition, or at least as many as possible, in the hope that it will encourage others to take an interest in the Section's work. I do hope you enjoyed Gary Poyner's article on the joys of observing the RCB variable **SU Tau** in the February *Journal*. There is still time to observe SU Tau before the field disappears into the twilight towards the end of April.

Leavitt's Standard Candles

Roger Pickard drew attention to Emma Foxell's (University of Warwick) article on Henrietta Swan Leavitt's 'Period Luminosity Relation' derived from the light curves of Cepheids: https://astrobites.org/2019/03/08/leavitt-variable-stars/

This appears on the Astrobites website (https://astrobites.org/); Astrobites is a daily astrophysical written by graduate students in astronomy from around the world. Do have a look.

Winchester Weekend

If anyone has material to display on the Section display boards at the Winchester weekend, e.g. project updates, light curves etc., please bring it along. If you are not attending, but still have any relevant display material, please send to the Director.

Chart News

John Toone

The following new charts are now posted to the VSS web site and are available in paper form from the Chart Secretary.

300.02 U Leo
The 20-minute field chart replaces chart 300.01. The chart has a few cosmetic improvements and the sequence is unchanged. A copy of the chart appears on page 49.

164.02 HR Lyr
New 1 degree and 10-minute field charts have been drawn that replace chart 164.01. The sequence has been overhauled and is derived from Tycho 2 Vj, APASS, SRO & Pickard. The 10-minute field chart was reproduced in VSS Circular 180 (June 2019).

375.01 alpha Ori
No previous BAA VSS chart existed for this famous naked eye red variable star. An 80-degree chart has been drawn which includes a sequence from Hipparcos Vj. This chart can also be found at the end of this Circular on page 48.

Photoelectric Photometry and a new Zooniverse project

Roger Pickard

Many years ago (actually, in the 1980's, 90's and early 2000's) and before the commencement of CCD photometry, a number of us undertook the exciting new venture of photoelectric photometry (PEP). Whilst this is, to all intents and purposes, done and dusted now, we thought this old data should not just be forgotten, but instead entered into a new BAA DATABASE.

To this end, a new Dropbox folder has been opened online at:-https://www.dropbox.com/home/PEP and you are invited to browse it and to add your own files.

In addition, rather than having files in different formats, we though it advisable to have just one format, but this will require somebody going through all the data and amending it where necessary, possibly by writing an Excel file that will accept all such data! Might we have such a volunteer please?

Anyone interested should contact me at the e-mail address on the back page.

John Fairweather brings to my attention a new Zooniverse project called 'Star Notes', which may interest readers of this Circular…

> We are happy to announce a new Zooniverse project: Star Notes
>
> The Harvard Computers were a group of women who worked at the Harvard Observatory from the late 1800s to early 1900s. This group included Annie Jump Cannon, Williamina Fleming, Henrietta Swan Leavitt, and many others. Our goal is to ensure that these notebooks, created by a remarkable group of people, are as accessible and useful as possible.
>
> The goal of Star Notes is to link these notebooks back to their original source material: 500,000 glass plate photographs representing the first ever picture of the visible universe. Each glass plate is identified with a unique plate number. We need you to find and transcribe these handwritten plate numbers in the pages of the notebooks!
>
> This project is part of Project PHaEDRA at the John G. Wolbach Library at the Harvard-Smithsonian Center for Astrophysics. The goal of Project PHaEDRA is to catalogue, digitize, and transcribe over 2500 logbooks and notebooks created by the Harvard Computers and other early astronomers.
>
> Get involved today: https://www.zooniverse.org/projects/projectphaedra/star-notes
>
> And be sure to check out 100+ other active Zooniverse projects over at: https://www.zooniverse.org/projects.
>
> Cliff & the Zooniverse Team

BAA Spectroscopy Mentoring Scheme

Andrew Wilson

The VSS and E&T Sections have decided to offer a Spectroscopy Mentoring Scheme to help members learn the processing techniques needed to create compliant spectra for the BAA Spectroscopy Database.

The BAA Spectroscopy Database contains nearly 6,000 spectra, with more being added each month and the number of active observers steadily rising. The aim of the database is to act as a repository of a wide range of spectra that can be of scientific value to researchers. In most circumstances' spectra are expected to be dark frame and flat field corrected, wavelength calibrated, instrument and atmospheric response corrected, and to conform with the BeSS standard. It can be a steep learning curve getting to grips with the software and techniques needed to apply these calibrations. So, the Variable Star Section and the Equipment and Techniques Section have decided to offer a Spectroscopy Mentoring Scheme. This is intended for members who need a bit of help in learning how to produce compliant spectra for the database.

As well as the mentoring scheme, there are already a variety of spectroscopy resources available on the BAA website that will help those new to spectroscopy. The E&T Section pages include this summary of links to many of these resources.

https://britastro.org/node/19378

Posting to the BAA spectroscopy forum is another useful place to seek advice and share results for feedback. This has the advantage that the discussions are public and often help a wider group of people.

https://britastro.org/forum/143

We have three experienced members who have already offered their services as mentors, and we are interested to hear from other experienced members who would be willing to become mentors. There is no expectation of a major time commitment, rather observers who are able to offer advice via email to those new to the subject to help them understand how to process spectra for submission to the BAA database. Given the range of spectrographs and different software packages in use today, a pool of mentors with a variety of experience would be very useful in both covering this variety and ensuring the mentoring does not always fall on the same individuals.

If you would like the help of a mentor or are interested in becoming a mentor, then please email me, Andy Wilson, at specdbm@britastro.org.

Pulsating Star Programme

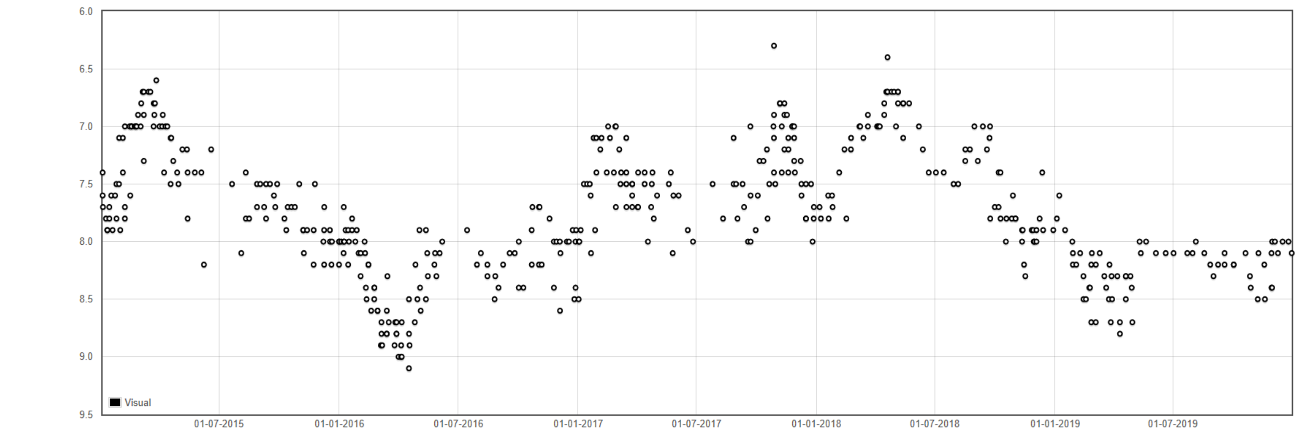
Shaun Albrighton

BAAVSS observations of four semi-regular stars – Y Lyn, V UMi, RS CrB and RS Cnc – are discussed, along with their light curves.

Y Lyn

VSX lists Y Lyn as type SRc, spectral type M6Sib-II, with a range of 6.58-8.25. A period of 110d is listed whilst a note refers to Sebastian Otero giving an additional period of 1400d. The GCVS gives type SRb. Observations during the past five years reveal a maximum range of approx. 6.7-9.0, slightly larger than quoted. Both a shorter and longer period are clearly visible, although the secondary, longer period appears to be around 700d, half that quoted in VSX.

Light Curve for Y LYN



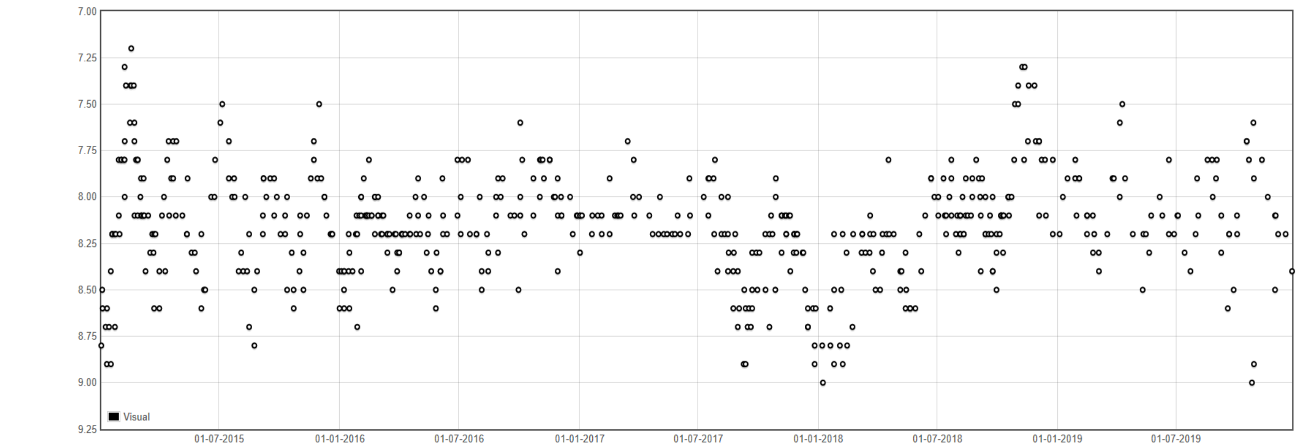
Symbol Key: **Crosses** = Negative observation, **Triangle** = Brighter than, Otherwise: **Circle** = Visual, **Diamond** = CCD, **Square** = Everything else

Contributors: S W Albrighton, M Barrett, R B I Fraser, T L Heywood, T Markham, R Pearce, J D Shanklin, J Toone, T Vale

V UMi

V UMi is one of my favourite variables, not only does it show a good range, approx. 7.4-8.8, but it is circumpolar from British latitudes. VSX lists the star as SRb M4-M7IIIab, range 7.06-8.7, 73 d.

Light Curve for V UMI



Symbol Key: **Crosses** = Negative observation, **Triangle** = Brighter than, Otherwise: **Circle** = Visual, **Diamond** = CCD, **Square** = Everything else

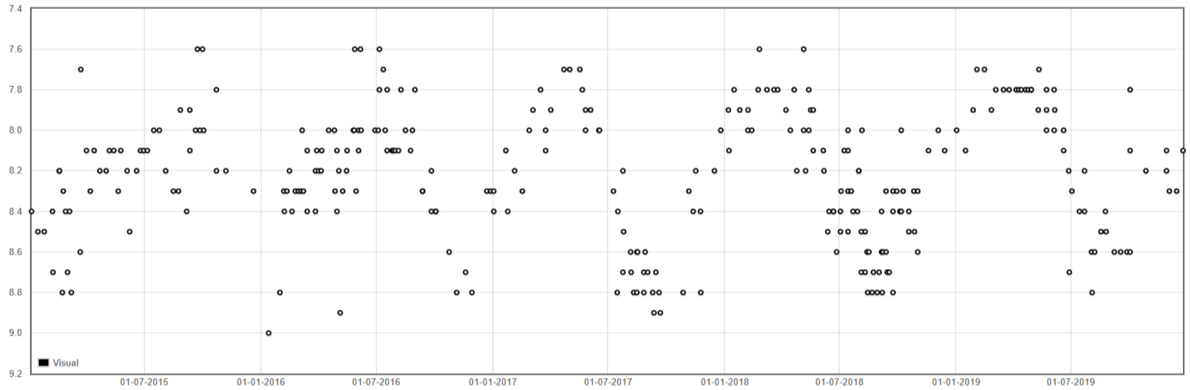
Contributors: S W Albrighton, M Barrett, D Gavine, T L Heywood, T Markham, R Pearce, M D Taylor, J Toone, J Whinfrey, N White

Sebastian Otero lists other periods of 126d and 737d. GCVS notes that the mean brightness varies with P2=760d. Observations clearly show the shorter period and hint at a longer period as well.

RS CrB

RS CrB is one of the newer stars added to the program, being added to the chart for RR and SW CrB. Whilst SW CrB has now been dropped from the program, RS CrB has proved itself a worthwhile addition. [VSX] lists the star as type SRa, M7, 8.7-11.6p, 332.2d. GCVS P2=69.5d. Our recent visual results yield a range of 7.6 to 8.9 and confirm the period of around 330d. Further research is needed to investigate the possible shorter period.

Light Curve for RS CRB



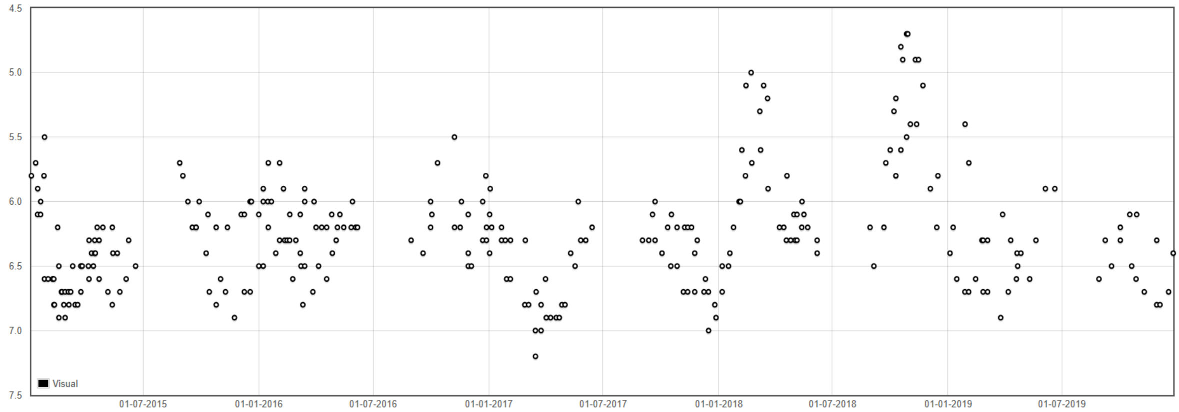
Symbol Key: **Crosses** = Negative observation, **Triangle** = Brighter than, Otherwise: **Circle** = Visual, **Diamond** = CCD, **Square** = Everything else

Contributors: S W Albrighton, R B I Fraser, T L Heywood, T Markham, R Pearce, J Toone

RS Cnc

For our final star we look at RS Cnc. This star is listed as type SRb, M6S, 5.33-6.94, P=242.2d. Sebastian Otero gives a period of 134.6d, whilst GCVS quotes P2=1700d. Our recent results appear to confirm a period of around 240d, whilst a much longer time frame is needed to investigate the potential longer secondary period.

Light Curve for RS CNC



Symbol Key: **Crosses** = Negative observation, **Triangle** = Brighter than, Otherwise: **Circle** = Visual, **Diamond** = CCD, **Square** = Everything else

Contributors: M Barrett, D Gavine, T L Heywood, T Markham, R Pearce, M D Taylor, J Toone

Supernova Betelgeuse?

Mark Kidger

The recent fade of Betelgeuse has created a great deal of interest that has extended even to the mainstream news media. There has been a great deal of information, and disinformation, about the star. While it is not completely impossible that Betelgeuse will become a supernova in the next few years or decades, what we know about the star makes it unlikely. A large part of the uncertainty comes from the fact that neither the mass, nor the distance are well-established. It is not even certain that Betelgeuse will become a core-collapse supernova. This article examines some of the facts, as known and looks at the uncertainties.

If you are a variable star observer, you would have to have turned into a hermit not to have heard that something is happening to Betelgeuse. This has got the Internet bubbling with excitement at the news of this “unprecedented event”, suggesting that Betelgeuse may be about to explode [*Note from the author: it is not an “unprecedented” event, at least, not yet, but we will come to that bit later*]. For the first time that I can recall, newspapers like the New York Times are covering news of a variable star. I have even had colleagues asking excitedly over lunch: “have you heard the news about Betelgeuse?”

So, just why is this fade of Betelgeuse causing so much excitement and is there any real story behind it? Of course, it is mainly due to the fact that Betelgeuse is no ordinary star. It is very massive, very large and very unstable. However, there is a lot of uncertainty about how large and how massive Betelgeuse is because its distance is quite uncertain and even more uncertainty about when its end-of-life crisis will arrive. Different sources quote quite different values. There are a lot of details that have not made it into the news that we should bear in mind.

Figure 1. Herschel Science Archive

The variations in brightness come, of course, because Betelgeuse is pulsating erratically, shedding mass as it does, trying to attain a stability that it can never achieve. Strangely, when its diameter is largest, it is faintest. The reason for this is that, when it is smallest, its surface is hottest and thus emits most visible light. When Betelgeuse expands, its surface gets cooler and emits less visible light. Each time that it expands, it loses a little of its outer layer, which gets puffed out into interstellar space. This is the standard process of mass loss that has resulted in seeding the interstellar medium with the heavy elements that form the vast bulk of our planet and a goodly part of our own bodies: truly, we are stardust and owe our existence to the noble sacrifice of stars such as Betelgeuse. Due to this mass-loss process, over its lifetime Betelgeuse has become surrounded by a huge shell of expanding gas and dust – its shed outer layers – that was observed in the infrared by Herschel (Figure 1.).

One of the most critical elements in the case of Betelgeuse is, how far away is the star?

For many years, a value of 520 light years was given for the distance. It is the value quoted in my childhood “bible”: The Observer’s Book of Astronomy. The inconvenience is that this puts Betelgeuse just slightly out of range of the traditional method of calculating stellar distances by measuring the parallax from the surface of the Earth.

It is true that, in the 1990s, ESA’s Hipparcos mission measured the parallax of Betelgeuse from space, giving a rather smaller distance of 430 light years. Hipparcos was a game-changer in stellar dynamics although its data is and was not without its issues. The 430 light year distance to Betelgeuse with an error of around 20%, meaning that there was a one-in-three chance that the true distance was not even in the range between 350 and 510 light years. This, in turn, leads to an uncertainty of a factor of more than two in the calculated luminosity of the star, which causes uncertainty in its estimated mass, which causes uncertainty in its future evolution… and so on. A later re-working of the Hipparcos data gave a best value of 520 light years, with a likely range from 450-590.

Other attempts have been made to measure the parallax and thus the distance of Betelgeuse with big radio observatories. One such attempt was made with the Very Large Array (VLA), giving a best estimate of the distance of 640 light years and a likely range from 500-790 light years. While another, combining the telescopes of ALMA in the Atacama Desert of Chile with the e-Merlin array of telescopes in the United Kingdom, gives a best estimate of the distance of 720 light years and a likely range from 570-830 light years.

In other words, modern techniques of observation can tell us no more than the fact that Betelgeuse is probably at a distance somewhere between 450 and 830 light years.

Of course, Hipparcos has now been replaced by Gaia, which will soon release its DR3 catalogue, leading to keen anticipation that it will resolve the issue of the distance to Betelgeuse once and for all. Unfortunately, Gaia was designed to measure stars down to magnitude 20, not naked-eye visible stars, which are massively saturated on its detectors. Quite some effort has been expended by the Gaia team to find ways of measuring bright, saturated stars but, these techniques are only valid up to magnitude +3. Even at the faintest magnitude that it has ever been observed, Betelgeuse would be far too bright to measure with Gaia.

It is true that Betelgeuse *has* been observed with Gaia, but in a special observing mode that requires non-standard data processing. This data requires several months of dedicated attention to make it publishable.

The next, and obvious question is, just why are we so anxious to know the distance to Betelgeuse?

Of course, the reason is a fairly simple one. If we know the distance to Betelgeuse, we can calculate exactly how luminous it is and that gives us a much better idea of how massive the star is. We know that Betelgeuse is a supergiant star in both senses of the word: it is both much larger and much more massive than the Sun, but how large and how massive are quite uncertain.

Betelgeuse is one of the few stars that can (just about) be resolved by telescopes on Earth as a tiny disk. Of all the stars in the sky, there is just one (excluding the Sun), R Doradus, which has a (slightly) larger apparent diameter, as seen from Earth, although it is closer and, in real terms, smaller. Not only can we see the star as a disk and not just as a point of light, but we can even see some detail on that disk (Figure 2.). In particular, the technique of speckle interferometry has been used for this. If you take high speed imaging of a star like Betelgeuse with a large telescope, it breaks up into a myriad of individuals speckles, each of which is a perfect, diffraction-limited image (assuming the telescope optics are perfect). The speckle image left shows a bright spot, interpreted as a plume of hot gas; other speckle images seem to show giant convection cells in the photosphere.

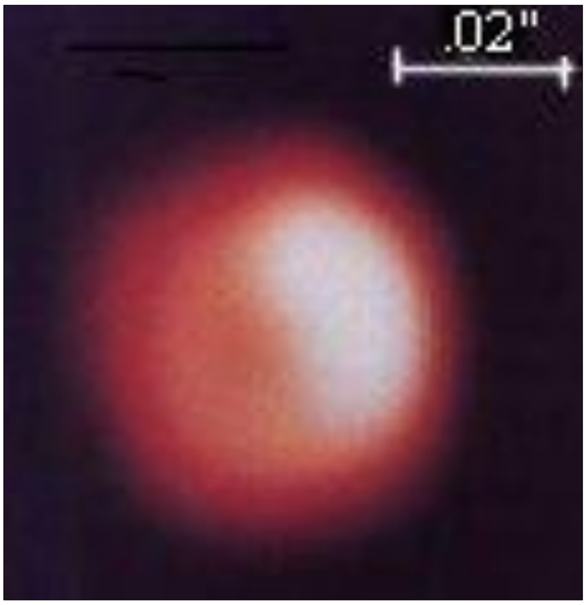


Figure 2. David Busher and the WHT.

Now, instruments such as SPHERE on the VLT are capable of obtaining diffraction-limited, resolved images such as that shown in figure 3, as the star dimmed down well below magnitude 1. This image is among the first observations to come out of an observing campaign led by Miguel Montarges at Leuven Catholic University (KU Leuven) aimed at understanding why the star is becoming fainter. Image: ESO, VLT, Miguel Montarges.

Figure 3. Betelgeuse taken with SPHERE in late 2019

Betelgeuse has a diameter about nine hundred times larger than our Sun. If we take the published diameter of 0".052 (there are both higher and lower figures, too) and a distance of 600 light years, the diameter comes out at 9.6AU. At the higher end of the distance estimates, if Betelgeuse were placed in the centre of the Solar System, even Jupiter would be inside its photosphere.

What about the mass of Betelgeuse? Recent estimates of the mass of Betelgeuse range from about nine times the mass of the Sun to just over twenty times, but older estimates give a much wider range from five to thirty Solar Masses. This is very exciting because it means that Betelgeuse is one of the most massive stars in the Galaxy and puts it in the mass range in which stellar death becomes a spectacular affair. It is unlikely to suffer a quiet death as a white dwarf star, as the companion of Sirius did. In the case of Betelgeuse, our best guess is that it is sufficiently massive for the core to collapse and to produce a standard supernova explosion.

However, because there is a really quite wide range of estimates of mass for the star, things are not quite as clear as has been suggested. To give an example of the problem that we face, we can contrast two modern estimates of the mass, one from fits to theoretical stellar evolution, the other from observing line profiles. The former gives a mass of 20 solar masses, the latter, a range from 7.7-16.6, with a most likely value of 11.6 solar masses.

- If Betelgeuse is at the upper limit of the mass that is estimated, it could even generate a black hole, although this seems unlikely.
- If the mass of Betelgeuse is at the lowest end of the currently estimated range of mass, it would not even be massive enough to become a fully-fledged, “core collapse supernova”, although still massive enough to produce a lower-intensity supernova.
- Given that the current best estimate is its mass is only just over ten times that of the Sun, we believe that Betelgeuse will be towards the lower end of the supernova scale[1], but a much larger event cannot be ruled out.

The eventual fate of a star in the 7-10 Solar Mass range varies critically on its exact mass. Here are the potential scenarios, according to the mass of a star:

Mass	Fate
≤7 solar masses	White dwarf. No supernova.
7-9 solar masses	Neutron star. Electron capture (low luminosity) supernova.
9-10.4 solar masses	Neutron star. Silicon flash/silicon deflagration supernova.
>10.4 solar masses	Neutron star. Normal Type II core-collapse supernova.

We can see that Betelgeuse is likely to be around the mass at which the fate of the star can change quite substantially for just a small change in mass. What will happen to Betelgeuse if it is only 8 Solar Masses will be significantly different to what will happen if it is 11 Solar Masses.

The next stage of the evolution of Betelgeuse is linked to what is going on in the heart of the star. Right now, the interior of Betelgeuse contains a series of shells, rather like a very thick onion. As we dive beneath the photosphere to the heart of the star, we find first a very tenuous outer layer of hydrogen and, far below it, a layer in which the temperature (around 15 million degrees Centigrade) and pressure (the gas is compressed until it is 5 times as dense as water) are great enough for hydrogen to be combined to form helium. Hotter and deeper still, we find another layer in which helium is being combined into carbon.

Probably, Betelgeuse has gone no further than this so far, although we can only argue it statistically for reasons that will become obvious a little further on.

At some time, though, in the future, Betelgeuse will suffer the fate of all the most massive stars and develop, if only briefly, a full, seven-layer onion structure.

When this happens, as we continue down, each layer will be even hotter and denser than the previous one. After the carbon layer, a layer will form in which carbon combines to form neon at 600 million degrees temperature and four million times the density of water. Then, inside that, there will be one where neon combines to form oxygen and, next, a shell in which oxygen combines to form silicon at 1.5 billion degrees. Finally, we will reach the innermost two: one in which silicon combines to form

[1] To become a core-collapse supernova, a star must, as the table shows, be more than ten times the mass of the Sun (https://iopscience.iop.org/article/10.1088/0004-637X/810/1/34). The current “best guess” for the mass of Betelgeuse puts it only just over this limit so, its exact fate is uncertain.

iron and, in the very heart of the star, will lie a nucleus of iron. There are no nuclear reactions that emit energy from combining iron into even heavier elements: every further reaction *consumes* the star's energy rather than producing more. In other words, Betelgeuse is not only passing through an end-of-life crisis, it is suffering from heart problems that will soon become mortal.

For silicon to be able to "burn" in the heart of the star – in other words, to combine silicon into iron by nuclear fusion – the minimum temperature that the centre of the star must reach is 3.1 BILLION degrees (3100000000ºC). How does this happen? The answer is that for the centre of the star to get hotter, it must get smaller. Time and again, gravity compresses it and the temperature rises until the next set of nuclear reactions can start in the core of the star, providing it with a temporary respite from final collapse and death. As the nucleus compresses, the outer layers of the star expand outwards, until the pressure exerted by the radiation counterbalances the inward force of gravity.

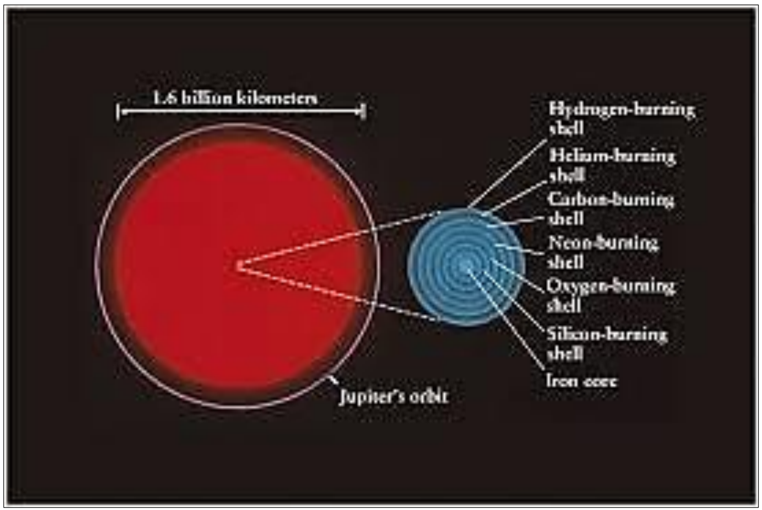


Figure 4. Ohio State Astronomy Department lecture materials

Each stage of nuclear reactions lasts less time than the previous one. For a star 25 times the mass of the Sun (i.e. a little larger than the largest estimate for the mass of Betelgeuse), the hydrogen burning continues for 7 million years before it is exhausted, but the carbon only lasts for some 600 years and the oxygen for some six months. By the time the star reaches its final resource – burning silicon – the fuel will sustain the 25 solar mass star for just one day; Betelgeuse is not this massive, so its silicon will probably last a few days but, even so, all seven "skins" of a star like Betelgeuse are only present in the final days of its life of around ten million years (Figure 4).

As the silicon burns, the heart of the star fills with iron "ash" and cannot generate the energy that the star requires to overcome the force of gravity. There will be a crisis, like that of a tower block undergoing a controlled demolition: suddenly, the bottom layers are unable to sustain the weight on top of them and the whole structure collapses.

This collapse lasts just a few seconds. In that short time, suddenly, huge amounts of hydrogen, helium and carbon meet in truly unbelievable conditions of temperature and density. The star starts an incredible frenzy of nuclear reactions, leading to a massive explosion of uncontrolled energy. This is a supernova explosion and results in about 90% of the mass of the star being blasted into space. The remaining 10% is the nucleus of the star, which is at the centre of the explosion and has been compressed to quite incredible density by the impact. Normally, in a core collapse supernova, this core forms a neutron star, an object that may be up to three times the mass of the Sun, compressed into an object just a few kilometres across. However, if the surviving core of the star is more than three times the mass of the Sun, it is too massive even to form a neutron star: such a star continues to collapse for ever, into a black hole.

Supposing, which, as we have seen, is not entirely a given, that Betelgeuse does become a fully-fledged core-collapse supernova, just how bright would supernova Betelgeuse get?

Given that it is by far the nearest star to us that could explode as a supernova, "very" is the answer. The supernova that formed the Crab Nebula, in 1054, was about 6000 light years away and, yet, it was visible in daylight. Betelgeuse is about ten times closer and would become around one hundred times as bright. It would, most likely, get to be about as bright as a half Moon, around magnitude -10 (remember that, in a half Moon, the light is spread over a significant area of sky – in supernova Betelgeuse, it would be concentrated into a tiny point of light of dazzling brilliance). However, other estimates suggest a much brighter peak, around magnitude -12 to -13: again, this depends critically on the mass and the distance.

Supernova Betelgeuse would provide a substantial problem for astronomers. Not only would its light be as disruptive as having another Moon in the sky, it would be far too bright to be studied by normal telescopes and instruments. At brightest, quite likely only solar telescopes would be able to get useful data. As it faded, there would be a real danger there would be a brightness gap in which it would be too faint for solar telescopes and too bright for normal telescopes to observe. Quite possibly, the heavy-duty neutral density filters that were in common use a few decades ago for observing brighter stars with photon-counting detectors, will make a rapid return[2].

Of course, one of the big questions has been: is the current fade the precursor of the death of Betelgeuse?

The plain answer is "no". There is nothing that suggests that it is. Estimates of how close Betelgeuse is to becoming a supernova vary from about twenty-five thousand to one hundred thousand years, with most sources now favouring the upper limit of the range. Given that the star is less than ten million years old, we can compare Betelgeuse to an octogenarian human but, as any octogenarian will tell you, just because he sneezes one morning, does not mean that he will die that day.

When Betelgeuse finally reaches the end of its life, things will move very fast indeed, but they will not necessarily be obvious to an outside observer. Only a few days will pass from the start of silicon burning, to the supernova explosion. The collapse from an apparently normal star, into a supernova will take just a few seconds. All we can say is that, at this moment, *probably*, Betelgeuse is still burning helium. If it has moved already onto carbon-burning, it is quite possible that the supernova explosion has already happened and that news of it is, even now, winging its way to us at the speed of light. However, it would be a quite incredible coincidence for the supernova to happen just at the moment in its several million years of lifetime when we are watching.

However, it is hard to know what to expect if a supergiant star like Betelgeuse is about to go supernova. Only in one case do we have any real information on the behaviour of a star before it exploded[3]. When, SN1987a appeared, on February 23rd, 1987, it was realised that the precursor star had been observed "accidentally" many times over the years and was catalogued. Put another way, it was realised rapidly that Sanduleak -69 202, a very luminous 12th magnitude, blue supergiant star, had gone missing and that it coincided exactly with the position of the supernova. Even better, quite a lot of people had captured the rise of the supernova to maximum brightness, immediately after explosion. There were even some photographs of the Large Magellanic Cloud that showed Sanduleak -69 202 in the days and weeks before explosion, demonstrating that it had not done anything

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[2] One of my memories of my first observing run with the Isaac Newton Telescope in La Palma was of the pained look on the face of my support astronomer when I wanted to observe a 15th magnitude calibration star. He informed me that "this telescope was not designed to observe such bright stars".

[3] Here, we ignore the unusual star, Eta Carinae, which may also be in a pre-supernova stage. It brightened in the 1830s and '40s until it was almost as brilliant as Sirius, until dropping back down to well below naked-eye visibility at the end of the century. Since the 1950s, Eta Carinae has started to brighten slowly again until, now, it is, again, reasonably easy to see with the naked eye.

particularly unusual in that time; even the night before, the star appeared completely normal. In fact, there is nothing to indicate that Sanduleak -69 202 had behaved in any way unusually in the decades before its collapse, as it was not obviously variable in any of the photographs of the Large Magellanic Cloud taken over the previous century. There was no, big fade or tell-tale in the light curve that the explosion was imminent. Presumably, during the last century before its explosion, Sanduleak -69 202 passed from carbon-burning to neon-burning, then oxygen-burning and, finally, silicon-burning, with no obvious light curve signature of the transitions.

Of course, you can argue that maybe Sanduleak -69 202 was unusual because it was a blue supergiant and not a red one, but that seems to be mainly because the cooler outer layers has been stripped-off before the explosion and we were seeing what were, originally, layers from deeper inside the star. Perhaps the tell-tale that Betelgeuse is about to go supernova will be it changing colour progressively?

There was just one, clear early warning to astronomers that Sanduleak -69 202 had exploded. In fact, we know *exactly* when the core of the star collapsed. At 07:35:35UT on 23rd February 1987, three neutrino telescopes around the world, detected a sharp burst of neutrinos. It's burst lasted a fraction over 12 seconds, during which time, 25 neutrinos were detected. For comparison, the famous solar neutrino experiment in Homestake Gold Mine in South Dakota, detected typically 1-2 neutrinos per day. The arrival of these neutrinos marked the exact moment of the sudden death of Sanduleak -69 202. The first optical detection of the supernova was at 05:40UT on February 24th, although made on a photographic exposure that had started three hours earlier, at a time when the brightness of the supernova was increasing rapidly already. In the case of Betelgeuse, most likely, the first news of the core collapse will be the detection of a massive neutrino burst. Here, if we scale from SN1987a, we are talking about a burst of not 25, but one to two ***million*** neutrinos: when it comes, if it comes, it will be unmistakeable.

The remaining question that we have to answer is: is what is happening to Betelgeuse an exceptional event?

This is where we started and is the $64,000 question. Have a look at this light curve for Betelgeuse (Figure 5). It is 10-day means for the 90 years from 1911 to 2001, taken from the archive of the American Association of Variable Star Observers (AAVSO). As Betelgeuse is one of the most-observed stars in the sky, its variations are extremely well documented since 1922, with sporadic observations going back a further couple of centuries.

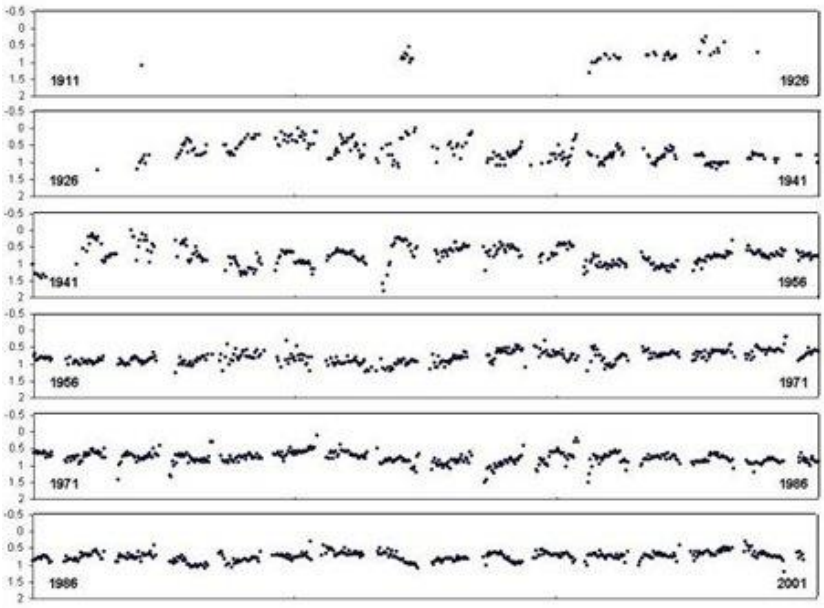


Figure 5. 10d means 1911-201 AAVSO IDB

The AAVSO light curve charts how this fascinating star has varied in brightness over more than a century. Twice in the 1940s and, again, as many as four times in the 1970s and 1980s, we can see that Betelgeuse actually got at least as faint, or even rather fainter than it is now. So, while rather unusual, the current minimum of Betelgeuse is, by no stretch of the imagination, really exceptional.

The biggest dimming event of all was in 1948, when Betelgeuse got almost as faint as magnitude 2, which is quite considerably fainter than it is now (I have been estimating +1.3 since before Christmas). Below is its light curve from 1992 (Figure 6) to the present, also from AAVSO. We can see that the current fade is unique in the last thirty years but, for the current minimum to rival the 1948 event, it would have to fall right down, out of the bottom of the graph. There are, though, at present, no signs that it is going to get any fainter. Of course, Betelgeuse may yet surprise us.

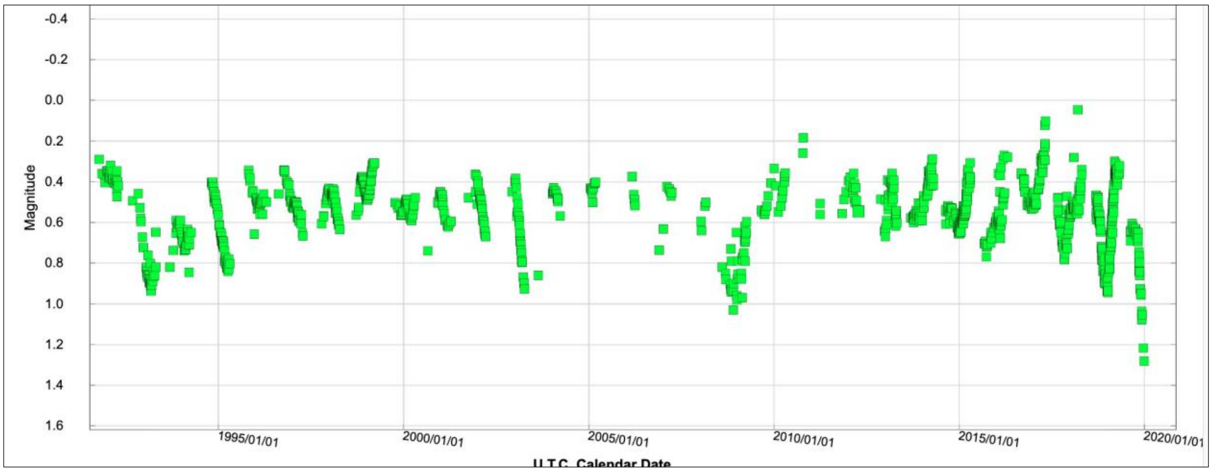


Figure 6. Betelgeuse 1992-2020. AAVSO IDB

What is clear is that there is no good reason to believe that Betelgeuse is heading towards an imminent supernova explosion: it is not *impossible*, but it is unlikely that we are watching it at the critical moment. However, just as SN1987a was a tremendous boost for stellar evolution studies, as astronomers watched a nearby supernova explosion in real time, with modern instruments, supernova Betelgeuse would be an even more stunning development for astronomy… were it to happen at some point in time.

Compared to long-period variables such as chi Cygni, the amplitude of Betelgeuse is tiny and the variations far more erratic. Only three years ago, Betelgeuse rivalled Rigel in brightness for a time but, since 2016, each annual minimum has been deeper than the previous one. Frequently, it is suggested in books and on the internet, that there is a period of about 5 years in the light curve, but it is far from obvious to my eyes; certainly, in recent years, other, shorter-period cycles, particularly the proposed period of 400 days, are more evident.

What Betelgeuse will do in the next few weeks and months is uncertain. Most likely, it will start to brighten again in the next few weeks and will be back to its normal brightness by the end of the year. However, what makes a star like Betelgeuse so interesting is that you can never be quite sure what is going to happen next, but the idea that it may be in the process of exploding is just wishful thinking, however much we might like it to be true.

At the end of the day, the biggest single problem with the star is that its distance, mass and age are so poorly known. It really does seem quite scandalous that, for one of the brightest stars in the sky, the distance is so uncertain, and the range of published masses covers a factor of six. Hopefully, my colleagues in the Gaia team will get the summer student that they are discussing requesting and that the student, whoever it is, will be able to crunch the numbers and remove some of the uncertainty about this fascinating and mysterious star.

[Update: 2020 February 18th – My latest estimates, dodging the almost nightly Madrid cloud and fog, show Betelgeuse at around magnitude +1.7. Orion looks really strange now and, Betelgeuse, shockingly faint. A calculation based on the 400 day and 6-year periods suggests that minimum should be reached on February 20th, 2020 and, from there, Betelgeuse should brighten quickly back to a more normal state. We will see.]

Update on PV Cephei and Gyulbudaghian's Nebula – 2010-2020

David Boyd

For the past decade the behaviour of the Herbig Ae star PV Cephei and its associated Gyulbudaghian's Nebula has been followed with Rc-band photometry.

I have now been monitoring the behaviour of the Herbig Ae star PV Cephei and its associated variable nebula, variously known as RNO 125, GM 1-29 or Gyulbudaghian's Nebula, for 10 years starting in March 2010 so it seems appropriate to provide an update. For consistency I have used the same comparison stars and equipment throughout: a 0.35m SCT, SXVR-H9 CCD camera and Rc filter. Figure 1 shows the appearance of the star and nebula in an image taken in January 2020. Only a thin sliver of the nebula was visible.

PV Cep is a relatively massive (~3.5 M☉) young star, less than a million years old, which is embedded in a dense molecular cloud. It is still forming by accreting material from a rotating disc which surrounds the star and is almost edge-on to our line of sight. This accretion process often creates a strong magnetic field in a new star which in turn drives bipolar outflows and jets along the magnetic axes of the star. In the case of PV Cep one of these outflows from the star is believed to have cleared a conical cavity out of the molecular cloud and light from the star is illuminating the inside of this cavity creating the nebula we see. According to Gaia DR2, PV Cep is 340 ± 7 parsecs from Earth.

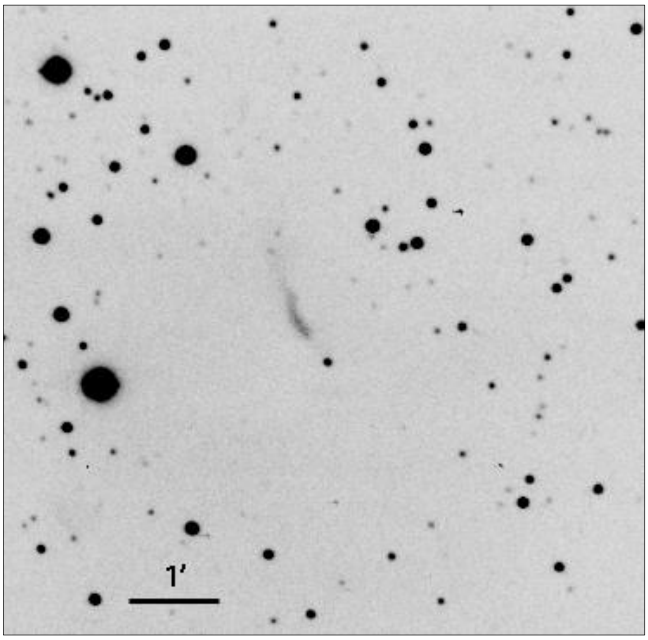


Figure 1: PV Cep and Gyulbudaghian's Nebula imaged on 17th January 2020 (North up)

The accretion process from the disc onto the star is irregular causing apparently random brightening and fading of the star on a timescale of months and years. Clouds of gas and dust close to the star and the inner edge of the accretion disc may also occasionally block or dim light from the star. It is probable that both these processes are contributing to the variations we see in the light from the star. These variations also alter illumination of the molecular cloud and cause the changes we see in the visibility of the nebula.

Figure 2 shows the 10-year Rc-band light curve PV Cep (in blue) and of the nebula (in red). The star brightened steadily from a low point at Rc = 17.0 in March 2011, reached a peak at Rc = 13.6 in January 2017 before fading rapidly and eventually falling to its lowest point since 2010 at Rc = 17.2 in August 2019.

The pseudo-magnitude of the nebula is created by integrating the total light from a constant-sized region around the nebula excluding the star, converting that to a magnitude and rescaling it so it can be included in the same plot as the star. In reality the brightness of the nebula is many orders of magnitude fainter than the star.

Figure 2 shows how the brightness of the nebula broadly follows the changes in direction of the brightness of the star but there appears to be an upper limit to the total brightness achievable by the nebula. Checks show that this is not a feature of the way the light from the nebula is measured but is intrinsic to the emission from the nebula.

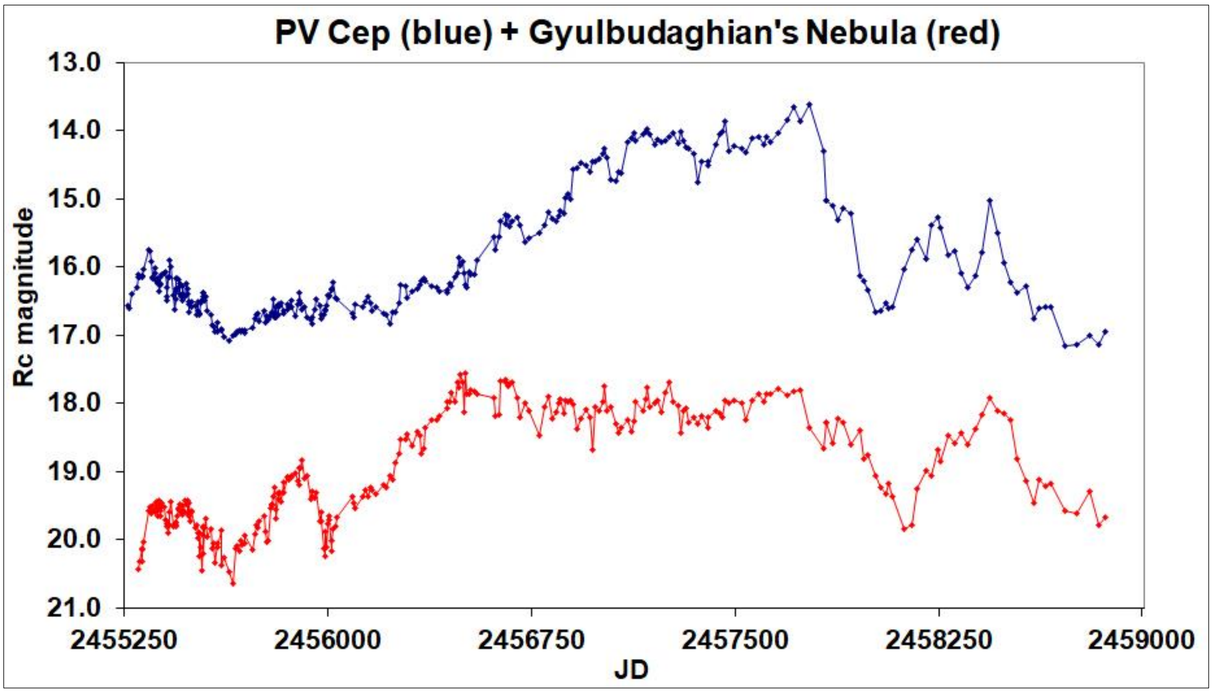


Figure 2: 10-year Rc-band light curve of PV Cep plus pseudo-magnitude of Gyulbudaghian's Nebula

CV & E News

Gary Poyner

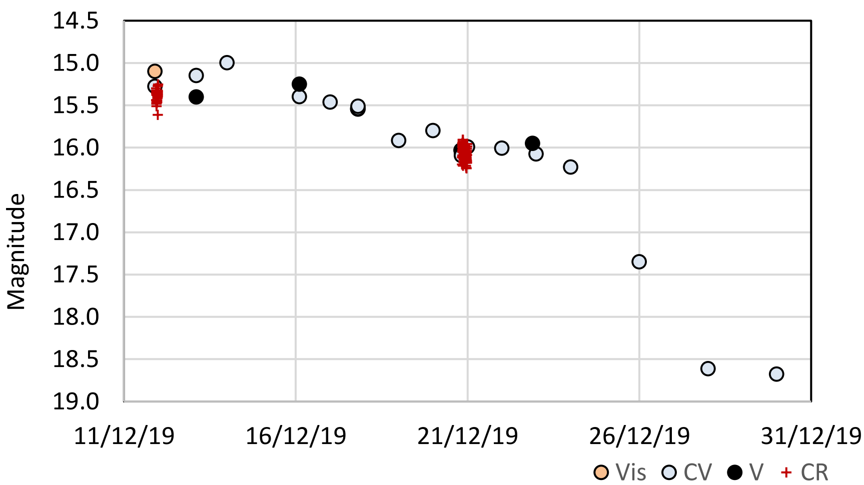
The December 2019 superoutburst of the UGSU star V402 And, and SN 2020ue are covered.

V402 And: The first outburst of this UGSU star (discovered by Sergei Antipin from Moscow plates and announced in IBVS 4578 in 1998) was observed in October 1999, when Tonny Vanmunster detected a faint outburst at magnitude 16.9C in the then titled Var62 And. The outburst was a normal one and didn't get brighter than 16.5 visual. The first observed superoutburst came a year later when Martin Mobberley detected V402 And bright at 15.7C on Sep 20.817 UT 2000. Superhumps were detected by various observers, and a preliminary Psh was given as 0.064d, revised after further data was received to 0.06336d by the vsnet collaboration team. VSX gives the Porb as 0.0621d (89.4 minutes).

Since 2000 a further eight confirmed outbursts have been detected, including three further superoutbursts. The most recent of these was detected by Jeremy Shears on 2019 Dec 11.828 UT at 15.28C. This was the first confirmed outburst detected since January 2011, although one solitary TG datapoint does appear on the AAVSO light curve on Aug 16, 2015 at 15.86TG. This was probably a normal outburst as negative <17.0 points appear on Aug 06 and Aug 23. Gaia detected the December superoutburst four days later on Dec 15.

The 2019 superoutburst peaked at 14.9CV on Dec 14, then slowly faded to 16.2C by Dec 23. A more rapid fade then occurred to 17.4CV by Dec 26 and eventually 18.6CV by Dec 28th. Minimum brightness varies around 19.0-20.0.

Although one of the fainter stars on the CV&E programme, V402 And is worth monitoring regularly. The gap in outburst detection mentioned above (2011-2019) shows that interest in this star has waned since the early CCD work of the later 1990's, yet orbital and superhump periods can still be refined with time series photometry, and at a superoutburst magnitude of ~15.0, V402 And is well within the range of visual observers.



2019 Superoutburst. Observers S. Johnston (CR), P. Leyland (V), M. Mobberley (V), G. Poyner (Vis. & CV), J. Shears (CV)

SN 2020ue in NGC 4636

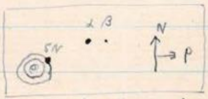
Discovered by Koichi Itagaki (Japan) on January 12.722 at magnitude 15.0C, it was soon identified as type Ia with a redshift of 0.003 (Transient Name Server).

From data reported to the VSS database, the supernova peaked at magnitude 12.304CV on Jan 25.232UT, with V magnitude measures appearing to be consistently 0.13 magnitudes brighter than the unfiltered measures. At the time of writing (Feb 27), the supernova had faded to 14.17V (Fig. 1).

SN 2020ue is only the second supernova to be discovered in NGC 4636, a ninth magnitude galaxy in Virgo. The first, SN 1939A, was discovered by Fritz Zwicky on January 17, 1939. This also was type 1a and peaked around magnitude 11.9.

Martin Mobberley has sent me a scanned copy of Reggie Waterfield's 1939 notebook (right), in which he describes photographing SN 1939A on February 12 – a 90 minute visually guided exposure with an 18-inch reflector. How times have changed!

Feb. 12 Super Nova in N.G.C. 4636 (α 12h 35m 41s, NPD 86° 32'.7, 1860)
Exposure from 13hm 55m to 15hm 25m = 90 minutes. Drove on
5th mag star just over 1° sp nebula. Plate shows nebula with tiny
star involved about ½' Np centre of nucleus — Photographic mag
roughly estimated at 14. The same was just after exposure picked
up in 18" reflector visually; & estimated as
approx. equal to star α, say 13.5–14.0 mag.
The plate also suggests SN = α, though owing to involvement in nebulosity
comp. is v. difficult. Obviously S.N has faded since Zwicky's 2nd
observation 12.5 mag Jan 20



Martin also comments that Percy Mayow Ryves observed it visually. Note that the RA is given in hours minutes and seconds, but there is no declination. Instead the NPD (North Polar Difference) is given to an 1860 epoch. Reggie Waterfield's' comet notebooks were left to Denis Buczynski who gave them to the BAA. Martin has scanned them for the comet section, and these can be seen at https://www.britastro.org/node/19389. The supernova observations can be found in book 1. Look out for a paper on Reggie Waterfield by Martin in a future BAA Journal.

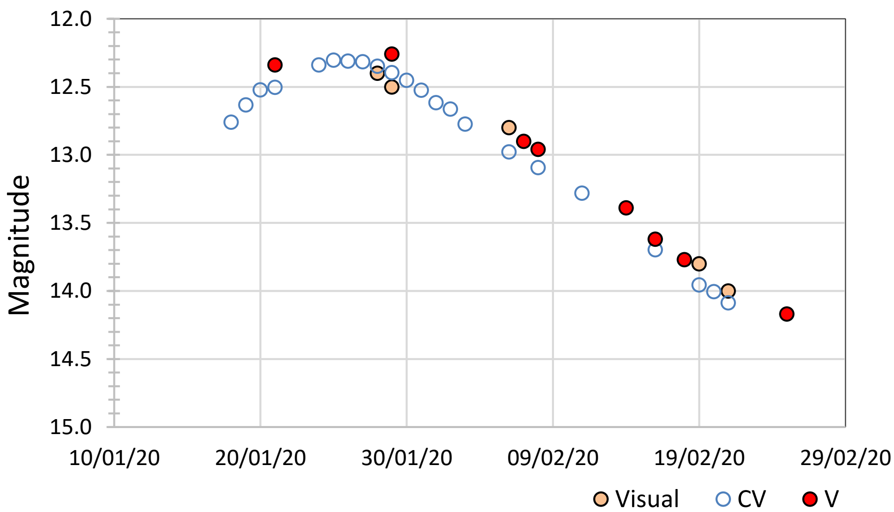


Figure 1. M. Mobberley (V) & G. Poyner (Vis. & CV). BAAVSS database

The unusual cataclysmic variable V630 Cas eleven years after its previous outburst

Jeremy Shears

V630 Cas is an unusual cataclysmic variable star with a very long orbital period of 2.56387(4) days, and which undergoes rare outbursts. Its previous outburst was in 2009 and it has been in "active" quiescence since then. The star is currently rather faint (CV ~ 16.9), but this might simply reflect a local minimum brightness of a multi-year variation during the star's quiescence.

V630 Cas is an unusual cataclysmic variable star with a very long orbital period of 2.56387(4) days (1) and which undergoes rare outbursts. The first observed outburst was in 1950, lasting about 2 months during with the star reached m(pg) = 12.3 (2). A second outburst was observed in 1992 with a 70 day rise to maximum at V = 14.3 and a decline over about 30 days (3). The most recent outburst occurred in the first half of 2009 (4). It lasted about 104 days, with the rise to maximum, at 61 days, being slightly slower than the decline, 43 days. At is brightest it had V = 14.0, 2.3 magnitudes above the mean quiescence magnitude. The outburst profile was similar to the 1992 outburst but was significantly fainter than the one in 1950.

Along with many other observers, I have continued to monitor V630 Cas during quiescence. Recently I noticed that the star was somewhat fainter than usual, as faint as CV= 16.9, compared to its average quiescence mag of 16.4.

To investigate this further I plotted the AAVSO data from 1991 Aug 1 to 2019 Dec 29, having selected C, CV, V, TG and vis data only. The resulting light curve shows the 1992 and 2009 outbursts. There is quite a bit of apparent scatter during quiescence: some of this is a real variation. Orosz et al. (1) found, using RoboScope data, that the star has a rather active quiescence with variations of up to 0.4 mag on short (1 – 5 d) timescales and variations of 0.2 – 0.4 mag on longer timescales (3 – 9 month). There appears to be a larger degree of variation in the second half of the light curve, but much of that is because the data are contributed by a wide range of observers, using different types of equipment. Whereas much of the data prior to 2005 was from a single source: RoboScope (with grateful thanks to Professor R. Kent Honeycutt, Astronomy Department, Indiana University, Bloomington, USA for providing it).

What the light curve also shows is the recent apparent dip in brightness. However, there also appears to be a long period sinusoidal variation across the light curve (with an apparent cycle length of 8.5 to 9 years; note this is from a visual inspection of the light curve and proper period analysis is required!). Thus, it might be that the present epoch represents a local minimum brightness in this cyclic variation. Further observations will of course prove whether this is correct or not. Keep watching!

In our 2010 BAA *Journal* paper covering the last outburst (4), Gary Poyner & I discussed when the next outburst might be. Based on the 17-year gap between the last two outbursts, we may have to wait until 2026 until the next outburst. However, predicting dwarf nova outbursts is notoriously difficult. Hence, this is another reason to keep this intriguing star under regular observation.

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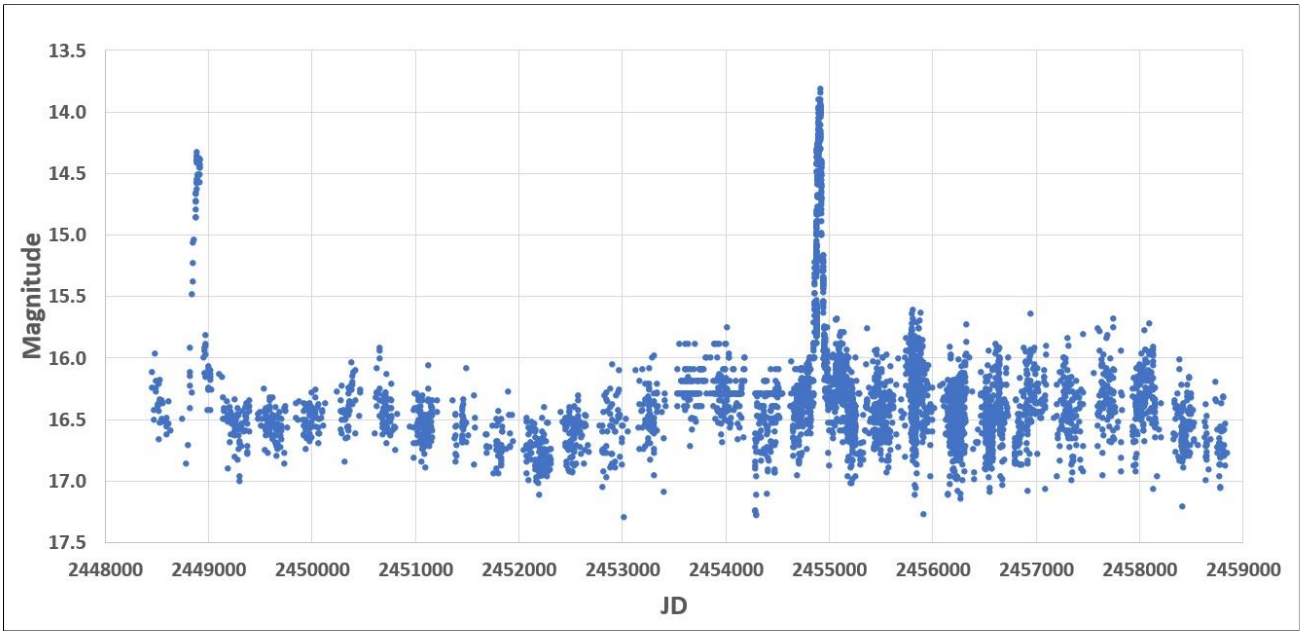


V630 Cas light curve 1991 to 2019, showing the 1992 and 2009 outbursts

BAA VSS campaign to observe the old nova HR Lyr

Jeremy Shears

Preliminary results of the BAA VSS campaign to observe HR Lyr during 2019 are presented. The light curve shows three brightening episodes each of ~50 days duration. Two had an amplitude of ~0.9 mag and one of ~0.5 mag.

Introduction to HR Lyr

Nova Lyrae 1919, or HR Lyr as it is now known, was a magnitude 6.5 nova discovered on 1919 December 6 by Miss Mackie at the Harvard College Observatory. A review of the photometric history of HR Lyr was presented in the BAA Journal in 2007 [1], finding that the system has been relatively stable at V ~ 16 ever since occasional post-nova monitoring began in 1925. More recently, the 22-year light curve between 1991 and 2012 was presented [2] which showed the system varied over the range V= 15.3-16.3 with occasional excursions to V~17. The light curve variations often take the form of nearly linear rises and falls on a timescale of 50 to 350 days with a typical value of about 100 days. Occasional ~0.6 mag outbursts were also seen, with properties similar to those found in some nova-like cataclysmic variables

Scope and objectives of the 2019 campaign

Apart from photometric monitoring, HR Lyr has not received much attention. The aim of this campaign, due to run until the end of the 2019/20 observing season, was to deepen our understanding of the photometric behaviour on a range of timescales. The campaign was launched via the BAA website a BAAVSS-alert at the beginning of 2019 April and further details were given in VSSC 181 and in the 2019 June edition of the BAA *Journal*.

Preliminary results: 2019 light curve

Observations of HR Lyr during the campaign have been obtained by:

Allen, Chris	Joslin, M	Sabo, Richard
Boyd, David	Leyland, Paul	Sargent, Richard
Cooney, Walter	Linnolt, Michael	Sharp, Ian
Dubovsky, Pavol	Mallett, John	Shears, Jeremy
Dufoer, Sjoerd	Menzies, Kenneth	Smith, David
Fleming, George	Miller, Ian	Storey, David
Gualdoni, Carlo	Mobberley, Martin	Walton, Ivan
Iozzi, Marco	Pickard, Roger	
Johnston, Steve	Poyner, Gary	

I am most grateful to all these observers for their hard work and dedication.

Only a very preliminary analysis is available at the moment, which is reported here. A more detailed analysis, including time resolved photometry, will be reported later.

Figure 1 displays the resulting light curve. It appears to show three successive brightening episodes, each lasting about 50 days. The profile of the first and third episode superficially look rather similar; each has an amplitude of ~0.9 mag, the fading segment has an inflexion where the rate slows briefly, and the magnitude at the end of the fade is slightly fainter than before the brightening episode started. By contrast, the second event was smaller in amplitude at ~0.5 mag, although of a similar duration at ~50 days.

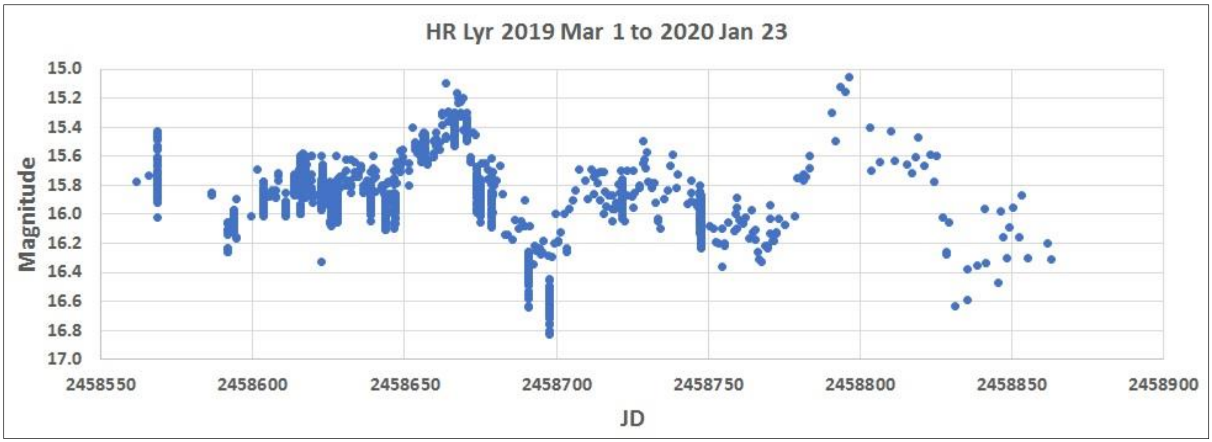


Figure 1: Light curve of HR Lyr from the 2019 observing campaign
Data are combined visual, CCD-V, CCD-CV

Although similar brightening episodes have been seen previously in the 1991-2012 light curve presented in reference [2], they were not common. They appear to be different from both the shorter ~0.6 dwarf nova like outbursts and the ~100 day brightening and fading ramps reported in that paper.

It is also worth noting that during the peak of the brightening episodes, HR Lyr was mag ~15.0, brighter than it has been since 2006.

Amateur spectroscopy of HR Lyr is challenging due to the faintness of the star. Nevertheless, Robin Leadbeater obtained a low resolution ALPY 600 spectrum which is similar to a low resolution 1983 spectrum from the literature. It shows a blue continuum with no obvious emission lines, though there is a hint of some small features common to both spectra [3].

HR Lyr: what next?

Although the 2019 campaign has officially ended, I am hoping that observers will continue to monitor the star, preferably on a nightly basis. It will be interesting to see, for example, if the brightening episodes of 2019 will be repeated, or whether it will return to its more usual behaviour. Further time series photometry would also be appreciated to see whether short term variations can be picked up, including a speculative 0.1-day period. Ideally, this would require a few runs of several hours

References

[1] Shears J. & Poyner G., JBAA, 117, 136 – 141 (2007)
[2] Honeycutt R.K., Shears J., Kafka S., Robertson J.W. & Henden A., AJ, 147, 105 – 113 (2014)
[3] Leadbeater R., BAA website Forum: https://britastro.org/node/17780

Australian Wildfires

John Toone

With the Australian wildfires being very much in the news at the end of 2019 I contacted the country's leading variable star observers Peter Williams and Rod Stubbings to enquire firstly that they were safe and secondly how was their visual photometry impacted.

From Peter Williams

Fortunately, Sydney has been spared much of the wildfires and no large fires have occurred where we are in southern Sydney. We are surrounded by extensive native bushland of the Royal National Park to our east and the Heathcote National Park to the west with water catchment areas extending further to the south. Our safety depends largely on the weather conditions should a major fire occur and the prevailing wind direction at that time. During a major blaze the intense fire actually creates its own weather system carrying burning embers well ahead of the fire front by many kilometres and any resulting "spot fires" must be put out before they take hold – assuming someone is there to actually do that! The A1 Princes Highway and railway corridor that separate us from the Royal do provide a fire break if the weather is calm. The highway is also our escape route should a fire come from that direction, so the authorities generally evacuate everyone before the fire arrives.

The fires surrounding Sydney have now been burning for over 3 months and it is difficult to comprehend the sheer scale and few people seem to appreciate how inaccessible is the wilderness areas in which these fires are.

Between the summer clouds and smoke from the fires I have been lucky to see the sun let alone the stars. Apart from a few observations of Betelgeuse when in Adelaide, there have been just 3 nights in October to December where the winds have carried the smoke away so there has been very little opportunity for variable stars. With my observations currently on-hold it may well be another year before I reach the 200K milestone.

As I type this the smoke is still blanketing Sydney and we can clearly see the smoke sitting in the nearby valley to our north and off eastward towards the highway, and it is entering our house with the windows just slightly open so these have just now been closed. Any steady rains you can send us from the UK would be greatly appreciated!!

Peter has advised me separately that Sydney had zero rainfall in the month of December and that the temperature at his home has peaked several times in the low to mid 40C's. One of Peter's daytime photo's is given showing the sun shining through the smoke, an image akin to what the dinosaurs perhaps saw just prior to extinction.

Rod in the State of Victoria has fared better:

Yes, it is not good in certain parts of Australia for the past few months, but the fires are well away from us in Southern Victoria for now. I have just done a review of the year 2019 and recorded 18,284 observations with 872 dwarf novae outburst detections. I would have managed a few more but the last three months were unusually cloudy, that puts my total to over 323,000.

Stella Kafka was in Australia last month at the Mt. Burnett Observatory giving a talk which is an hour drive from my house. I wanted to meet her, and it was nice meeting and getting to talk with her. Stella was there co-leading the Connecting the Public to the Night Sky Workshop as part of the Robotic Telescopes Student Research and Education (RTSRE) Conference which took place in Melbourne.

It is unfortunate that wildfires are a regular hazard to inhabiting and observing within Australia. I have seen a wildfire myself when flying from Cairns to Sydney in 2004 and I recall that Rob McNaught suffered the loss of his house and important astronomical memorabilia to a wildfire back in 2013.

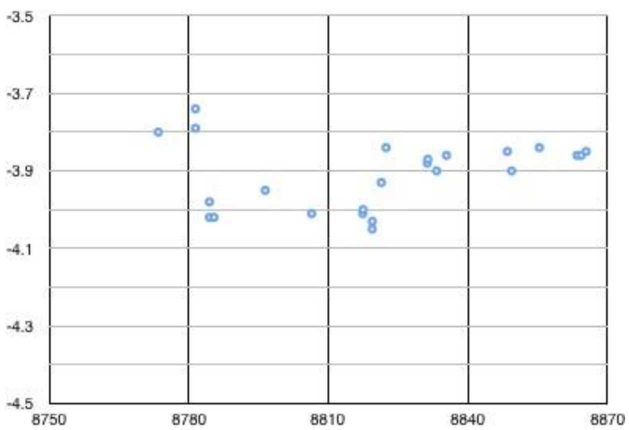
Hopefully as Peter said, the UK will donate some of its plentiful rain and the temperatures will subside to normality soon so that astronomical work can return to pre-wildfire levels.

Eclipsing Binary News

Des Loughney

zeta Aurigae - 2019 Eclipse

In VSSC 178 attention was drawn to the 2019 eclipse of zeta Aurigae. Ingress was predicted to be around 25th October and egress around 2nd December. The midpoint of the eclipse was scheduled for 13th November. Out of eclipse magnitude has been found to be 3.75V and eclipse magnitude 3.99V. There are differing accounts of the depth of the eclipse. GCVS states it be 0.27V and Krakow 0.6V. In 2017, the last eclipse depth was found to be 0.22V



The diagram left illustrates the measurements that were possible, given the weather in Edinburgh, of the 2019 eclipse by DSLR photometry. The vertical axis V is magnitude and the horizontal axis is JD. The limited measurements before the eclipse and during the eclipse suggest that the findings for out of eclipse magnitude and eclipse magnitude are confirmed. The predicted times of ingress and egress are more or less as predicted. What is not as predicted is the out of eclipse magnitude following the eclipse.

Measurements were continued until 16/1/20. It can readily be seen that the magnitude of the system following the eclipse is not 3.75V but more like 3.85V with dips to 3.90V. It therefore appears that the zeta Aurigae system is not just one of eclipsing binary variability - there is another form of variability. Which star or both is affected is difficult to say. It is intended to monitor the system for the foreseeable future to confirm another mode of variability.

QZ Carinae

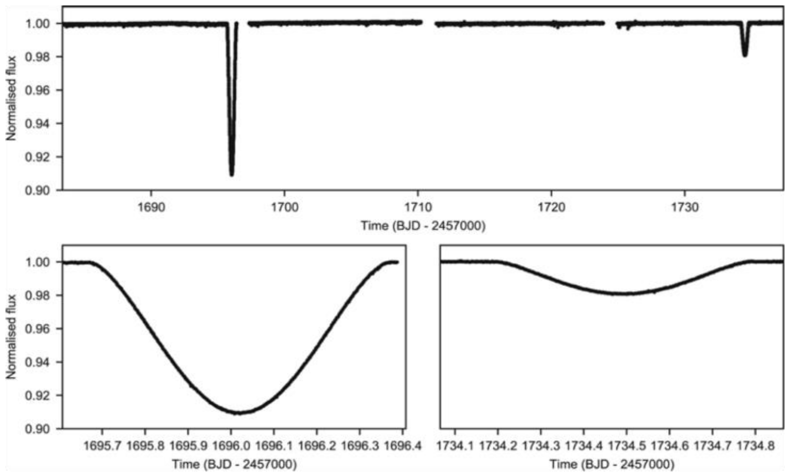
The AAVSO has just published a paper entitled 'QZ Carinae - Orbit of the Two Binary Pairs' which can be downloaded from:<https://www.aavso.org/apps/jaavso/article/3520/>. Here is the abstract:

"We present an updated O–C diagram of the light-time variations of the eclipsing binary (component B) in the system QZ Carinae as it moves in the long-period orbit around the non-eclipsing pair (component A). This includes new Variable Stars South members' measures from 2017 to 2019, BRITE satellite observations in 2017 and 2018, and 100 previously unpublished measures made at Auckland Observatory from 1974 to 1978. We conclude that QZ Carinae has not yet completed one orbit of the two pairs since discovery in 1971. The duration of totality of primary eclipses was measured to be 0.295 ± 0.02 day (7.08 ± 0.48 hours), rather longer than earlier values from light curve models. Other observational findings include the shape of primary and secondary eclipses and small-scale short-term brightness changes."

The paper is interesting because it describes measurements by amateurs (CCD and DSLR photometry) and satellite observations. It illustrates the teamwork that facilitates the study of such systems.

New Eclipsing Binary - alpha Draconis

A famous well known bright star has been found to be a detached eclipsing binary. alpha Dra (brightness 3.68V) or Thuban has been known to be a binary with a period of 51.4 days for some time. It has not been classified on any of the expected databases as a variable. It has now been reported as an eclipsing binary in a recent article: <https://iopscience.iop.org/article/10.3847/2515-5172/ab5112>. The article is titled 'A Dance with Dragons: TESS reveals alpha Draconis is a detached Eclipsing Binary" - RNASS Vol 3, No 10, 31/10/19. The discovery came from looking at some data collected by TESS which is short for the 'Transiting Exoplanet Survey Satellite'. The article considers that the eclipses have been missed because the period is relatively long, and the eclipses are short (six hours) and partial.



To the left is the figure, from the article, illustrating the light curve of the system.

The article states that the primary eclipse shows a drop of 9% in light flux and the secondary eclipse a drop of 2%. I would be grateful if someone could explain how these percentages can be translated into a drop in magnitude.

b Persei Eclipse Campaign AAVSO Alert Notice 688.

The Alert Notice called for measurements of this system around the expected complex eclipse on17/18 January 2020. The data submitted has been published (10/2/2020) on the webpage: <https://www.aavso.org/b-per-campaign-january-2020>. It can readily be seen that the eclipse was well observed. In Edinburgh the sky was clear on the night of the 17/18 January and 18/19 January, so some good data was obtained by DSLR photometry. The eclipse had not commenced on 17/18 but was well seen the following night. Unfortunately, the recovery that took place on HJD 2458868 was not seen as the next possible measurements could not be made, due to the weather, until 26/1/20 HJD 2458875.

The Brightest Eclipsing Binary - gamma Persei

This system is not in the Krakow database nor the GCVS database. It's out of eclipse magnitude is 2.93V. Wikipedia describes it as a wide eclipsing binary system with an orbital period of 5,329.8 days (14.6 years). The total eclipse was first observed in 1990 and lasted for two weeks. During the primary eclipse the magnitude drops by 0.55. Unfortunately, the last eclipse occurred in 2019 when it was well observed by TESS. Another is therefore not due to about 2035.

Campaign to observe the 2020 eclipse of EE Cephei

David Boyd

There is an opportunity for amateurs to contribute to a campaign to observe the eclipse of the unusual binary EE Cephei which is expected to begin in early March 2020

Astronomers at the Nicolaus Copernicus University in Toruń, and the Nicolaus Copernicus Astronomical Centre in Warsaw are organising an observing campaign for the 2020 eclipse of the unusual binary EE Cephei.

Mikołajewski & Graczyk (1999) first suggested that the eclipse may be caused by a dark disc with a low mass star or a close binary in its centre. Differences in the eclipse light curves of EE Cep may be caused by the precession of the disc. Broad "atmospheric" wings may precede and follow the mid eclipse by 3-4 weeks. An analysis of the 2014 eclipse has been submitted for publication by Pieńkowski et al. (2020). This indicates that their model may need some revision. The nature of the system is still not well understood and amateur observations during the campaign will be of value.

The beginning of ingress will take place around the 7th of March (JD 2458916.4) with mid-eclipse around the 3rd of April (JD 2458943.19). It is recommended to start observing at least two months before mid-eclipse and continue until at least two months after mid-eclipse. Special attention should be paid around the 20th of May 2021 (JD 2459354.7). In the previous epochs at this point of the orbital period, an increase of Ic-band flux was observed. This phenomenon is expected to start around the 25th of October 2020 (JD 2459148.1) and finish around 9th of December 2021 (JD

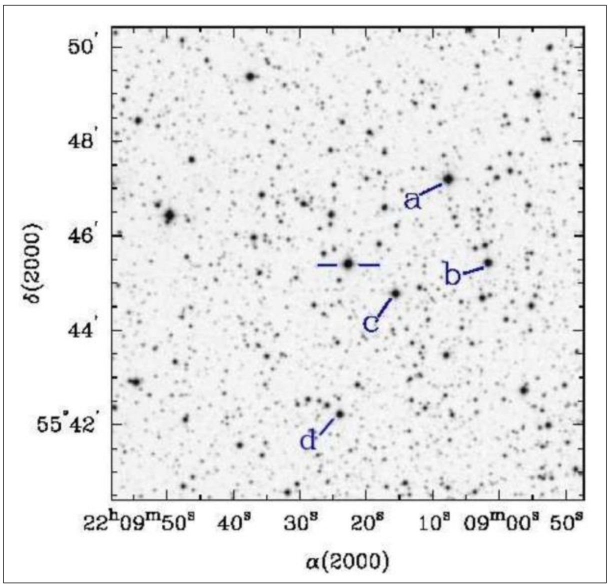
2459558.2). Observing in the Johnson-Cousins system with an accuracy of 0.01m or higher is advised.

I contributed photometry and spectroscopy to the 2014 eclipse and have continued to monitor EE Cep regularly since then. The comment above about an increase in the Ic-band flux is largely a result of my observations during a time when other observers had lost interest.

The campaign has a website at http://sites.google.com/site/eecep2020campaign/ . The contact for the campaign is Dariusz Kubicki kubicki@gmail.com who is at the university in Toruń. I have been told that EE Cep is the subject of his PhD thesis so he should be well motivated!

The recommended comparison stars for the campaign are marked on the image below.
“a” is BD+55 2690 and is recommended if using a single comparison star.
”b”, “c”, and “d” are GSC 3973 2150, BD+55 2691 and GSC 3973 1261 respectively.
GSC 3973 2150 and BD+55 2691 are listed in Simbad as possible variable stars but over the past 6 years I measured the standard deviations for all 4 stars as
BD+55 2690 0.007
GSC 3973 2150 0.006
BD+55 2691 0.004
GSC 3973 1261 0.010
V-band magnitudes for these stars can be found in the photometry table for the AAVSO variable star chart for EE Cep.

Mikołajewski & Graczyk, Mon. Not. R. Astron. Soc. 303, 521 (1999)
Pieńkowski et al., https://arxiv.org/abs/2001.05891v1 (2020)



Spring Eclipsing Binaries: 12-18 hours

Christopher Lloyd

O-C diagrams showing the period behaviour of stars from the BAA VSS Eclipsing Binary Programme are presented together with current ephemerides. The stars discussed are RS CVn, U CrB, TW Dra, AI Dra, 68 u Her, Z Her, δ Lib, U Oph and V566 Oph. A like secular period decrease is found for 68 u Her and Z Her shows a significant period increase ~ 1995.

Introduction

The British Astronomical Association Variable Star Section (BAA VSS) has a recommended list of 85 eclipsing binaries, including 29 priority stars, that are accessible to observers with small telescopes or DSLR cameras, or in most cases even binoculars. All the stars lie north of Declination $\delta = -9^\circ$ with half north of $\delta = +45^\circ$. They are distributed rather unevenly in RA with on average about three times as many stars in the summer and autumn skies (RA ~ 18 – 6 hours) as during the winter and spring. The Spring eclipsing binaries covering the RA range 12 – 18 hours contains only 10 stars of which all but ZZ Boo are discussed here. The complete listing also contains links to other resources. Follow the links to the previous three articles covering the Summer, Autumn and Winter binaries.

The purpose of this article is to provide some information about the period changes of a selection of the more interesting or unusual systems and also to provide a current working ephemeris to enable useful predictions of minima. The link on the variable name leads to the CDS Simbad listing which contains further links to data and references, and the VSX link connects to the VSX database and other resources at the AAVSO.

Eclipse timings should be as accurate as possible and for that reason it is recommended that the remaining visual observers migrate to DSLRs. From the O-C diagrams previously shown it is clear that there has already been a distinct movement away from visual timings of eclipses towards CCD and DSLR timings in recent years and while this has improved the quality of the O-C diagrams it has led to a significant drop in the number of observations.

RS CVn 13 10 36.91 +35 56 05.6 VSX EA/AR/RS 7.93 9.14 $1^m.21$ $4^d.80$

The RS Canum Venaticorum stars are an important subclass of close binaries and are characterised by strong magnetic fields that generate chromospheric activity and large cool spots that can cover 50% of the star's surface. In the case of the prototype of the class it is a very well-studied Algol system with components of F5V and K2IV, which are similar in mass and luminosity, and both are detached from their respective Roche lobes. The system shows a typical Algol light curve with a deep primary eclipse of $1^m.1$ and a shallow secondary of $0^m.1$. The light curve also shows significant year to year changes as the spots migrate over the surface of the cooler component and this can affect the depths and shape of the eclipses, most obviously the secondary. Eclipse timings are available from the 1890s and show substantial variation amounting to ~ 10% of the period (see Figure 1). Given the importance of the system it has seen serious neglect over the past 40 years and the variation is seriously under sampled. The period variations can be interpreted as a sinusoidal variation with a period of 122 years upon which is superimposed a low-amplitude cyclical variation of 40 years, which is approximately twice the period of the spot cycle. It is not clear whether the main change seen in the O-C diagram is sinusoidal, or parabolic which seems more likely physically, or some other combination of period changes. From the relatively sparse data over the past 30 years the period appears constant but in detail the variations in the modern data are complex. The current ephemeris of primary minimum is

$$HJD_{MinI} = 2446925.498(6) + 4.7977022(34) \times E$$

but this may suffer from short-term uncertainties of ±$0^d.01$.

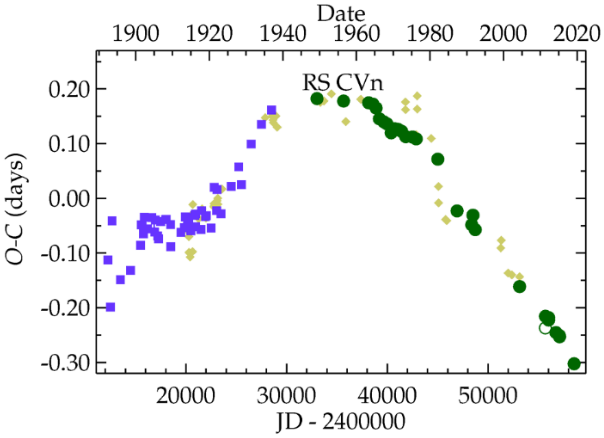


Figure 1. The historical O-C diagram of RS CVn showing the photographic (squares), visual (dots) and PEP/CCD (circles) timings. Secondary minima are shown as open symbols. The plot is dominated by a rapid reduction in period upon which are superimposed secondary short-term effects, but in detail it is open to interpretation. The lack of observations over the past 40 years is obvious.

δ Lib 15 00 58.35 -08 31 08.2 VSX EA/SD 4.91 5.90 $0^m.99$ $2^d.33$

As its name suggests *δ* Librae is one of the brightest stars on the list and it is also the most southerly. It is a well-studied system but photometry in general and reliable eclipse timings in particular are sparse probably due to the lack of suitably bright comparisons. The system which contains an A0V primary and a K0IV secondary which fills its Roche lobe. The disparity in temperature of the components is reflected in the difference in the eclipse depths which in *V* are $0^m.95$ and $0^m.1$ respectively for the primary and secondary. There is evidence of a variation in the *γ* velocity of the spectroscopic orbit consistent with a third component of about 1*M* with a period *P* = 2.762 years and there is also some support in the *Hipparcos* astrometry for a third component. However, confusingly although this component is generally accepted the variation in the radial velocities that led to its discovery is probably not real. Visual eclipse timings date back to 1900 but these provide little constraint of the period behaviour and it is only with the modern timings that a clearer picture emerges. The O-C diagram is given in Figure 2 and *δ* Lib does show significant period changes which can be described by a secular increase in period and a cyclical change due to another component in an eccentric 23-year orbit. However, the data since 2000 are not consistent with this interpretation and it seems more likely that there are discrete period changes between constant values. The problem with any interpretation is that the timings are sparse so there is little detail in the O-C diagram. Clearly the period variations of this system are complex and not understood so this is a high priority target. The current ephemeris of primary minimum is

$$HJD_{MinI} = 2448788.4236(41) + 2.3273338(14) \times E$$

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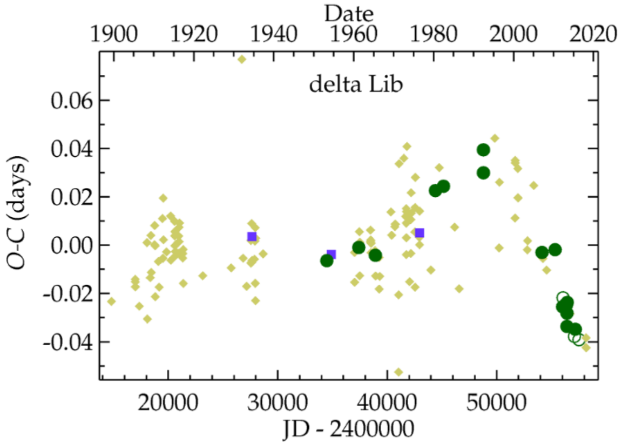

Figure 2. The historical O-C diagram of δ Lib is almost entirely defined by visual observations and these are broadly consistent with the scatter of modern timings where they exist. At present the behaviour is not understood.

U CrB 15 18 11.35 +31 38 49.4 VSX EA/SD 7.66 8.79 $1^m.13$ $3^d.45$

Although U Coronae Borealis is a classical Algol binary it is one of the more complex and active 'direct impact' systems showing alternating stream-like and disc-like accretion states and circumstellar material. The light curve shows a deep primary minimum of $1^m.1$ and a very weak secondary of ~ $0^m.05$. The primary component is B6V and is partially eclipsed by the secondary, F8–G0III-IV which fills its Roche lobe. Eclipse timings reach back to ~ 1850 and show large and complex period changes with significant short-term activity (see Figure 3). These were at one point attributed to a third body, but that notion was rejected, and the modern data show subtle complex changes, and a substantially longer period than the historical data. The current mean ephemeris of primary minimum since JD = 2444000 is

$$HJD_{MinI} = 2444058.3450(27) + 3.4522343(9) \times E$$

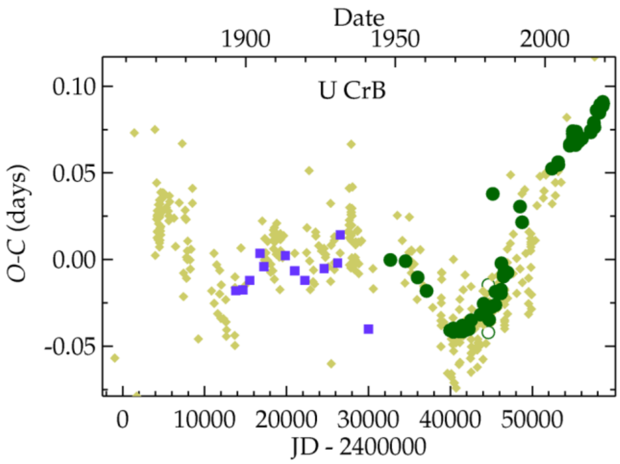

Figure 3. The large and complex period variations of U CrB currently defy a simple explanation.

TW Dra 15 33 51.06 +63 54 25.7 VSX EA/SD 8.00 10.50 $2^m.50$ $2^d.81$

TW Draconis is a well-studied classical Algol system with components of A5V and K0III, which fills its Roche lobe. The primary eclipse is total and very deep, $2^m.5$, making this system the faintest of this group at minimum. The secondary minimum has a depth of only $0^m.1$. The primary also shows a δ Scuti variation with P = 0.053 days and an amplitude of a few mmag in V. Sporadic visual eclipse timings deep into the 19th century combined with extensive modern data show that TW Dra underwent a huge change in its mean period about 1940 (JD ~ 2430000) but there are also smaller changes on a variety of time scales (see Figure 4). The period behaviour of the system can be accommodated by two very different interpretations of almost every aspect of the O-C diagram, but they both require additional ad hoc discrete or continuous period changes. In one interpretation the smaller variations are superimposed on a major secular period increase while in the other, the abrupt change about 1940 marks a difference in behaviour as well as period. The difficulty is that the behaviour before 1940 is not well defined. There is also a suggestion of a small periodic variation in the modern data with P = 6.5 years, probably due to a third body, which should be a testable result. The current ephemeris of primary minimum is

$$HJD_{MinI} = 2459001.2912(11) + 2.8067469(14) \times E$$

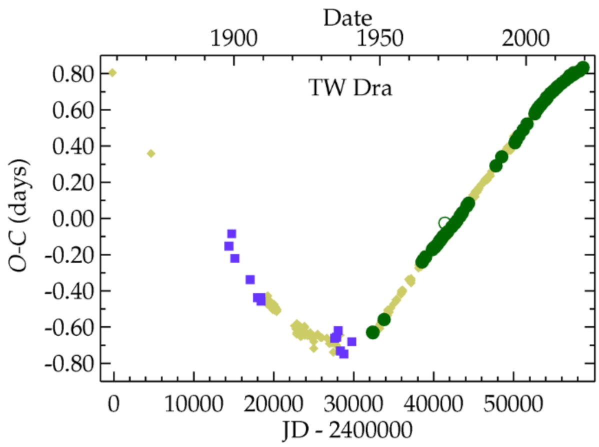

Figure 4. The enormous variation in the O-C residuals of TW Dra is not satisfactorily explained by any simple interpretation.

AI Dra 16 56 18.15 +52 41 54.4 VSX EA/SD 7.05 8.09 $1^m.04$ $1^d.20$

AI Draconis is a short-period classical semi-detached Algol-type eclipsing binary with components of A0V and near G0V, which fills its Roche lobe. Primary minimum has a depth of $0^m.85$ in V and the secondary is only $0^m.1$. Prior to 1978 the system was believed to show just one period change but as can be seen from Figure 5 the real situation is much more complicated. More recent studies suggest that the period behaviour can be described by the effect of two unseen companions with periods of 18 and 43 years plus a secular change or a more ad hoc combination of periodic and secular changes that may be due to magnetic cycles. Clearly the period variations of this system are complex and are not understood so this is a high priority target. The current ephemeris of primary minimum is

$$HJD_{MinI} = 2454758.3102(14) + 1.1988203(7) \times E$$

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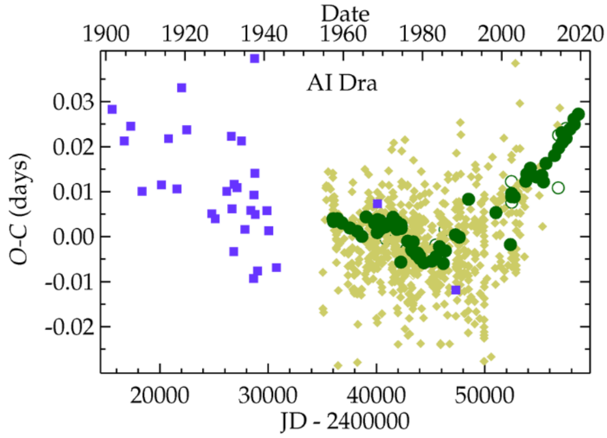

Figure 5. The small but complex variations of AI Dra are dominated by a clear increase in period but whether this is basically secular or abrupt is not clear. There are also ad hoc or cyclical variations in period.

U Oph 17 16 31.72 +01 12 38.0 VSX EA/DM 5.84 6.56 $0^m.72$ $1^d.68$

Unlike most of the stars on the list U Ophiuchi is not a classical Algol but contains two similar early-type stars, most likely B4Vn and B5Vn. Consequently, the system shows two similar eclipses ~ $0^m.7$ deep in *V*. Eclipse timings date back to 1880 and these show no major secular change in period, however, the modern data show a clear cyclical variation (see Figure 6). Analysis of the timings reveals two effects, the larger is due to the light-travel time introduced by a third body with *P* ~ 38 years and an amplitude ±0.01 days, and this produces the dominant variation in the O-C diagram. The second effect is a low-amplitude apsidal motion with an amplitude ±0.003 days and an unusually short apsidal period, *U* ~ 21 years. The third body responsible for both these effects probably lies a few milliarcseconds distant from the spectroscopic binary and some evidence for it may have been found in the Hipparcos data. The recent Gaia DR2 astrometric data show very significant excess noise, ~ 0.5 mas, which must be related to the third body, so at least part of the orbit may eventually appear. U Oph is also a well-known optical double (ADS 10428, CCDM/WDS 17165+0113) with fainter companion, *V* ~ 12 at *r* ~ 19 arcsec, but Gaia has shown this to be too distant to be physically associated with the inner system. The long-term mean observed ephemeris of primary minimum is

$$HJD_{MinI} = 2429467.8770(17) + 1.67734585(16) \times E$$

and this is reliable to < 0.01 days so can be used to identify minima anywhere in the cycle. Both minima can be used as they are almost equally deep, and this will allow a better determination of the apsidal motion.

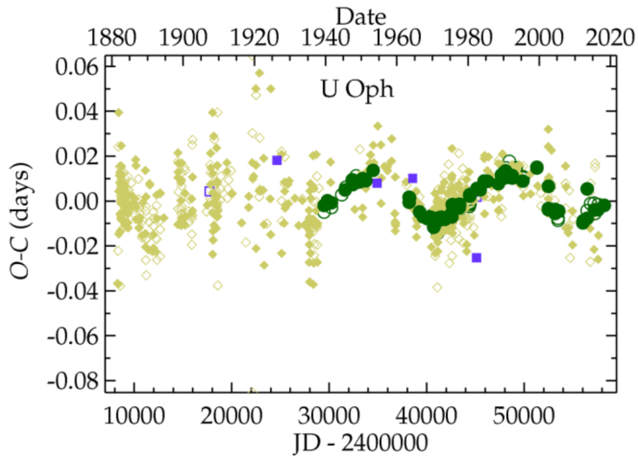

Figure 6. The small variation in the O-C residuals of U Oph due to a third body with P ~ 38 years and a small apsidal motion with U ~ 21 years.

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68 u Her 17 17 19.60 +33 06 00.0 VSX EA/SD 4.69 5.37 $0^m.68$ $2^d.05$

Although often referred to as 68 u Herculis this system is also correctly identified as 68 Her or u Her, but care has to be taken to avoid confusion with the Mira variable U Her. The system is a member of the relatively rare class of hot Algols and contains a B2V primary and a B8III secondary which fills its Roche lobe. The eclipses are modest for an EA system with the primary being $0^m.7$ deep and the secondary ~ $0^m.25$. As the star is so bright, *V* ~ 4.7, it has a long history of observation, and eclipse timings date back nearly 150 years, with photoelectric timings for 100 of those. Having said that the system is relatively poorly observed and until now has shown no sign of any period change, but the most recent observations do suggest a decreasing period. The complete O-C diagram is given in Figure 7 and the line shows the quadratic fit to the primary minima close to $O-C$ = zero excluding the discordant points with $O-C > 0.01$. The quadratic ephemeris of primary minimum is

$$HJD_{MinI} = 2422184.9260(12) + 2.05102663(27) \times E - 4.8(1.4)e11 \times E^2$$

so, the quadratic term is significant at about the 3σ level. Although this result strongly suggests a period change further observations over the next 5 – 10 years will be needed to confirm the trend. Secondary eclipses provide much poorer timings so should be avoided. The current linear ephemeris of primary minimum is

$$HJD_{MinI} = 2459000.8387(11) + 2.05102492(26) \times E$$

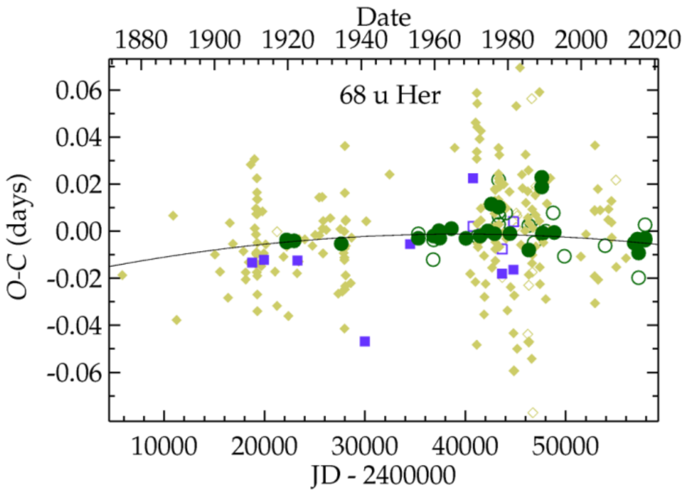


Figure 7. The rather sparse O-C diagram of 68 u Her showing the likely secular period decrease.

V566 Oph 17 56 52.41 +04 59 15.3 VSX EW/KW 7.46 7.96 $0^m.50$ 0^d41

V566 Ophiuchi is well-observed over-contact A-type W UMa system which has not yet reached thermal equilibrium. It is one of the shortest period stars on the list and also has one of the lowest amplitudes. The components are spectral type F4V and both eclipses are very nearly equally deep at ~ $0^m.45$ in *V*, and the secondary is total. Eclipse timings date back to only 1943 but in that time, period changes have accumulated to almost half a cycle (see Figure 8). The O−C diagram is dominated by a dramatic lengthening of the period, but more subtle changes are superimposed. There is some evidence for a ~ 20-year cycle which might be due to a third body or magnetic effects.

Despite the importance of the system it has been neglected in recent years. The mean ephemeris of primary minimum since JD = 2455000 is

$$HJD_{MinI} = 2455032.3364(12) + 0.40965896(27) \times E$$

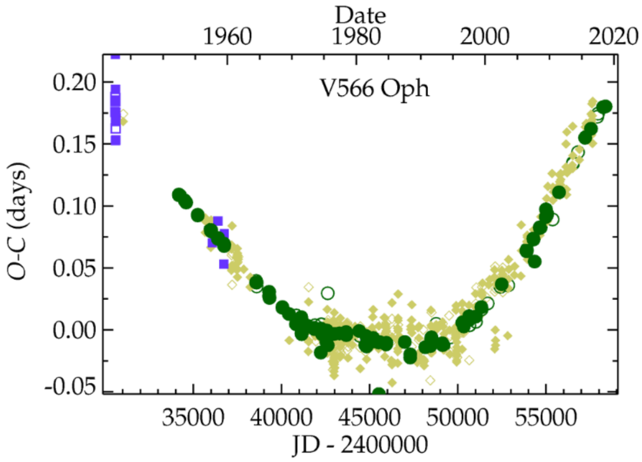


Figure 8. The O-C diagram of V566 Oph is dominated by a secular increase in period but other short-term, possibly cyclical changes are present.

Z Her 17 58 06.98 +15 08 21.9 VSX EA/AR/RS 7.30 8.18 0^m. 88 3^d.99

Z Herculis is an RS CVn variable containing an F4IV-V primary and a larger, cooler secondary - probably a G-type star. Both components are evolved but the system is detached. The light curves and solutions are of some antiquity but show a deep primary eclipse of 0^m.9 and a weak secondary of 0^m.1 with the out-of-eclipse light essentially constant. Times of minima are available for over a century (see Figure 9) but no significant period changes were seen in the data to 1980. However, for the last 20 years the period has clearly been significantly longer, most likely due to an abrupt change ~ 1995. The current ephemeris of primary minimum since JD = 2450000 is

$$HJD_{MinI} = 2450247.3549(26) + 3.9928168(22) \times E$$

but there are short-term variations of ~ 0^d.01 probably due to the movement of spots on the surface of the secondary.

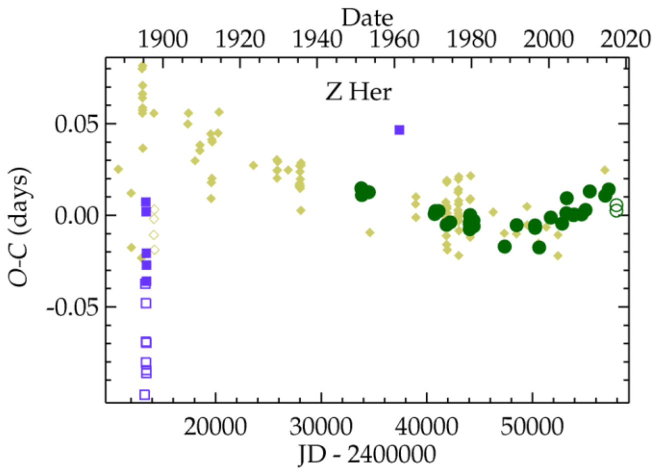


Figure 9. The period of Z Her appears to have undergone an abrupt increase ~ 1995.

Some recent observations of eclipsing binaries using the Open University COAST telescope.

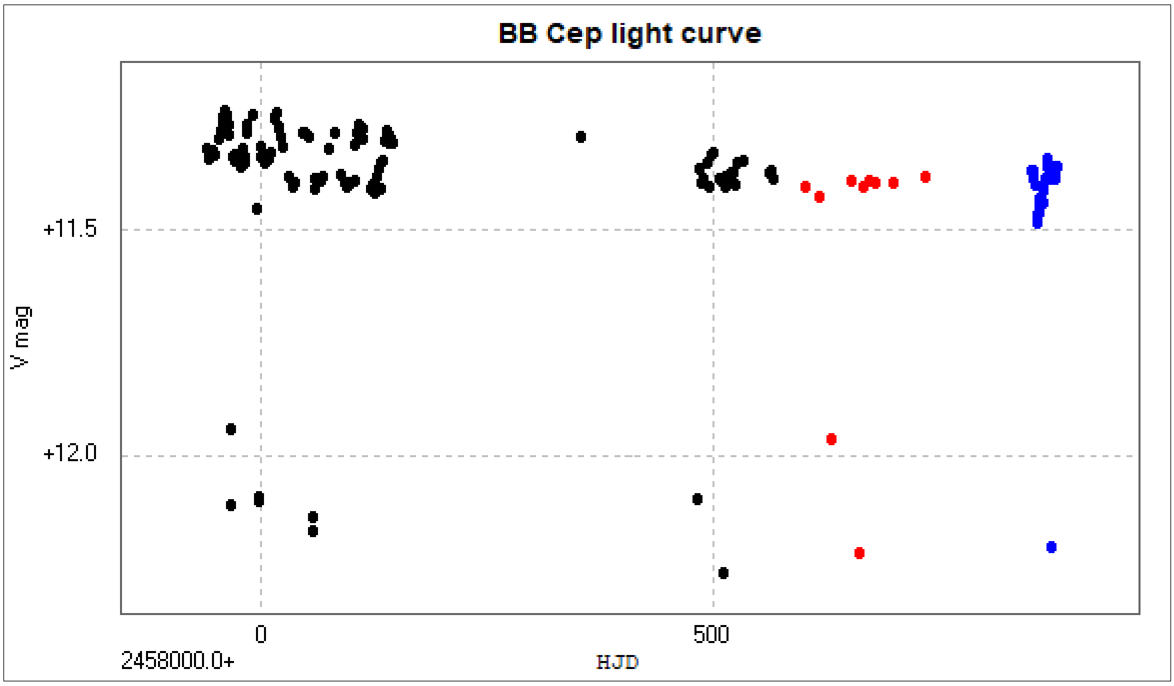
David Connor

An ongoing project to observe eclipsing binaries with the Open University COAST telescope, a 14 inch / 35 cm Schmidt-Cassegrain telescope located on Mt Teide in Tenerife, continues to generate results.

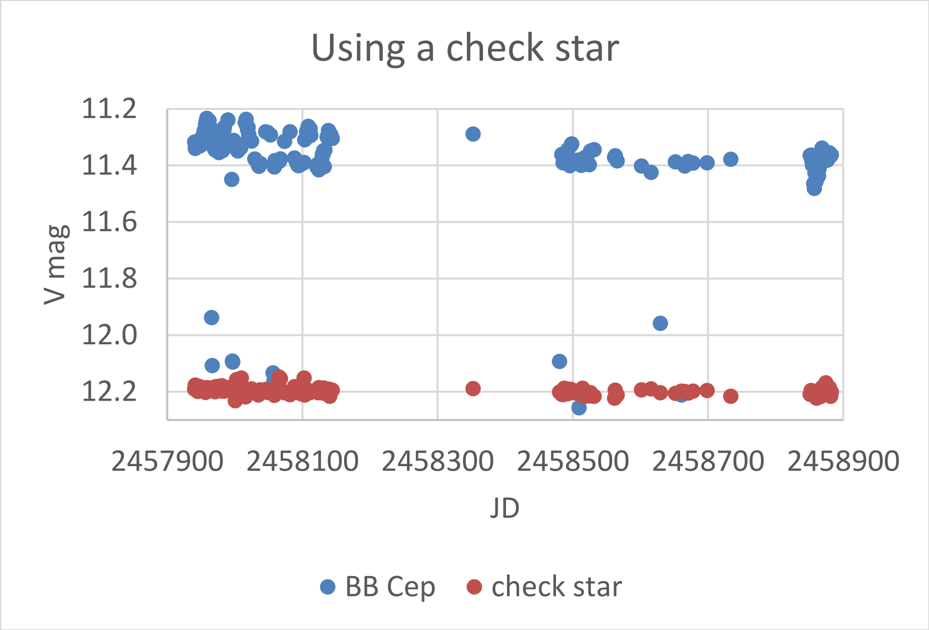
The following are some examples of longer period EB systems. Details of the system types and periods are from the AAVSO VSX, accessed 2020 February 3.

BB Cep (EA/DS p=30.1856d)

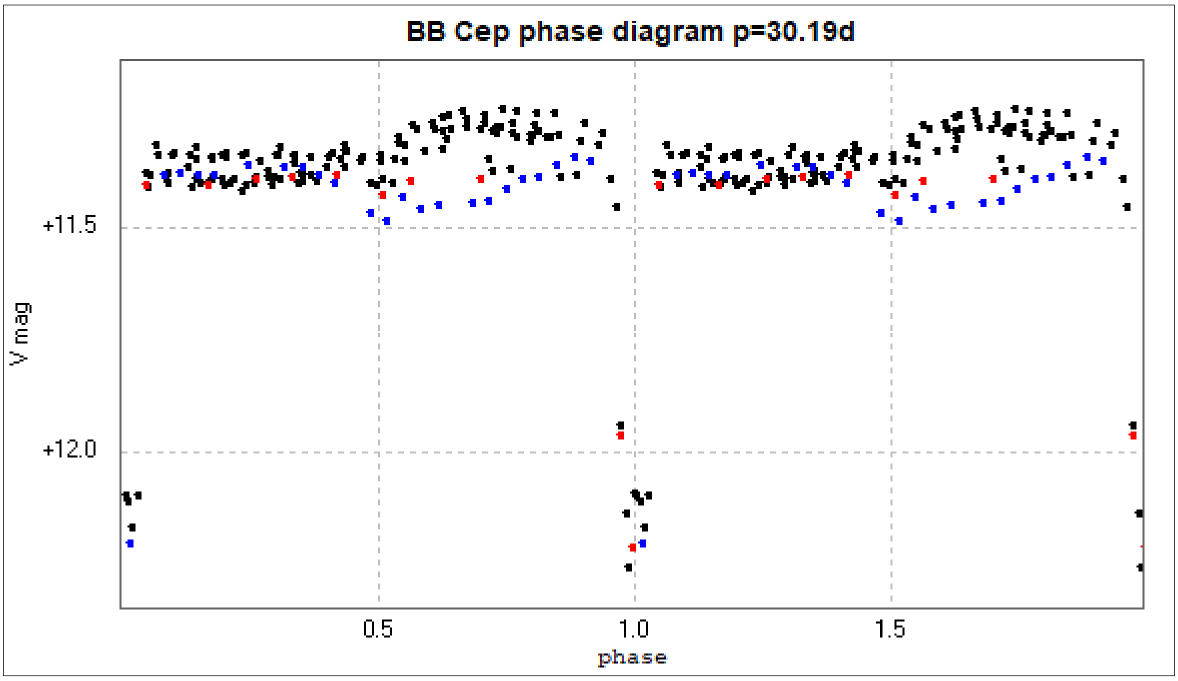
The following light curve of BB Cep was obtained from 164 images taken between 2017 July 6 and 2020 January 30. The light curve is in three coloured sections to highlight regions with different characteristics.



To help reduce the probability that these evident changes are due to systematic or other observational errors the following chart shows the light curve of BB Cep together with that of a check star. A similar procedure was followed for the other variables described below.



In the phase diagram, the doubling of the black section is due to the slight decrease (~0.05 mag) in magnitude which occurs at about JD 2458029.

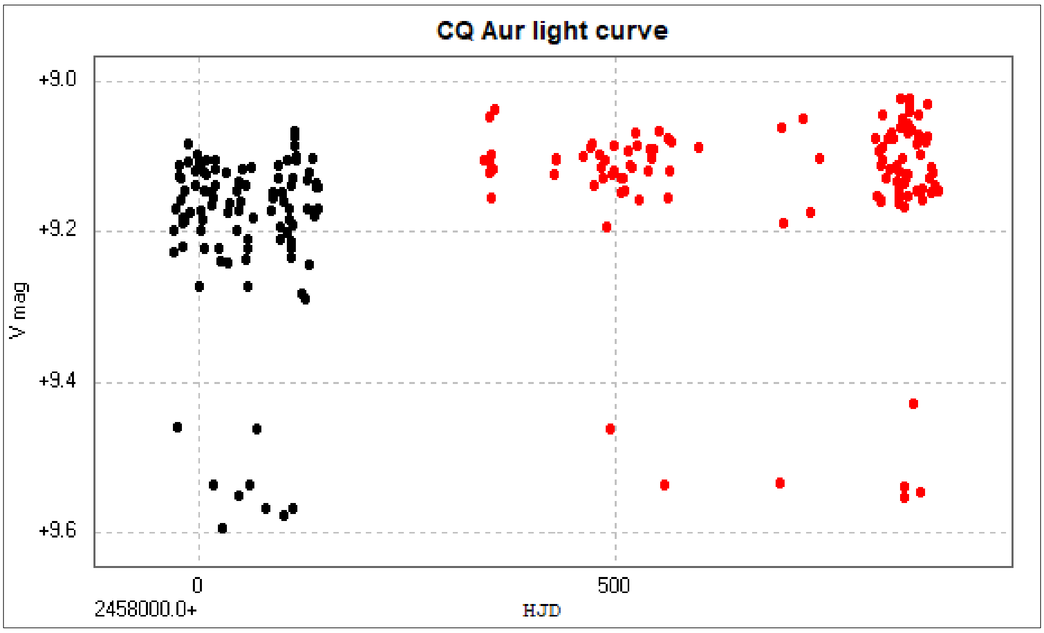


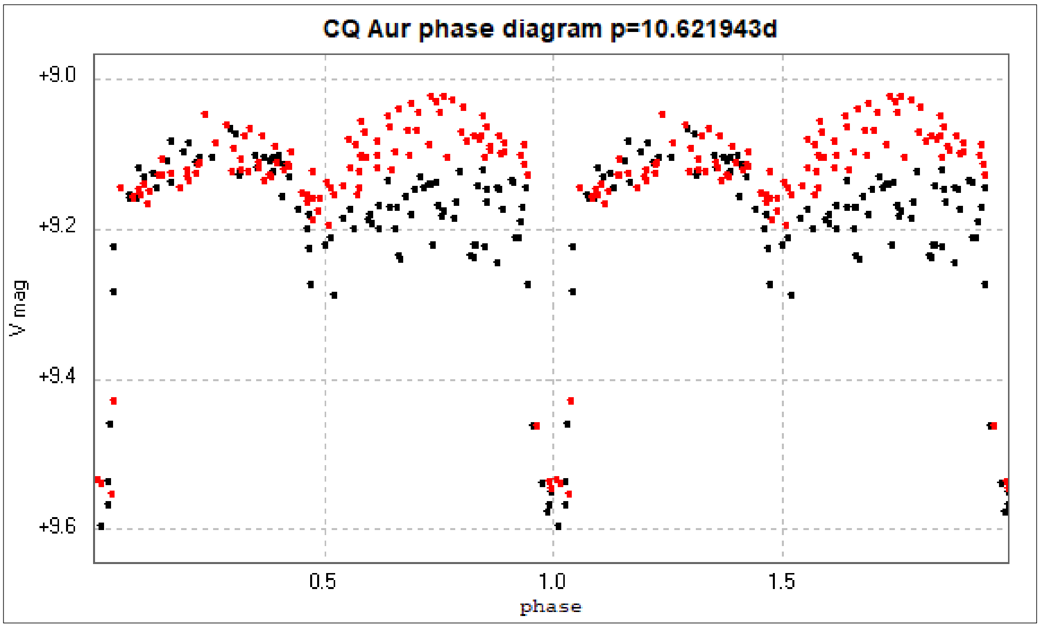
For all sections of the light curve, the phase diagram between phase 0 and phase 0.5 (a low amplitude secondary minimum?) is essentially flat. The second half of the phase diagram (phases 0.5 to 1), on the other hand, changes during these observations. Observations between 2017 July 6 and 2019 May 12 (in black) show this section increasing then decreasing, observations between 2019 May 26 and 2019 September 7 (in red) suggest that this section is now horizontal, and observations between 2020 January 2 and 2020 January 30 (in blue) show that it is decreasing then increasing.

Lacking further data, including spectroscopic information, experiments with Binary Maker 3 suggest that these changes would be consistent with an area on the leading edge of the larger, cooler component decreasing in luminosity/temperature during these observations, similar to RS CVn stars.

CQ Aur (EA/GS/RS p=10.621943d)

Another colour coded light curve. Constructed from photometry of 212 images taken between 2017 August 8 and 2020 February 8, the value of maximum magnitude shows a gently increasing trend. When plotted as a phase diagram it is evident that the magnitude between phase 0 and phase 0.5 has remained essential the same, while the magnitude between phase 0.5 and phase 1 has increased over this time interval by about 0.1 mag. [1]

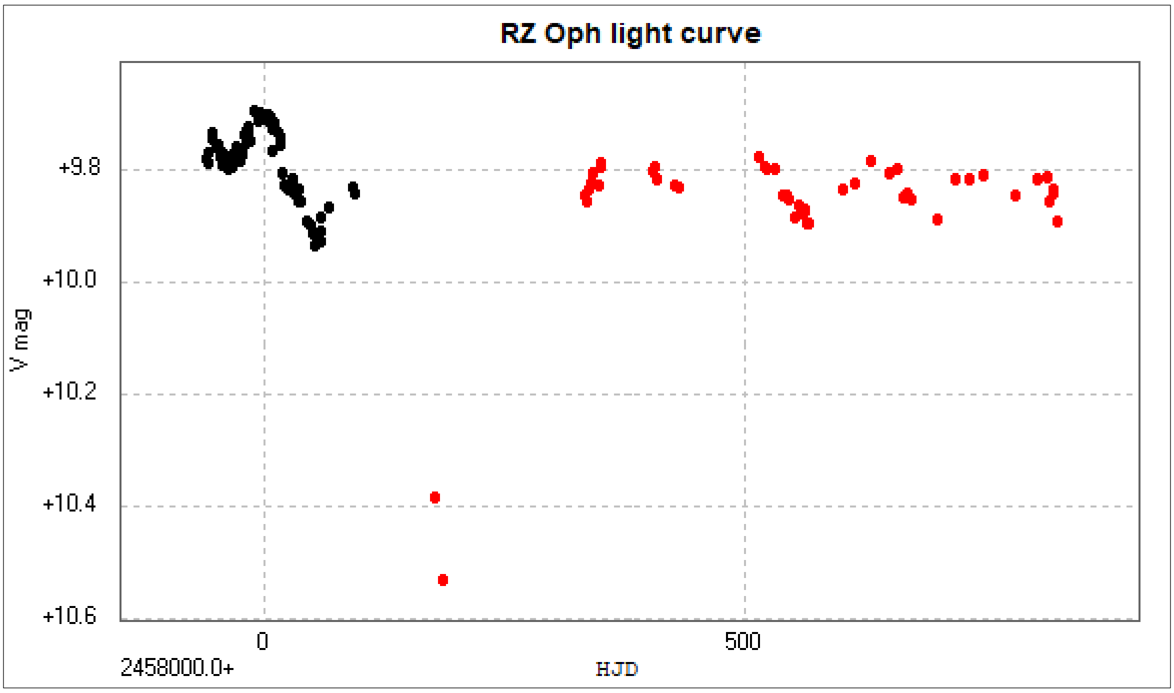


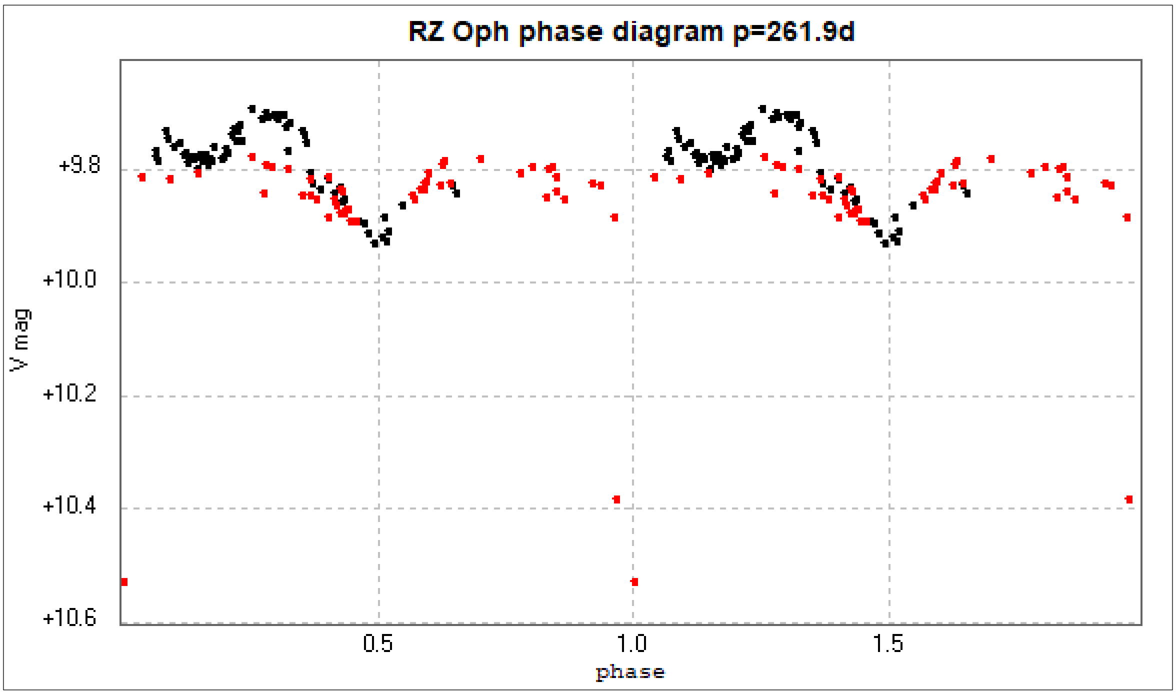


Again, this type of behaviour is consistent with an RS CVn type variable, as has been described by Kang 1993

RZ Oph (EA/GS p=261.9277d)

117 observations between 2017 July 5 and 2019 December 7 resulted in the following light curve and phase diagram



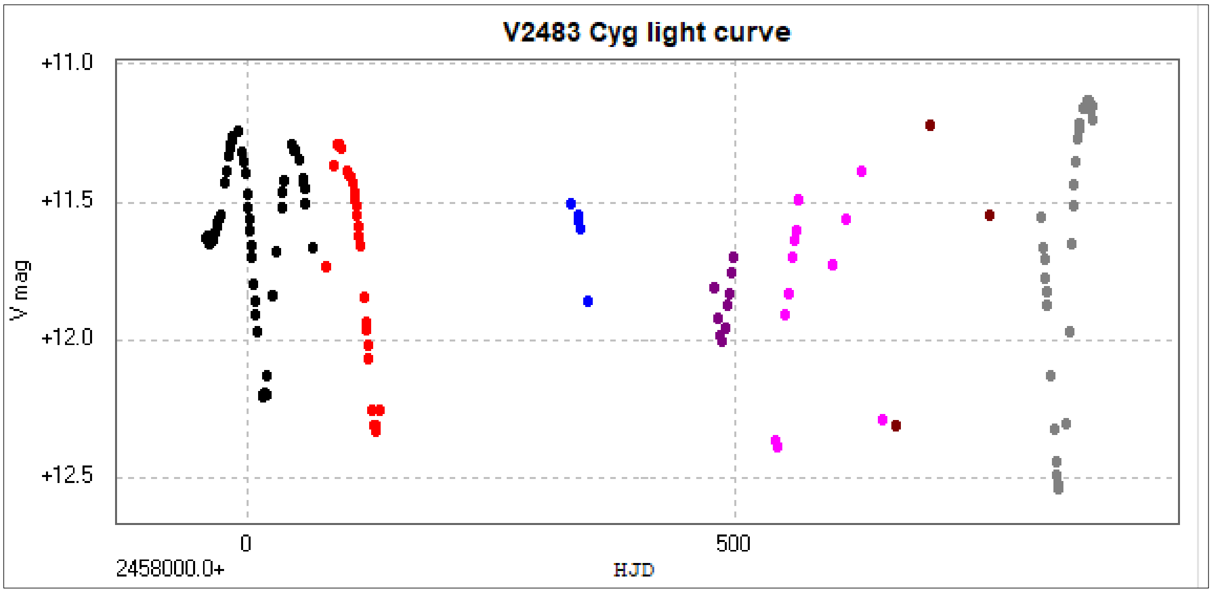


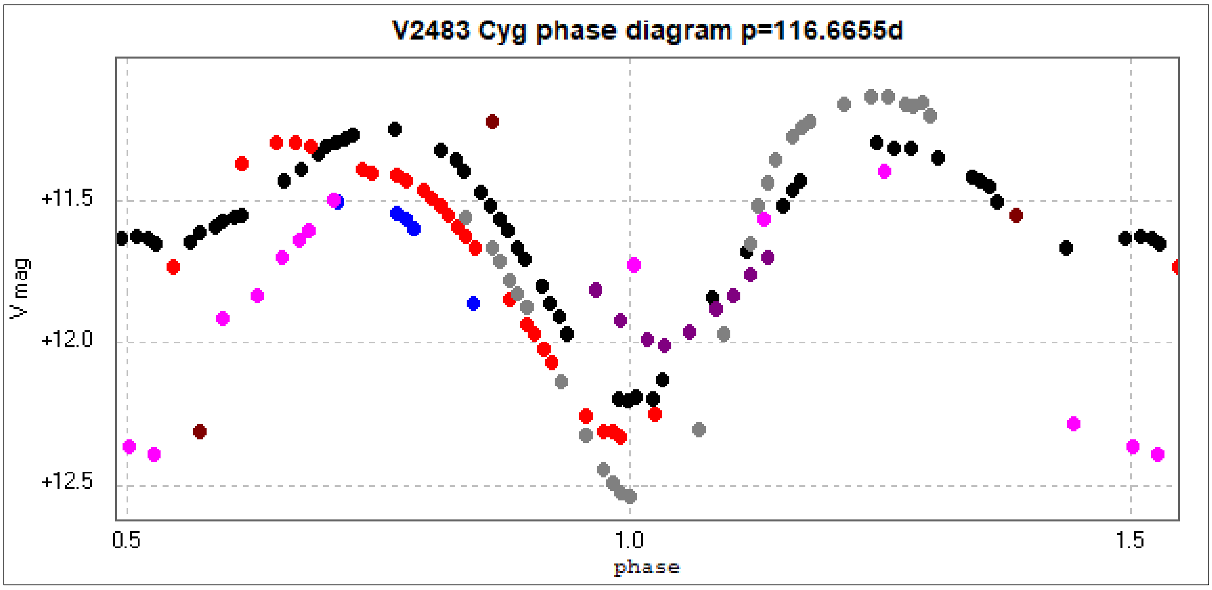
The maximum between phases 0 and 0.5 in the first group of observations is higher than that between phases 0.5 and 1. The latter group of observations shows the two maxima being more like each other, giving a more symmetrical phase diagram. These changes to the light-curve outside eclipses are consistent with temporal changes to an accretion disc around the hotter (F type) component, see e.g. Olson 1993.

V2483 Cyg (EB/GS p=112.40d)

The light curve and phase diagram of V2483 Cyg, from 133 observations between 2017 July 23 and 2020 January 19, have been colour coded into blocks of 116.7 days, which is the best fit period to these observations found by Peranso. The catalogue period of 112.4 days was based on observations of an insufficient number of cycles for an accurate period determination (Otero *et al* 2005)

It is evident that the first 'block', in black, does appear consistent with the EB designation. However, subsequent observations with COAST show a light curve which is not the regular shape expected of a 'simple' eclipsing binary, but one whose amplitude varies significantly from one cycle to the next. This effect is evident in the phase diagram.





This type of light curve is perhaps more consistent with an RV Tau type variable (see OGLE – RV Tauri stars for some examples of RV Tau light curves). These variables are pulsating stars on the post Asymptotic Giant Branch of the HR diagram. This group is subdivided depending upon detailed changes to the light curves. The RVb sub-class might be members of binary systems which show long term modulation to their mean brightness, possibly caused by a dusty disc surrounding the whole system (L.L. Kiss, A. Bódi, 2018). In addition, their periodicity might not be 'strict' (*op. cit.*), which might explain the varying phases of the maxima with respect to the minima.

Future work
Observations of these variables is ongoing with COAST, and further information about these and other eclipsing binaries in this project can be found on my website.

References

1: http://articles.adsabs.harvard.edu/full/1993Ap%26SS.201...35K

Serendipitous discovery of an Eclipsing Binary

James Screech

New discoveries can still be made by the amateur in astronomy despite the ongoing work of large-scale professional sky survey systems. Using only a small telescope and CCD camera, I report the discovery of an EA type eclipsing binary by chance.

I've been observing variable stars using CCD & DSLR cameras for a little over 3 years, having given up on astrophotography due to light pollution. I've used a few different setups over the years but currently use a Canon 500D with a 200mm f2.8 lens un-guided on a Celestron SE4 mount and an Atik 414ex with a photometric V filter, ED70 telescope with a finder guider on a Celestron AVX mount. I mainly observe short period eclipsing binaries with both systems.

On the night of 29th – 30th December 2019 I setup my ED70 system to observe a new variable for me FI Lyn, an EW with a period of just under 9 hours with the hope of getting a full light curve. Due to cloud in the early evening I didn't start my observing run until about 19:45, but with the long winter night I still hoped for a full light curve. Everything went fine and I packed the telescope away the following morning.

It wasn't until later in the day that I transferred the images to my main computer for analysis with Muniwin. Using a chart plotted using VSP I selected the relevant stars and produced a nice clean EW plot for FI Lyn. As an afterthought, I checked the images for other short period variables using Muniwin's 'find variables' feature and to my surprise I found four in the field! It didn't take long to identify three of these as known variables (KL Lyn, KM Lyn & NSVS 4767492) but the fourth remained a mystery. I couldn't find it referenced as variable at its location in any catalogue. I initially identified the star as UCAC4 709-047369 (08 18 10.41 +51 38 19.4) using CdC.

Figure 1 below shows the raw data light curve, there is a lot of scatter in the photometry due to the faintness of the star and the short exposure I was using not to saturate FI Lyn (mag 9.5 -9.9).

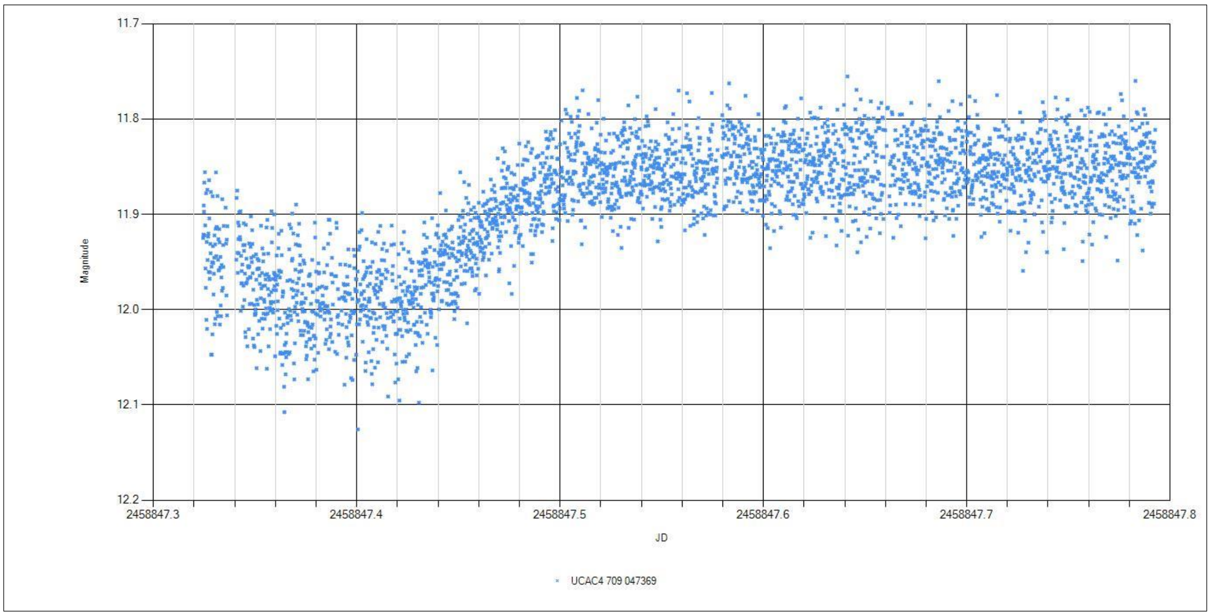


Figure 1.

The shape of the curve becomes even clearer when the data if run through a running average algorithm to reduce the noise, figure 2 below. This smoothed data shows quite clearly the light curve of an EA type with unfortunately the beginning of the eclipse missing. As the eclipse profile is flat bottomed the eclipse must be total, with totality lasting approx. 0.06d (1h 25m) and the rise back to maximum taking 0.08d (1h 55m). Therefore, assuming the drop to minimum is symmetrical with the rise, the total eclipse time was about 0.22d (5h 15m).

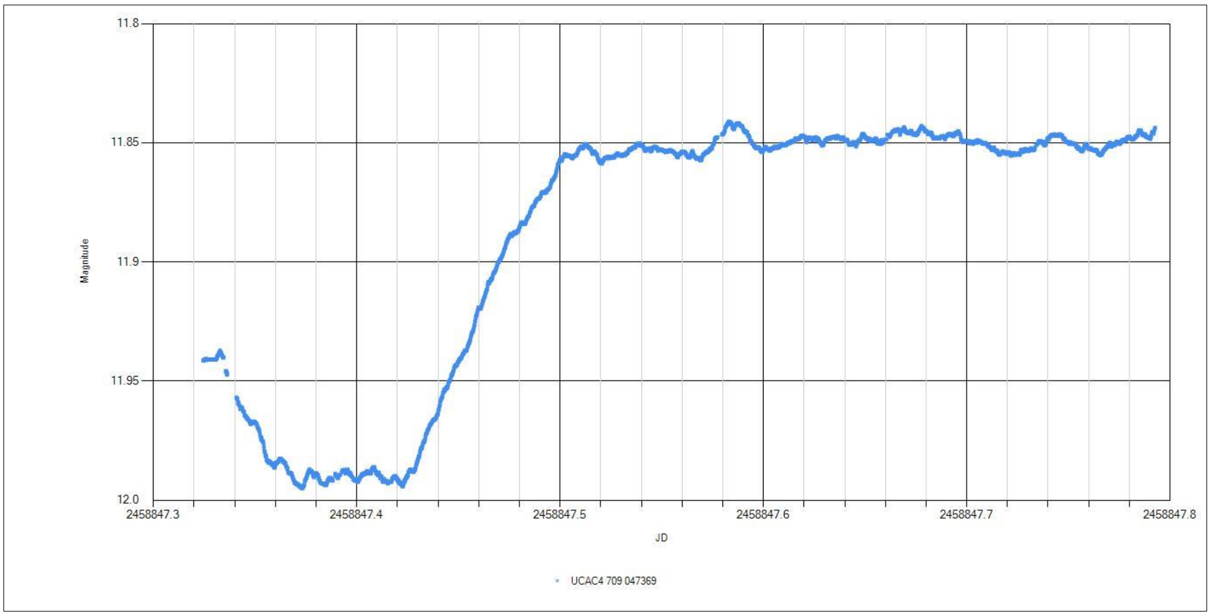


Figure 2.

I initially contacted Jeremy Shears at the BAA VSS for advice of reporting the discovery, and he pointed me to the AAVSO VSX. After reading the submission documentation I filled out their forms for the star. A few days later I was contacted my Sebastian Otero from the AAVSO with suggested changes to my submission, including using the star's GSC id (GSC 03421-01402) instead of the UCAC4 id initially used. The star had previously been suspected as being variable with a period of 0.497935d but was marked as dubious so they didn't consider it as discovered, therefore my claim stood. On 30th January 2020 I received an email from the AAVSO VSX confirming my claim of discovery.

After my initial observing run, I have observed the field a further eight times (up to 11th February 2020) with no further eclipses seen, see table 1 below.

Start time	End time
2458852.30	2458852.46
2458855.31	2458855.68
2458864.22	2458864.60
2458868.23	2458868.65
2458869.23	2458869.72
2458877.24	2458877.78
2458886.25	2458886.77
2458891.25	2458891.77

From my observations so far, I can say the eclipse lasted in total about 0.22d, period is longer than 0.76d, the eclipse is either total or annular, the eclipse I captured could potentially be either a primary or secondary minimum. Due to the brightness only dropping by 0.14mag I suspect that this may be a secondary minimum, with the brighter larger star passing in front of a smaller fainter star (based on the assumption that larger stars are generally brighter than smaller stars), however this suspicion will only be confirmed when more minima have been recorded.

I will continue monitoring this star at every opportunity over the coming months to try and capture more minima and to calculate the period and confirm that this observation was of a secondary-minimum.

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Please make sure of your spelling before submitting to the editor. English (not American English) is used throughout this publication.

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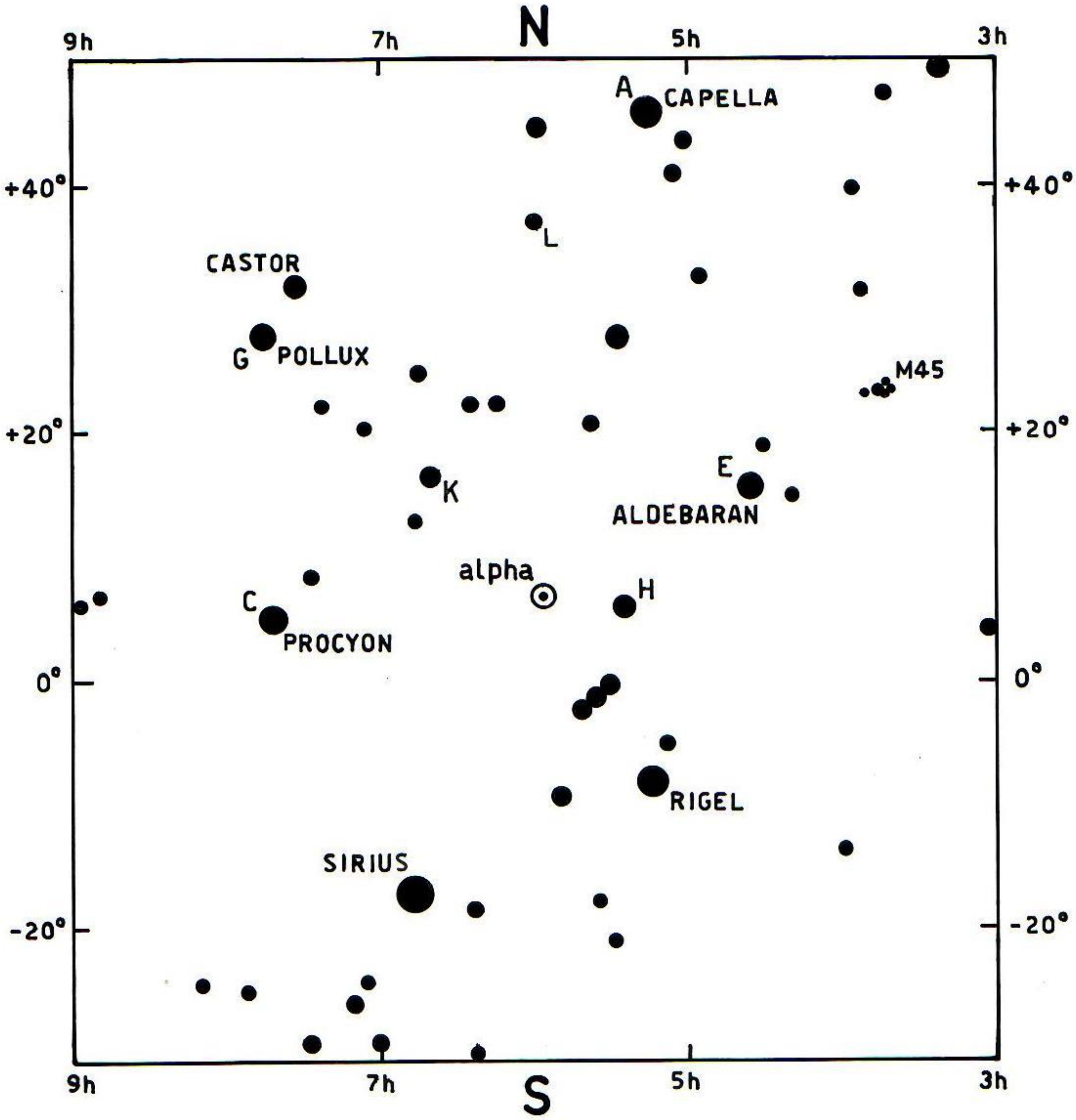
alpha ORIONIS 05h 55m 10·3s +07° 24′ 25″ (2000)



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NORTONS SA	C 0·4	K 1·9	EPOCH: 2000
SEQUENCE:	E 0·9	L 2·6	DRAWN: JT 25-01-20
HIPPARCOS VJ	G 1·2		APPROVED: RDP

300·02 20′ FIELD INVERTED

U LEONIS 10h 24m 03·3s +14° 00′11″ (2000)

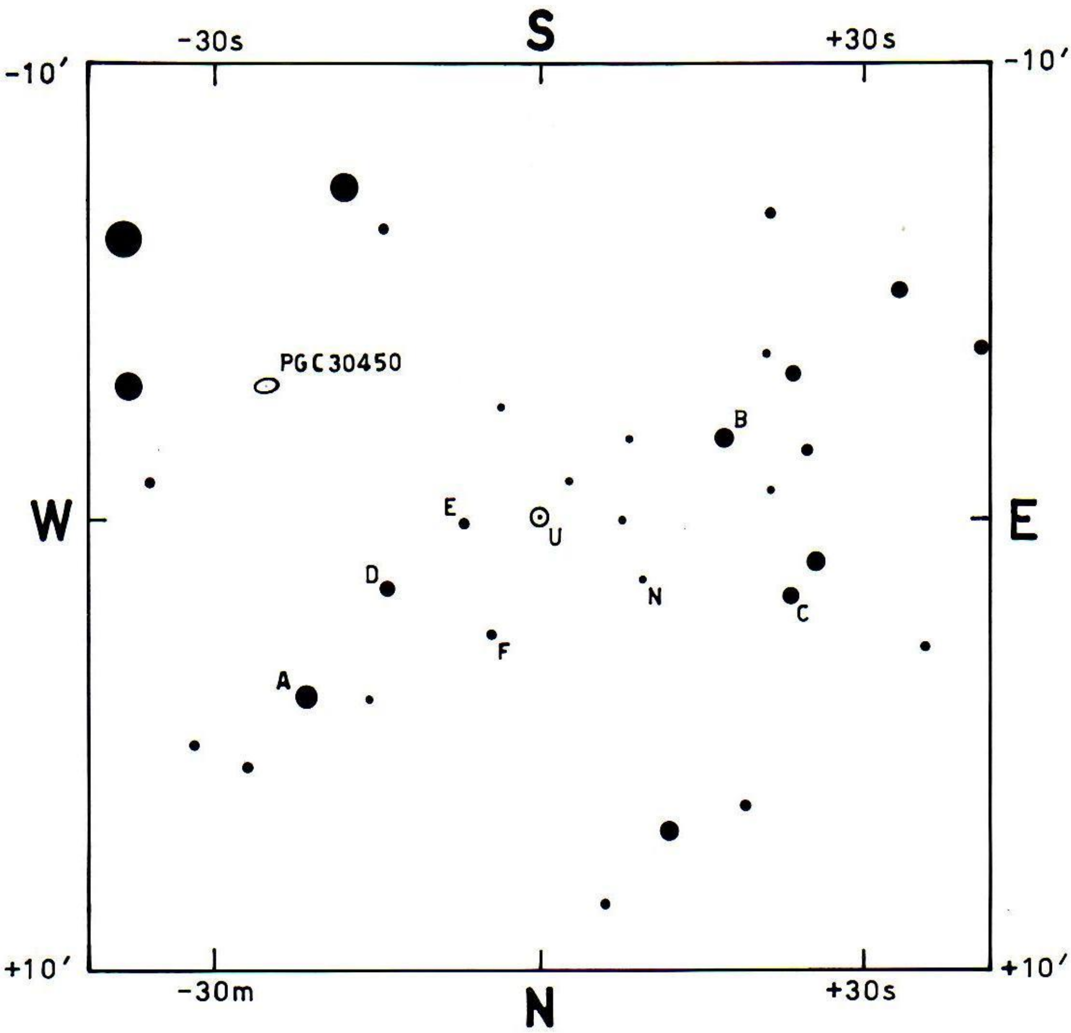

CHART:
GUIDE 8 & BOYD

SEQUENCE:
N DOWNES & SZKODY
OTHERS BOYD

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C 13·9	N 17·3
D 14·2	

BAA VSS
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