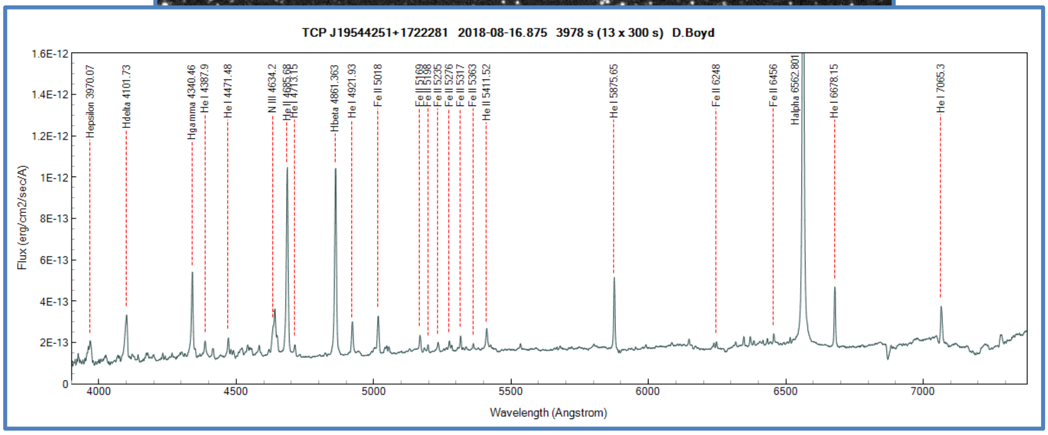
The British Astronomical Association

Variable Star Section Circular

No. 177 September 2018



Office: Burlington House, Piccadilly, London W1J 0DU

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Cover images
Vend47 or ASASSN-V J195442.95+172212.6
2018 August 14.294, iTel 0.62m Planewave CDK @ f6.5 + FLI PL09--- CCD. 60 secs lum.
Martin Mobberley
Spectrum taken with a LISA spectroscope on Aug 16.875UT. C-11. Total exposure 1.1hr
David Boyd
Click on images to see in larger scale

Observers' Workshop - Variable Stars, Photometry and Spectroscopy.

Venue: Burlington House, Piccadilly, London, W1J 0DU (click to see map)

Date: Saturday, 2018, September 29 - 10:00 to 17:30

For information about booking for this meeting, click here.

A workshop to help you get the best from observing the stars, be it visually, with a CCD or DSLR or by using a spectroscope.

The topics covered will include:

- Visual observing with binoculars or a telescope
- DSLR and CCD observing
- What you can learn from spectroscopy

And amongst those topics the types of star covered will include, CV and Eruptive Stars, Pulsating Stars and Eclipsing Binaries.

The Q&A sessions for all topics will help you find out all you need to know from the speakers and experts on hand.

Speakers to include Roger Pickard, John Toone, Andy Wilson, David Boyd and Richard Lee.

Booking information

The workshop costs £2 for BAA and Affiliated Society members, and accompanied young people under 16, and £3 for non-members, to cover refreshments. Lunch is not included as there are plenty of cafes & eating places close by.

To book your place contact the BAA Office by 2018 Sept 21:

- Book through the BAA online shop
- Tel: 020 7734 4145

Roger Pickard, Director BAA VSS
roger.pickard@sky.com

From the Director

Roger Pickard

Joint BAA-AAVSO meeting

I'm delighted to advise that this meeting was a great success, and everybody seemed to thoroughly enjoy themselves. Many thanks go to David Boyd who did much of the organising on the VS side. Now, many thanks also go to Andy Wilson who has transcribed all his notes into those you'll read later in this Circular. Thank you, Andy. The talks are also available for BAA Members to enjoy again at https://britastro.org/video/13861

AUTUMN MIRAS

M = Max, m = min.

W And	*m*=Oct
RW And	*m*=Sep/Oct
UV Aur	*M*=Sep/Oct
X Cam	*M*=Nov/Dec
	m=Sep
SU Cnc	*m*=Nov/Dec
RT CVn	*m*=Sep/Oct
omicron Cet	*M*=Nov/Dec
V CrB	*M*=Oct
W CrB	*m*=Nov
SS Her	*M*=Aug/Sep
	m=Oct/Nov
R Hya	*M*=Oct
SU Lac	*M*=Sep/Oct
RS Leo	*m*=Nov/Dec
W Lyn	*m*=Oct/Nov
X Lyn	*m*=Nov/Dec
T UMa	*M*=Oct/Nov

Source BAA Handbook

A Zooniverse project to classify periodic variable stars from SuperWASP

I would like to draw your attention to the Zooniverse project by Professor Andrew Norton of The Open University which appears later in this Circular and hope that many of you will take part.

The VISTA Variables in the Vía Láctea (VVV) Survey

In addition to Andrew's project mentioned above, John Fairweather also drew the following to my attention.

This survey is an ESO Public Survey that is mapping the central region of the Milky Way in near infrared light. It is also acquiring ~100 repeated exposure in the Ks band, so we can construct a movie of the sky.

One of the key goals of the VVV Survey is to identify new variables stars, i.e., stars whose brightness changes periodically with time. Many of them are stars that expand and contract, as if they were breathing, such as RR Lyrae, Cepheids or Miras. Each of these stars breath pulsate only during a very specific phase of their evolution, corresponding to a very specific internal stratification that we understand and are able to model very well. Once we identify one of these variables, we can predict what is their real luminosity, their mass and their age.

The real luminosity, i.e., the energy they produce per second, allows us to derive their distance, by comparison with their apparent luminosity. Distances are of paramount importance in astronomy, because they allow us to go from our two-dimensional view of the night sky to a three-dimensional representation of our Galaxy in space. On the other hand, their age will give us information about when did star formation occur in that region of the Milky Way. Hence it will tell us how did the inner Galaxy form.

In order to identify one of these variables, we look at the period and the shape of their luminosity (or brightness) change versus time, also known as "light curve". However, some variables have similar light curves, that are not easy to tell apart with automatized software. In addition, some variables have light curves similar to those of binary stars. The latter do not change their individual luminosity, but the total light we see might change because they periodically eclipse each other.

We have millions of light curves for variables that we have not yet identified. Here we have uploaded thousands of them to be classified. Because no automatized software does a better job than your brain (they are faster, but not smarter) perhaps you can lend us a few of your neurons for a short period of time and help us with the task of identifying what kind of variable star we are looking at. You will be contributing to the mapping of the 3D inner structure of the Galaxy we live in, and to the understanding of when the stars we see on a dark night formed.

John also notes: - Andrew's project uses data from SuperWASP (All-sky survey), which the Chile's project doesn't (central Milky Way), but I would imagine the data would overlap – I'm not sure if that is a duplication of effort?

Charts

If you use or refer to a sequence (other than the modern AAVSO ones) that is not in the database please advise both the Director and Ian Miller who looks after the sequence data files on behalf of the BAAVSS.

V648 Car

This article by Steve Fleming, Terry Moon and David Hoxley appeared in the last Circular and has now been placed online in the "Articles" section of the VSS web page.

LISA spectrograph available

BAA member Andrew Smith, one of our more advanced spectroscopists, has very kindly donated a LISA spectrograph to the BAA for the Association to use in support of its initiative aimed at encouraging members to take up spectroscopy. We are looking to lend the spectrograph to people who have suitable projects in mind.

This is a sophisticated instrument capable of a wide range of variable star projects. It would for example make a nice step up for those already using an Alpy or Star Analyser or offer a good opportunity for an experienced photometrist to become involved in spectroscopy. The LISA comes complete with a guide camera but no imaging camera. It is a reasonably heavy spectrograph, especially when combined with both imaging and guide cameras, requiring a solid telescope mounting and robust focuser. So, any applications should demonstrate that your existing equipment is capable of handling the weight, and you should already have an appropriate imaging camera, typically a mono chromatic CCD.

Those with a track record in spectroscopy and who have been submitting to the BAA Spectroscopy Database will be considered favourably, as well as experienced photometrists who submit their observations to the BAA VSS Database. All spectra taken with the LISA will need to be fully processed and submitted to the BAA Spectroscopy database. The results should also be written up and submitted to either the VSSC or the BAA Journal.

Any application for the LISA needs to be based around a good variable star project that would suit the LISA and the duration of the project should also be specified. This should include time to get familiar with the LISA, and spectroscopy processing software for anyone who is new to the subject. The following projects are intended as suggestions which could be used as the basis for the application, while all good project ideas will be considered.

- Spectroscopic monitoring of Mira stars over a pulsation cycle.
- Intense observations of bright novae to monitor their changing spectra over the duration of an outburst.
- Observations of Young Stellar Objects such as T Tauri and Herbig Ae stars. Monitoring these stars to see if changes in their spectra are visible over various time periods.
- Searching for Be stars.

If you are interested in borrowing the LISA spectroscope you are invited to submit your proposal to Roger Pickard by 31st January 2019. David Boyd, who already owns a LISA, will be happy to advice on suitability of equipment and to offer support to whoever uses it, as will Andy Wilson.

The applicant must be a member of the BAA and the BAA VSS and have some experience in using a spectrograph or performing photometry.

CV&E News

Gary Poyner

RCB's
Quite apart from R CrB itself (see below), we have a couple of active RCB stars worth mentioning which are well placed for observing in our skies at this time of year.

AO Her: First recognized as an RCB star as late as 2013 after being catalogued as a 370d SR star, AO Her has been in an active state since that time. Seven fades to minimum have been recorded, including deep minimums of ~18.5V during September 2015, October 2017 and April 2018. Maximum magnitude is around 11.0mv, and is therefore an easy target for small telescopes. AO Her is currently recovering from the April '18 low state and is currently (late-August 2018) magnitude 13.2V. This rise is a little steeper than the last recovery in 2016 and is definitely worth keeping your eye on.

VSX

V742 Lyr: Initially catalogued as NSV 11154, V742 Lyr has undergone three fades since 2010 when the first observations were recorded. In March 2015 a brief fade to magnitude 16.0V was observed from a maximum of 12.0V. A partial recovery to mag. 13.0mv followed, before a further decline to 14.5mv followed that. A slow 6-month recovery to maximum was then interrupted when in August 2017, V742 Lyr faded by seven magnitudes to mag 19.0V in just eight weeks. After spending four months in this deep minimum V742 Lyr slowly began to brighten, and by late August 2018 has reached magnitude 13.2mv and continues to rise very slowly.

VSX / arXiv

U Aqr: At a declination of -16 37', it's hardly surprising that observations of U Aqr are quite sparse in the VSS database. Nevertheless, with remote telescope observing pretty much the norm these days, U Aqr remains an interesting RCB star to monitor with both shallow and deep fades observed over the past century. U Aqr has been fading since early Spring of this year and is currently at magnitude 18.0V. Previous deep fades have been recorded to below 19.0V, so we might yet have some way to go before minimum is reached. If you can image that low or have access to a remote telescope, why not add it to your list?

VSX

V482 Cyg: Whilst the previous three objects are all active at this time, V482 Cyg remains stubbornly the opposite. The last fade occurring in this RCB star was 1996 (to magnitude 13.0mv), and since that time V482 Cyg has varied between magnitude 10.5-11.5, with just occasional suggestions that it hadn't 'switched off' altogether with some observers recording a brief drop to magnitude 12.0 before normality is quickly resumed. Prior to 1996, three fades to 14.0-15.0mv had been recorded in 1977 (AAVSO), 1988 & 1990. AAVSO data starts in 1967. Subtle changes are easy to miss in a star which appears unchanging from night to night, so care should be taken when observing. Just tell yourself that it will fade at some stage!

VSX

CV's

AM Her: The proto-type magnetic Polar AM Her has now returned to high state (12.5-13.0mv) following a very long 16-month period in low state varying between 15.0-16.0mv. From a visual inspection of the AAVSO light curve, this looks like the longest low state on record. The recovery was a little unusual – a rise from 15.2mv on Jly 2 to 13.3 mean by July 10 looked to be the one we had been waiting for, but a drop of 1.9 magnitudes from 13.5 on Jly 14.0 to 15.4 on Jly 14.9 suggested that we were in for an interesting time. Low state was resumed until July 23 when a (comparatively) slow rise began from 14.0mv to 12.9 by Jly 21.9 where it remains still.

An over simplified explanation to AM Her stars behavior is that these systems are accreting CV's with a highly magnetic white dwarf which disrupts the formation of an accretion disc. Instead we have an accretion stream being channelled along the magnetic field lines to impact onto the white dwarfs' pole (or both poles at times). The majority of radiation observed at this time is from the accretion stream and impact area on the WD (lots of X-rays too). This is the scenario at high state. At irregular intervals something disrupts the mass transfer from the secondary (magnetic field, starspots) and the whole system enters low state until normality is resumed. Most (but not all) of these systems are synchronous, in that the WD spin is locked to the Porb of the system, which is typically 80-300 minutes.

VSS Chart / VSX

And finally, Hungarian VS observer Robert Fidrich has reported his discovery of a bright new symbiotic star in the constellation of Saggitae. You can see details of his discovery on two BAAVSS alert notices 5054 and 5057, and the cover image on this circular, kindly supplied by Martin Mobberley and David Boyd, showing the new ZAND star and spectrum bright at magnitude 11.0. It's not often we get new bright symbiotic stars discovered, especially by amateurs, so I hope many of you will add it to your observing programme. You can use either of the names ASASSN-V J195442.95+172212.6 or Vend47, and charts are available from the AAVSO VSP, again using either of the above designations. Our congratulations to Robert on his discovery!

VSX

AC Herculis

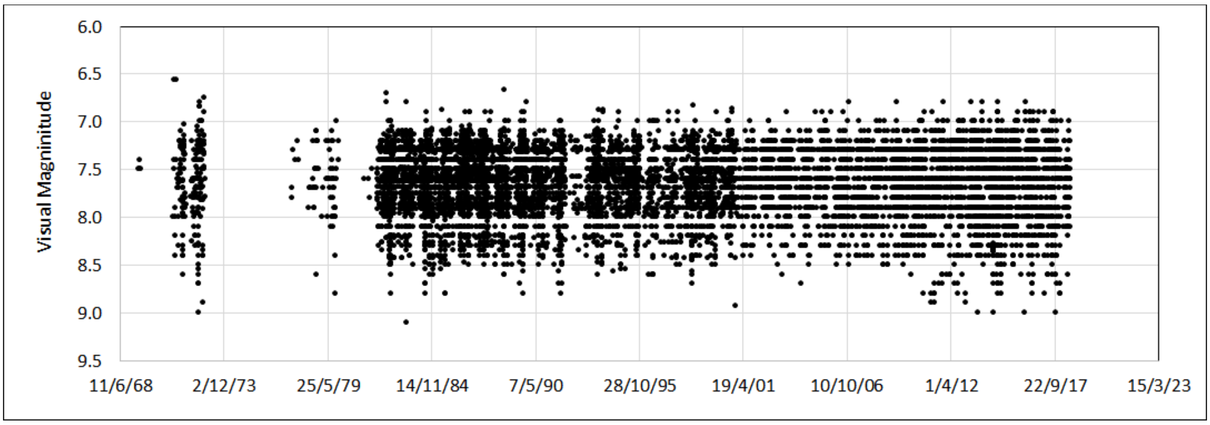
Shaun Albrighton

RV Tauri stars are a rare type of variable, with only 120 listed (1996). Theory suggests that they represent the very late evolutionary stage of a solar mass star (usually population II) and are pulsating supergiants of spectral class F, G or K. Having passed through the AGB branch of the Hertzsprung Russell diagram, they have lost a significant proportion of their mass, typically now having a mass of M=0.5-0.7 solar masses and are now re-entering the instability strip. It is believed that they only live in this state for a few thousand years, hence why we only observe a small number of these objects. The stars themselves represent a point prior to the expulsion of a planetary nebula and contraction to a white dwarf. So, by observing these stars we are exploring stars in their final stages of evolution.
The main characteristics of the light curve of RV Tauri stars is the double wave with alternating primary (deep) and secondary (shallow) minima. The amplitude of variation can reach 3 to 4 magnitudes. The formal period is measured between two adjacent primary minima (double minima) and lie in the range of 30 to 150 days.

There are two types of RV Tauri stars, RVa and RVb. RVa are stars that do not vary in their mean magnitude, whereas RVb stars do show this secondary variation. This is typically in the range of 600 to 1,500 days, with an amplitude of 2 magnitudes. Whilst some RV Tauri stars adhere to this simplified definition, others display more complex light curves, with an almost random distribution of depths of minima. Pulsations in the star mean that it is hottest and smallest halfway through primary minima towards maxima and coolest near deep minima. As brightness increases, hydrogen emission lines often appear in the spectra and may be double. These fade after a few days. RV stars are also strong infrared sources, with substantial amounts of dust surrounding them.

AC Herculis is a bright RVa type variable, which can (with early morning observations) be followed for practically the whole year from British latitudes. It is listed in VSX as spectral type F2plb – K4e(C0,0), mag range 6.85-9.0V, with a period of 75.29d.

To date the BAAVSS has received over 9,500 estimates of AC Her, between June 1969 and July 2018, and a full light curve is seen below. This reveals a magnitude range of about 6.8 -9.0.



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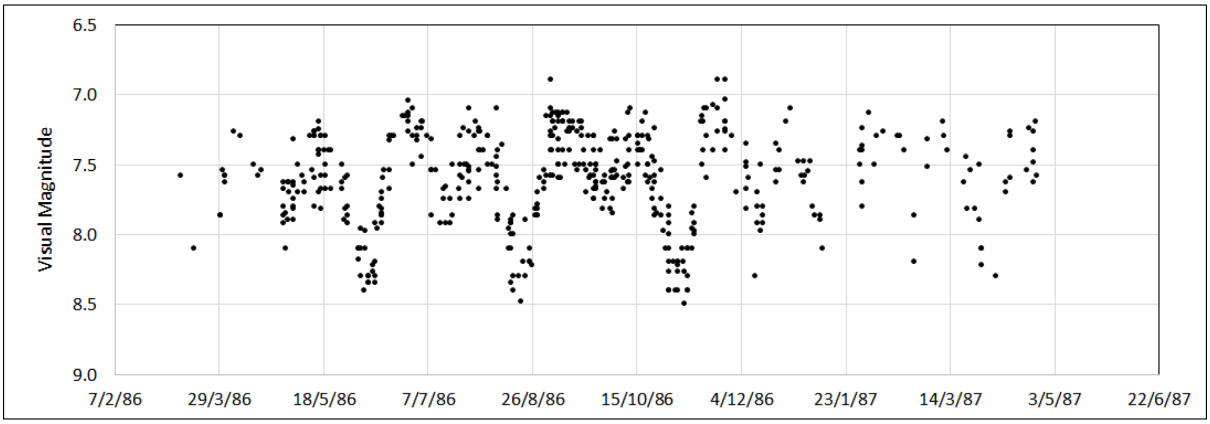
The below plot confirms the typical light curve of AC Her, readily showing the alternating primary and secondary minima.



Analysis of all observations using the AAVSO VStar program reveals the top five results. It will be noted that the most prominent hit represents the half period i.e., primary to secondary minima or vice versa. As such it is the second result of 75.43 days which represents the correct result. Results of 37.86d and 37.54d possibly indicate small changes in the period

Period (days)	Power	Amplitude (mag)
37.72	1699.3	0.30
75.43	709.6	0.19
37.86	433.3	0.15
37.54	238.3	0.13
42.04	178.0	0.11

To investigate this possible change in periods, three separate time frames were chosen, 1970/71, 1986-88 and 2015-2018 (it should be noted that the observations from 1970/71 are both fewer and appear more scattered). Below is a table listing the main period, power and amplitude for each of the three time frames. These results suggest that there has been a reduction in period from 76d to 75d over the 48-year period.

	Period (days)	Power	Amplitude
1970/71	76.02	22.7	0.27
1986-88	75.38	113.1	0.21
2015-18	74.94	45.9	0.25

To summarise BAAVSS confirm AC Her to be of type RVa, with a maximum range of 6.8-9.0, and a period of 75.43 days, longer than the VSX listing of 75.29 days. In addition, there is some suggestion that the period may have reduced. Continued observations are therefore requested so that confirmation of this trend can be monitored.

References

Nonlinear pulsations of the RV Tauri stars, A. B. Fokin. Astron Astrophysics 292, 133-151 (1994).
adsabs.harvard.edu

Long Term Changes in RV Tauri stars, John Percy (1993). SAO/NASA Astrophysics Data System (ADS). *adsabs.harvard.edu*
RV Tauri, Dr Matthew Templeton. *aavso.org/rvtauri*

VSS Chart / VSX

R CrB in 2018 – The Longest Fully Substantiated Fade

John Toone

In June 2009 (BAA VSS Circular 140, pages 22-26) I reported that R CrB had dropped to a record faint level during a deep fade that had commenced in mid-2007. R CrB reached its faintest level in late March/early April 2009 at magnitude 15.1 (both mv and V). Now I can report that the current fade of R CrB is also a record in terms of length.

The previous longest continuous fade of R CrB lasted just under 11 years between 1863 & 1874 and a light curve of this fade is reproduced on page 703 in Burnham's Celestial Handbook. To measure the precise length of this fade I consulted Ludendorff's monograph of R CrB during the years 1783-1905 (No 57 of the Publications of the Potsdam Observatory). Here is the result:

Fade in 1863
The timing can only be approximated through Schmidt's observations who recorded R CrB at normal maximum on 28 October 1863 (JD2401807) and his next observation was <10.5 mag on 22 November 1863 (JD2401832). The mid-point of these observations is 10 November 1863 (JD2401820).

Recovery in 1874
This can be more accurately fixed through Schonfeld's observations who recorded R CrB at mag 6.3 on the 24 August 1874 (JD2405760) and 6.1 on the 9 September 1874 (JD2405776). Therefore, one can be confident that R CrB was effectively back at maximum by 3 September 1874 (JD2405770).

The duration of the 1863-1874 fade can be calculated as JD2405770 – JD2401820 = 3950 days.

The start of the current fade of R CrB can be assumed as 7 July 2007 (JD2454289) when R CrB dropped to mag 6.3 (the lower limit of pulsations at maximum) and started to free-fall.

Therefore, the current fade equalled the length of the 1863-1874 fade on: JD2454289 + 3950 = JD2458239 = 30 April 2018.

The current fade of R CrB exceeded 11 years during the joint AAVSO/BAA VSS meeting in Warwick on 7 July 2018. As I write these words (31 July 2018) R CrB is still approximately 0.5 mag below normal maximum brightness and the record fade in terms of length continues.

(Editor's Note: As of August 31st, R CrB has still not reached maximum brightness)

VSS Chart / VSX

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KIC 9832227 – a potential Luminous Red Nova in 2022

David Boyd

First detected as variable in 1999 during the Northern Sky Variability Survey (NSVS), the star GSC 03543-01211 in Cygnus was initially classified as an RR Lyrae variable. Subsequent observations by the All-Sky Automated Survey (ASAS) concluded it was an EW-type eclipsing binary. It was included in the target list for the Kepler satellite and assigned the Kepler Input Catalog designation KIC 9832227. Subsequent analysis of ground-based and Kepler data concluded that its true nature remained uncertain (Kinemuchi 2013). However, Molnar et al. (2017) found by analysis of all available data between 1999 and 2016 that its behaviour was consistent with a contact binary that had an exponentially reducing orbital period.

This was recognised as a similar situation to the red nova V1309 Sco (Nova Sco 2008) which was retrospectively found to have been a contact binary with an exponentially reducing orbital period which eventually led to merger. Assuming KIC 9832227 is the precursor to such an event, Molnar estimated the two stars will coalesce in the year 2022.2 ± 0.7. The orbital period at the present time is 0.458 days. From colour indices measured with Sloan photometric filters and a comparison of measured and model spectra, Molnar estimated the effective surface temperature of the composite object to be 5828 K.

My measurements with a 0.35m SCT using B and V filters on 2018 April 18 and August 5 gave V = 12.46 and V = 12.34 with (B-V) = 0.71 on both dates. Figure 1 shows the field of KIC 9832227 on August 5. There is an AAVSO comparison star chart for the field. These magnitudes are consistent with Sloan photometric observations from 2014 reported by Molnar which showed an approximately sinusoidal variation with amplitude 0.2 mag about a mean V mag of 12.45 (converted from their Sloan g and r mags).

Figure 2 shows a low resolution (R~1000) spectrum of KIC 9832227 recorded on 2018 August 5 using a LISA spectrograph on a C11 scope. The main absorption features are marked. The spectrum was flux calibrated with the V mag recorded at the same time. Its profile is similar to an early G spectral type which is consistent with the temperature estimated by Molnar.

Most changes in stellar evolution take place over thousands or millions of years. A stellar merger event is one of the few which can happen within a matter of years. Thus, the future behaviour of KIC 9832227 is of great interest. Changes in the object may become apparent as merger approaches. As yet there are no good models of how the stellar merger will proceed and its observational consequences, so observation will be important to constrain model development. At a distance of only 585 parsecs according to Gaia DR2, if KIC9832227 experiences a Luminous Red Nova explosion, and it attains a similar absolute magnitude to V1309 Sco, it could shine at 2nd magnitude and become the second brightest star in Cygnus.

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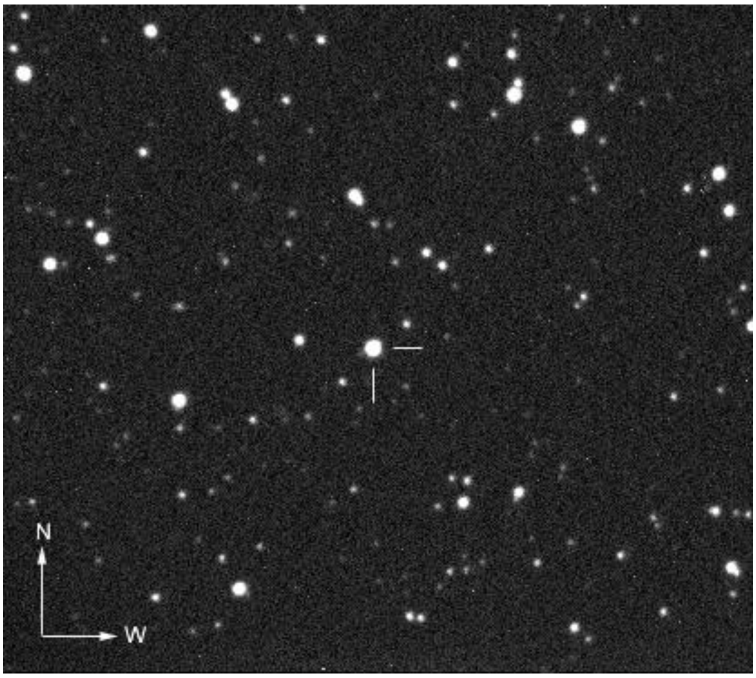

Figure 1. Field of KIC 9832227 on 2018 August 5.

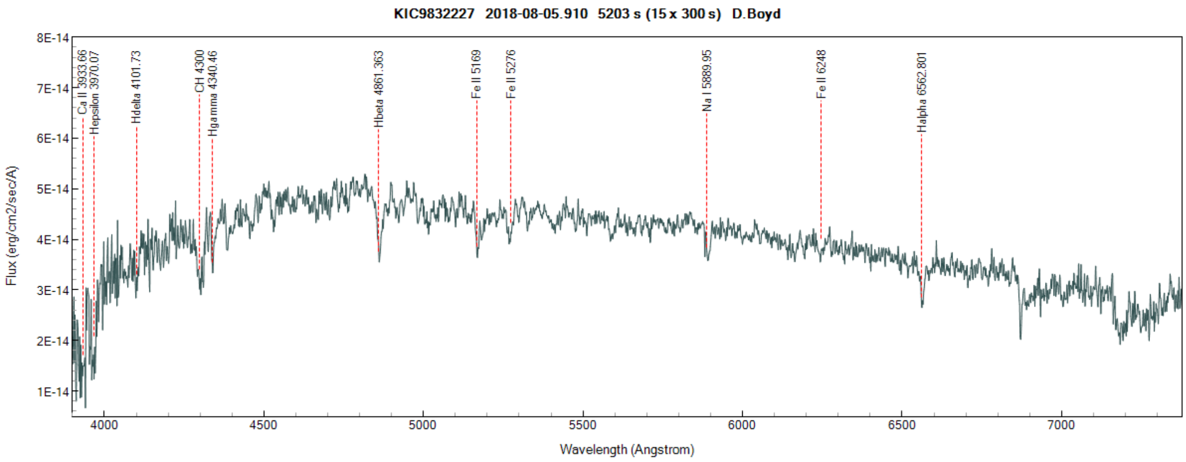

Figure 2. Low resolution spectrum of KIC 9832227 recorded on 2018 August 5.

References

Kinemuchi K, https://arxiv.org/abs/1310.0544v1 (2013)
Molnar L. A. et al. https://arxiv.org/abs/1704.05502v1 (2017)

VSX

KK Per, an irregular variable hiding a secret?

Geoff Chaplin

On the face of it KK Per is not very promising - an M2 star with a 0.5 mag range [1] and an unpromising looking set of observations. Figure 1 shows data based on visual observations by experienced observers (those with over 100 observation of this star) after adjusting for individual observer's bias (largely related to the Purkinje effect [2]) and put into 10-day buckets.

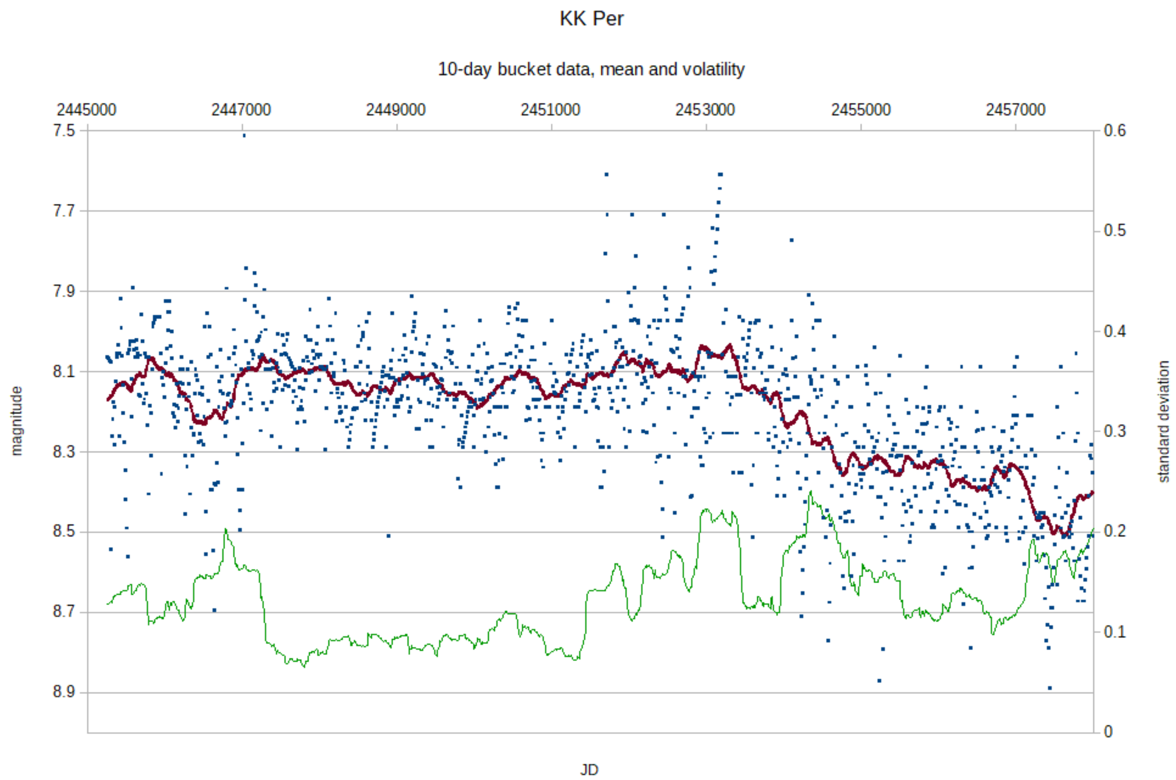

Figure 1: bias adjusted 10-day bucket data

Fourier analysis very weakly picks out periods around 380-440 days, and wavelet analysis also very weakly picks out periods in a similar area plus 310-340 days, plus 160 days. Using methods of signal processing we can remove the recent apparent trend decline and use the auto-correlation matrix to identify cycles (Figure 2). This results in identification of two cycles only – 168 and 322 days (approximately double the first) – explaining 25% of the signal although the range of variation is a mere 0.1 magnitude.

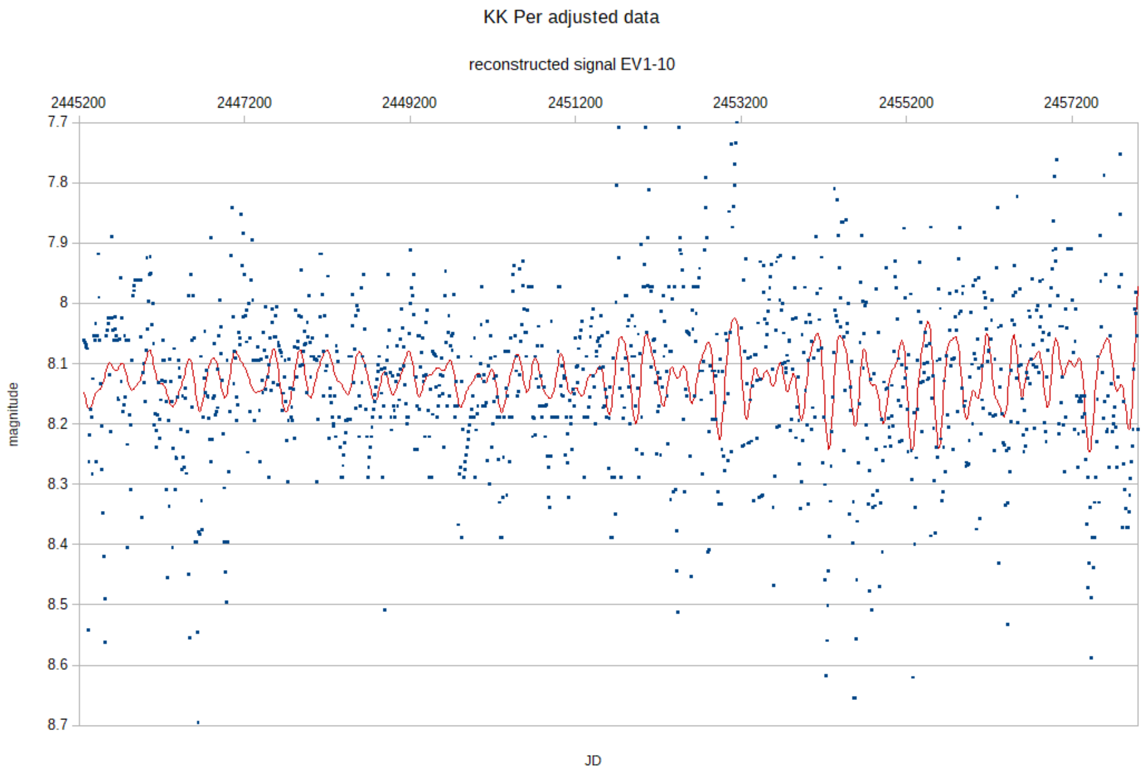

Figure 2: de-trended data and reconstructed signal

Is the 168-day cycle real? Given the standard deviation of the raw data is well over a magnitude to identify a wave of 0.1 mag seems unlikely. It should be easy to tell – less than a years' observations using DSLR or CCD equipment should be able to confirm or deny the relatively fast period. Electronic observations made once every couple of weeks using a filter (ideally V) are all that is required. Each observation run should comprise 30-100 exposures to average out atmospheric variation and other sources of random noise to get a night's average accurate to 0.01mag or thereabouts. Choose an exposure time to make sure the brightest comparison is not saturated and the faintest is above 100:1 noise level. See you in a year!

References

1. BAA pulsating program, http://www.britastro.org/vss/
2. Sigismondi, C., arXiv:1106.6356v1

VSX

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Joint BAA/AAVSO meeting on Variable Stars
Warwick University
Saturday 7th and Sunday 8th July 2018

Andrew Wilson

The joint meeting of the BAA and the AAVSO (American Association of Variable Star Observers), and the BAA Summer meeting were held at the University of Warwick. Separate lecture theatres were used for the two meetings, with the joint first and last lectures of the day joint sessions with all the delegates present. The meeting was opened by the BAA Vice President Dr Shears, welcoming the 150 delegates from 10 countries.

<u>Saturday BAA / AAVSO and BAA Summer Meeting Plenary Opening Session</u>

Chemical composition of planets in our Galaxy

Prof Giovanna Tinetti (University College London) began by discussing our Earth as a planet within our galaxy. The Earth is a rocky planet composed primarily of silicates, with a mild temperature of around 15 degrees Celsius. The atmosphere is 21% molecular oxygen, which is surprising since it is very reactive and would not be expected to persist in the atmosphere. Its presence is a direct result of life on Earth as it is continually replenishing the supply of oxygen. In our Solar System, the rocky planets are found close to the Sun, then further out we find the gas giants Jupiter and Saturn. These are much more massive at around 100 to 300 times the mass of the Earth and are mainly composed of molecular hydrogen and helium. Further out still we come to the ice giants Uranus and Neptune, at about 15 times the mass of the Earth. These also contain a lot of hydrogen, but also ices and rock. It is only very recently that we have learned that on average every star in our galaxy hosts at least one planet, meaning there are at least two thousand million planets in our galaxy. These are known as exoplanets, meaning a planet orbiting another star rather than our own Sun. We can only detect a tiny fraction of these exoplanets, roughly 3,800 discovered to date. It is from the statistics of these detections that we are now able to estimate the number of planets in our galaxy. Exoplanet discoveries by the Kepler spacecraft allow us to estimate the distribution of planet sizes. We have found that large planets like Jupiter and Saturn are relatively rare, with a new class of planet called super-earths the most common planet in our galaxy. These super-earths range from between the mass and size of the Earth to the mass and size of Neptune. We know very little about them as we have none in our solar system, only a rough estimate of their sizes and masses, from which we can calculate their bulk density. We think some may have a big iron core, while others are composed of rocks, and some from ices.

Surveys with new space telescopes, like NASA-TESS and ESO-PLATO, are expected to lead to the discovery of hundreds of thousands of exoplanets in the coming decade. Though we also want to know more about the planets we have already discovered, including the chemistry of their atmospheres.

To discover information about the atmosphere of an exoplanet we frequently use the transit method. This only works for planets whose orbits are aligned such that the exoplanet transits the disc of their host star. A tiny fraction of the starlight passes through the planet's atmosphere, and with very high precision photometry and spectroscopy it is possible to detect the absorption due to the exoplanet's atmosphere. This technique only results in a few points in the planet's spectrum, with large error bars. However, it has been possible to detect the presence of water vapour in giant planets. To perform detailed analysis of exoplanet atmospheres will require the next generation of space telescopes, such as the James Webb Space Telescope (JWST).

About a year ago the Trappist 1 system was discovered by a team in Belgium. This is a system with 7 planets orbiting a star that is smaller and cooler than our Sun. Each of the planets transits the star, and they are known to have a range of sizes between Mars and Earth, so they are rocky planets. Their orbital distance suggests a mild temperature that has the potential for supporting life. The next generation of space telescopes, such as the JWST, will be needed to make meaningful observations, such as detecting molecules in their atmospheres and determining habitability.

The ARIEL space telescope has been selected as the next ESO medium class mission. It is a 1 metre telescope scheduled for launch in 2028. It will perform systematic spectroscopic observations of about 1,000 rocky and gaseous exoplanets. ARIEL is designed to give high quality spectra enabling determination of chemical composition and abundances.

Blue Skies Space is a new company looking to build smaller less ambitious satellites, that can deliver data faster than the flag ship missions. They will use off-the-shelf components combined with platforms created for telecommunications and Earth observation satellites. Their first venture is the TWINKLE satellite, with a 50cm telescope in low Earth orbit, providing visible and near infrared spectroscopy. The launch is planned for around 2021 to 2022. Its main purpose is to look at exoplanets, but it will also study solar system objects such as asteroids and comets. The aim is to fund the mission by selling time on the telescope. If this funding model is successful, then it is the intention to build many more TWINKLEs type satellites.

Saturday morning BAA-AAVSO Joint Session 1

The HOYS-CAPS Citizen Science Project

Dr Dirk Froebrich (University of Kent) kicked off the first session of the BAA-AAVSO joint meeting with a talk on the HOYS-CAPS Citizen Science Project. In this project, amateur astronomers contribute to "Hunting Outbursting Young Stars" by submitting their images of specific star forming regions.
Stars form in cold massive clouds of gas and dust. Gravitational collapse within these clouds leads to the creation of protostars. The conservation of angular momentum leads the infalling material to settle into a disc before accreting onto the central object. It is from this disc that any planets will eventually form. To understand these processes, we need to establish the mass accretion history and the structure of the accretion disc. It only takes about half a million years to accrete one solar mass. However, this is not a steady process, instead there are outbursts when the accretion rate increases by several orders of magnitude. A good example is the variable star FU Ori, which exhibited an outburst where it increased in brightness by 5 magnitudes and the mass accretion rate by a factor of 100.

The dust in the accretion discs around young stellar objects can block the light from the forming star as it moves around its orbit. By studying the light curves of these stars, it is possible to determine information about the structure of the inner accretion disc and size of the dust grains from the changes in colour. A monitoring cadence of one observation per day will achieve a resolution of about 0.01 AU in the inner accretion disc.

The HOYS-CAPS project monitors target stars about once per day using small to medium size telescopes. This is achieved by having lots of contributing observers around the UK, and further afield. If one observatory is clouded out, there is a high probability that another observatory will have clear skies.

Participants supply dark subtracted and flat field corrected fits images of the target regions. The project has a website with instructions on how observers can upload their observations, http://astro.kent.ac.uk/~df/hoyscaps/index.html, and a Facebook group for discussions. Dr Froebrich is visiting astronomical societies around the UK, giving this presentation to encourage amateur observers to contribute to the HOYS-CAPS project.

Recent activity of SU Aurigae

Mike Poxon, the Young Stellar Object Section Leader at the AAVSO, discussed the recent activity of SU Aurigae. This is a spotted Classical T Tauri Star in the Taurus Aurigae star forming region. It is an UXOR type of young stellar object that shows Algol like dips due to an eclipsing object. The star has hot spots from accretion and an extensive disc. The accretion rate is about a ten millionth of a solar mass per year. The rough period between fades in the light curve is 310 days. Bart Staels found a deeper than usual fade in early 2018. The fade is deep in all colours and with UXORs you usually see reflected light off the dust as it recovers, but this is not seen in SU Aurigae. A little time later an even deeper fade has been seen. So SU Aurigae is like a UXOR, but not completely, and it raises the prospect of whether the dips might be due to a planetesimal.

Observational Evidence for Starspots on T Tauri Stars

Andrew Wilson, the BAAVSS Database Secretary, next spoke about the research he is conducting for his PhD project at the University of Exeter under the supervision of Prof Tim Naylor. Colour-Magnitude Diagrams (CMDs) of young star clusters show a spread that is indicative of a spread in age. However, it could be the stars formed at around the same time, but a physical property of the stars is at least partially responsible for the spread. One such property is magnetic fields of the Young Stellar Object (YSO). A strong magnetic field would inhibit convection, slowing contraction of the YSO towards the main sequence and thus causing a spread in the CMD. Starspots are a good indicator of stellar magnetic fields. Spectra of T Tauri stars in the Orion Nebula Cluster and the sigma Orionis Cluster are being analysed to discover if they indicate the presence of a large surface covering by starspots. The method used is to search the spectra for the presence of TiO molecules. The spectra are of K-type stars and their photospheres are normally too hot for TiO molecules. However, starspots are cooler regions of the photosphere, and in K-type stars would be at the right temperature for TiO to form. Hence if TiO is seen in the spectra of K-type stars, then this is a strong indicator for the presence of starspots. The spectra of one of the stars appears to indicate a starspot coverage of around 80%. While this is very high, it is not unprecedented with another team finding a similar surface coverage for a different YSO in 2017.

The Discovery of TT Crateris

John Toone, the BAAVSS Chart Secretary, gave an overview of the discovery of TT Crateris, a remarkable achievement by amateur astronomer Richard Fleet. Visual discoveries of dwarf novae are rare. The first was U Gem, discovered on 15th December 1855 by J R Hind, at Bishop's Observatory, London. Next came T Leo, discovered on 25th April 1862 by C H F Peters at Hamilton College Observation, New York. Then came RU Peg, discovered by K R Graff at Urania Observatory, Berlin. The discovery of TT Crt was made much later, during the 1986 apparition of Comet Halley. A sequence of comparison stars had been selected along the path of the comet, and on 17th October Comet Halley passed within 1 arc minute of TT Crt. On 4th November 1986 Fleet noticed that comparison star B had a previously unseen companion, this was the discovery of TT Crt. Three outbursts were seen at 100-day intervals within the 1986-1987 apparition. John Toone discovered the star in outburst on 23rd April 1988. An outburst was then predicted for April 1989, and this was seen on 3rd April. It was given its official designation of TT Crt on 28th April 1989. Fleet's is the only dwarf nova to be discovered visually by an amateur astronomer, with the other three having been professional discoveries many years earlier, when professionals still made visual observations.

Saturday afternoon BAA AAVSO Joint Session 2

AR Scorpii, a remarkable highly variable star discovered by amateur astronomers

Prof Tom Marsh (University of Warwick) told the story of how in May 2015, a group of amateur astronomers contacted Prof Boris Gaensicke at the University of Warwick, regarding a puzzling star they had been observing. This star, AR Sco, has turned out to be one of the most remarkable objects in the sky, unique for astonishingly strong pulsations every 2 minutes, and for radiating power across the electromagnetic spectrum, from radio to X-ray wavelengths.

Originally it was classified as a delta Scuti star with a period of about 3 hours, but it has an amplitude of 2 magnitudes and this is larger than expected for delta Scuti stars. The location of AR Sco in an amplitude versus period plot places it near to a pulsar binary. It also shows emission in the far infrared and radio which is not expected for a Cataclysmic Variable (CV). It has a weird spectral energy distribution (SED) showing a classic form for synchrotron emission, indicating strong magnetism and particle acceleration.

In May and June 2015 there were observing runs on the star using the 4.2m William Herschel Telescope with the high-speed CCD camera ULTRACAM. They discovered huge short period changes, with up to a factor of 6 increase in amplitude over a 30 second period. While the pulsations do change, they remain consistent over long time periods. These results indicate it must be a rotating magnetised compact object with a 2-minute period, either a white dwarf or a neutron star.
The companion star is a cool M5-type main-sequence star. The compact object orbits the main sequence star in 3.56 hours. The mass of the main sequence star is around 0.3 solar masses, and the compact object is around 0.8 solar masses. This would imply a white dwarf rather than a neutron star. The X-ray luminosity is too low and the spin rate too slow for a neutron star, and hence it is thought to be a white dwarf.

While it is like an intermediate polar (IP), its spectrum shows no sign of accretion, so it is unlikely to be an IP. Monitoring with ULTRACAM shows that it is slowing down with a spin-down timescale of 5 million years. This means the white dwarf is losing rotational kinetic energy at a rate equivalent to ¾ of the solar luminosity, more than enough to power the system. Most of the synchrotron emission is coming from the main-sequence component, due to induced heating from the fast-rotating magnetic field of the white dwarf. The X-rays and radio are also coming from the main sequence component, although the power source is the spinning white dwarf magnetic field.

The evidence points towards AR Sco being the first discovery of a white dwarf pulsar. New observations are being obtained with the 10.6m GTC using HiPERCAM with ugriz filters. These are indicating variations are present on timescales of about a second but not shorter.

Long term orbital behaviour of eclipsing SW Sex stars

Dr David Boyd told how in 2006 Prof Boris Gaensicke encouraged him to begin a long-term project to investigate the orbital behaviour of the 18 brightest eclipsing SW Sex stars. These are nova like CVs in which the high rate of mass transfer between the main sequence secondary star and the white dwarf primary, via an accretion disc, maintains the system in a persistent bright state. The initial aims of the project were to establish accurate ephemerides for these stars and to check if any of them deviated from a linear ephemeris. At the 100th Spring Meeting of the AAVSO in Boston in May 2011 David presented the results of the first 5 years of the project which combined new measurements of eclipse times with previously published observations. At that time, most of the stars appeared to be behaving consistently with linear ephemerides. However, five stars indicated possible cyclical variation in their orbital periods and three more were clearly not following linear ephemerides. After a further 7 years David now has a total of 670 eclipse timings and has computed updated ephemerides for all the stars. It now appears that for 13 of the 18 stars cyclical variation of the orbital period is statistically more probable than no variation. For three stars the results are inconclusive and for the other two the orbital period is steadily reducing at 2 and 7 msec/year. The periods of these cyclical variations range from 9 to 42 years with amplitudes between 14 and 170 sec. The most likely reasons for these variations are either a third body in orbit around the binary, in which case the variation should be strictly periodic, or magnetic activity cycles in the donor star resulting in a quasi-periodic variation. Eclipse timings alone would require many more years of observation to distinguish between these two alternatives. These results pose the question whether the likelihood of cyclical orbital period variation in around 70% these novalike variables is indicative of similar behaviour in the general population of cataclysmic variables.

Seven years on the ROAD (Remote Observatory Atacama Desert)

After several attempts at different places to set up a remote observatory, Dr Franz-Josef Hambsch found the ultimate destination in San Pedro de Atacama at Alain Maury's Spaceobs. Since its start on 1st August 2011, the exceptionally good weather conditions have led to the production of huge quantities of data. The hardware and software are mostly off the shelf. A 40cm optimized Dall Kirkham (ODK) from Orion Optics, UK is the workhorse riding on a DDM85 direct drive mount from ASA (AstroSysteme Austria). The CCD is an ML16803 from FLI equipped with Astrodon UBVRI photometrical filters. Analysis of the images is carried out using the LesvePhotometry program written by Pierre de Ponthierre, an amateur astronomer from Lesve, Belgium. Maxim DL is used for image acquisition and CCDCommander for automation. From the start the focus was on pro-am collaborations, with contributions to campaigns on the ring system J1407, WD1145 the 'zombie star', observations of galactic novae, the Luminous Blue Variable R71, and the Blazhko effect on the RR Lyrae star AL Pic. Most of the data are shared with VSNET in Kyoto Japan, the Centre of Backyard Astrophysics (CBA) USA, and several professional astronomers. Most of the observations are also accessible from the AAVSO database (AAVSO user code HMB). Related publications with co-authorship can be found on ARXIV entering Hambsch in the search box.

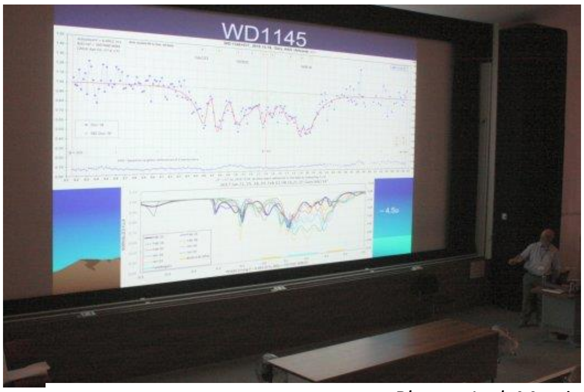

Photo: Jack Martin

SN1987A and connections to Red Novae

Dr Thomas Morris presented a binary merger model for the progenitor of Supernova 1987A. In this model, the system would have originally comprised a binary of 15 and 5 solar mass stars in a wide orbit. The system would have merged some 20,000 years before the core collapse supernova. This can explain many of the unusual features of SN1987A, such as the progenitor being a blue supergiant. The common envelope phase would have given rise to nova-like outbursts that could explain the ring systems illuminated by the supernova explosion. This kind of outburst may explain the eruptions of V838 Mon, V1309 Sco and perhaps the 1840s outburst of eta Carinae. The 2001 to 2007 light curve of V1309 Sco observed by the OGLE project provides strong evidence for a merging binary within a common envelope. There will likely be more discoveries of such systems by Gaia and the Large Synoptic Survey Telescope (LSST) due to start observations in 2021. In 2022 it has been predicted that the contact binary KIC 9832227 will merge resulting in a Red Nova.

Saturday BAA-AAVSO and BAA Summer Meeting Closing Plenary Session

The final fate of planetary systems: A window into the composition of exoplanets

Prof Boris Gaensicke (University of Warwick) closed the Saturday lecture sessions with a talk on the composition of exoplanets from the spectra of white dwarfs.

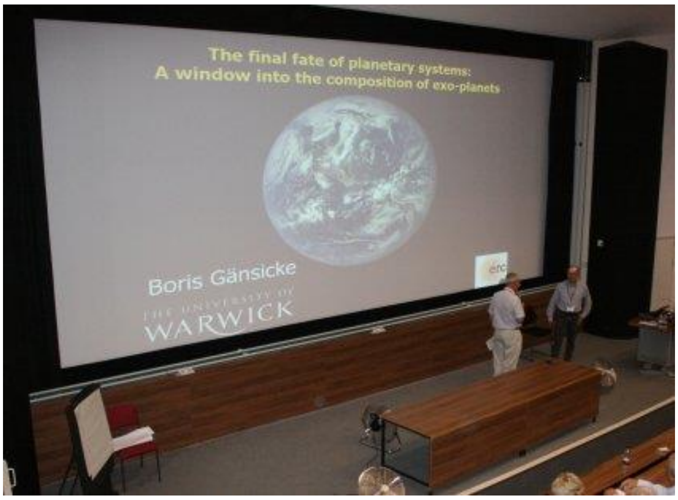

Photo: Jack Martin

A large fraction of solar-like stars has planets. When these stars reach the end of their lives, they become red giants, losing about half their mass, before finally becoming white dwarfs. The inner planets will be engulfed by the red giant, while the outer planets will survive. This means a large fraction of white dwarfs will have planetary systems. The mass loss from the star can cause objects orbiting far from the star to be lost to interstellar space, one possible explanation for the interstellar asteroid, Oumuamua, discovered in 2017. This can also result in dynamically instabilities in the surviving planetary orbits, leading to collisions between planets that scatter in crust, mantle and core debris in the system.

White dwarfs are very compact objects, with about half the mass of the Sun crammed into the volume of the Earth. This gives them a very high surface gravity that results in chemical stratification, with heavy elements near the core and light elements at the surface. Any heavy elements at the surface of a white dwarf should sink below the surface within 2 to 3 million years.

Metal pollution has been seen in the spectra of white dwarfs for many years, for example Van Maanen's Star in 1917. There is also evidence from spectral line profiles for debris discs of gas and dust around white dwarfs, and an infrared excess due to dust has been observed around 40 white dwarfs. If asteroids or planets stray too close to the surface of a white dwarf then the immense gravity will tidally disrupt them, breaking them apart. This would lead to the observed infrared excess and debris discs. As this material falls onto the surface it can be seen as absorption lines in the spectra of the white dwarfs. This must have happened within the last few million years to be visible in the spectrum, as otherwise the material would have sunk below the surface of the white dwarf becoming invisible.

The spectra from the heavy element pollution in white dwarf spectra also enables us to study the abundances of elements. These abundances should match the composition of the asteroids and planets which have been broken up and settled onto the surface of the white dwarf. This gives an excellent method for studying exoplanet composition, which is otherwise very difficult with modern technology. The Hubble Space Telescope (HST) is able to measure the abundances of 10 to 15 elements. It is then possible to plot abundance ratios normalised to silicon, the same technique that planetary scientists use to study Solar System asteroids. It is found that O, Mg, Si and Fe are the major constituents of the white dwarf pollution, which is very similar to our Solar System and the Earth.

Different white dwarfs have been detected with abundance ratios that match planet crust, mantle and core. Some also show an oxygen excess when compared to the oxygen content from rocky minerals. This is a strong indication of water rich planets. In 2017 Xu et al published a paper on the detection of nitrogen, indicating an icy Kuiper-belt analogue.

The huge increase in accurate distance measurements to stars from the Gaia mission, is resulting in the discovery of about ten times the number of white dwarfs than previously known, around 260,000. New large multi-object spectrographic surveys will enable spectroscopy of around one hundred million stars over the next 10 years, including the new white dwarfs. This will allow the white dwarfs to be searched for heavy element pollution. Spectra obtained with JWST will enable detailed mineralogy of dozens of debris discs. The LSST will provide light curves of millions of white dwarfs, that may enable the detection of exoplanets orbiting white dwarfs using the transit method. It is even possible that habitable zones exist around white dwarfs, the distance at which liquid water can exist. Cold white dwarfs are stable for billions of years, so there has been speculation that this could even lead to planets orbiting white dwarfs hosting life.

<u>Sunday Morning BAA-AAVSO Joint Session 3</u>

Starting in Spectroscopy

The Sunday morning session was opened by François Cochard of Shelyak Instruments. François began by explaining that as well as building a wide range of spectrographs for amateurs, Shelyak Instruments are actively involved in the spectroscopy community. Helping at the OHP Spectroscopy Star Party and other events to provided practical help to people starting out in spectroscopy. Astronomers carry out spectroscopy as it enables them to learn many things about astronomical objects, including their chemistry, the rotation and pulsations of stars, the redshift of galaxies, changes on short timescales, though most of all because it is fun! It is also possible to do meaningful science from city centres as the spectrum reduction process removes the worst effects of light pollution.

Photo: Andy Wilson

François went on to explain how spectroscopy is practically done. With a spectrum you do not see an image of the sky, instead you see images of spectra. A guide camera is used to place the spectrograph slit onto the target star, and then to guide the telescope to keep the slit positioned on the star. During processing, the images of the spectra are converted into plots of intensity by wavelength. When first starting out it is best to learn to use your spectrograph on a bench indoors during daytime, not at the telescope at night. Once the spectrograph has been setup and a basic understanding of its use attained, then it is time to move onto observing at the telescope. Observers find there is a process of continuous improvement, as you learn to use your spectrograph and improve results. Sharing results and joining collaborative programs adds to the enjoyment while contributing to genuine scientific research.

François has written a book on the subject which has been translated into English, 'Successfully Starting in Astronomical Spectroscopy, A Practical Guide'.

Pushing the Limits using Commercial Spectrographs

Robin Leadbeater began by noting how the BAA spectroscopy community has grown dramatically over recent years, with workshops, help in purchasing spectrographs through Ridley grants, forum activity, and over 2,000 spectra contributed to the BAA Spectroscopy Database over its first 18 months. Robin has consistently pushed the limits of what is achievable with amateur spectrographs. He performed high cadence spectrophotometry using a Star Analyser on the T Tauri variable star DN Tau. By taking spectra every 20 seconds he observed a sudden short-lived outburst which would have been invisible in longer exposures. Robin has been leading the way with the classification of supernovae by amateur astronomers. His modified Alpy spectrograph with a lower resolution grating enables him to classify supernovae down to 17th magnitude. This 200 lines per mm grating does not disperse the light as much as the normal Alpy 600 lines per mm grating, so leading to a brighter spectrum at the cost of lower spectral resolution. With his LHIRES III, Robin achieved high precision radial velocity measurements down to 1 kms^{-1}, robustly detecting the radial pulsations of Deneb at around 8 kms^{-1}. A key technique Robin used to achieve this resolution was to superimpose calibration spectrum lines on the stellar spectrum by installing a calibration lamp in front of the telescope optics.

Towards Full Automation of High Resolution Spectroscopy

Andrew Smith has previously automated a low-resolution LISA spectrograph on a 300mm F5.4 Newtonian. His next project was to build a homemade fibre-fed medium resolution echelle spectrograph, coupled to a 400mm Orion Optics UK ODK. Echelle spectrographs have an advantage over other spectrographs as they give a high resolution coupled with a wide spectral range. The spectrograph that Andrew built has a spectral range from 4,000Å to 6,900Å with an R value around 10,000. The R value is a measure of the resolution of a spectrograph, the higher the number the higher the resolution. Amateur spectrographs typically range from the low resolution with an R of about 100 to high resolution with an R of about 20,000. The new spectrograph is intended for accurate radial velocity measurement and to this end is temperature stabilised to better than +/- 0.04 degrees Centigrade.

The automation utilises the core capabilities and script-ability of Software Bisque's The Sky X, combined with the pointing accuracy of the Paramount ME II. However, a number of challenges were encountered due to the small field of view provided by the fibre guide-head at the 2.7m focal length of the 400mm ODK. To successfully obtain spectra, the target object must be centred and tracked on a 75-micron hole. The separation of the finding and guiding tasks by using a dichroic beam splitter proved to be the solution. Andrew is now able to enter target information, press "Run" on his Python program and retreat to the comfort of his arm chair while the spectra are acquired.

Applying Transformation and Extinction to Magnitude Estimates – How Much Does it Improve Results?

Gordon Myers and Kenneth Menzies addressed the question of whether transformation and extinction corrections should be applied to photometric magnitude estimates. Plots of magnitude and colour were used to quantify the significance of these corrections. Effects of different filters, CCDs, DSLRs, field of views, and the airmass of the observation were analysed.

To obtain good quality photometry, it is necessary to carefully choose comparison stars, for example within 2.5 magnitudes and 0.5 magnitudes of colour difference of your target star. It is also important to evaluate your equipment by checking linearity and measuring the transform and extinction coefficients. The AAVSO tools VPhot, Transform Generator, and Transform Applier facilitate an easy correction to observations. They found that magnitude corrections for CCD observers are small but significant for most amateur equipment, and critical for most DSLR observers. If observers are happy with 0.1 magnitude errors then it is possible to do without these corrections, but if accuracies around 0.01 magnitude from the ‘true’ magnitude are needed then these corrections are essential.

Sunday Morning BAA-AAVSO Joint Session 4

Red Dots Initiative: science and opportunities in finding planets around the nearest red-dwarfs

Dr Guillem Anglada Escude (Queen Mary, University of London) gave an overview of the Pale Red Dot campaign and the new Red Dots Initiative. Red dwarf stars are the most common type of star in our galaxy. They are small cool stars and their size and mass makes it easier to discover small exoplanets in orbit around them. As these stars are smaller in physical size, so a transiting exoplanet of a given size will block a larger proportion of the stars light as compared to a larger star. As these stars are of lower mass, so the orbit of an exoplanet will cause a larger Doppler shift wobble in the stellar spectrum than for a planet of the same mass orbiting a more massive star. When compared to a Sun like star, discovering exoplanets around red dwarfs is about 30 times easier using the transit method, and 15 times easier using the Doppler shift method. The main problem is that red dwarfs are faint stars, so only nearby red dwarfs are sufficiently bright to give a strong enough signal to detect exoplanets.

The Pale Red dot campaign (2016) continuously monitored Proxima Centauri with the HARPS spectrometer. This campaign aimed to measure the Doppler shift in the star’s motion due to an orbiting planet. Although this is a mature technique for finding planets, stellar activity contaminates the Doppler measurements at the same level as the planetary signals under investigation. To distinguish stellar activity from true planets, quasi-simultaneous photometric observations to the Doppler measurements were obtained.

In 2017 a second campaign called Red Dots was performed to monitor three more very nearby red-dwarfs spectroscopically and photometrically over 3 months. Many of the photometric observations were contributed by pro-am astronomers with moderate size telescopes (about 0.4m apertures), which are ideal for this kind of observation.

As of today, 8th July 2018, the Red Dots 2 campaign has started. Amateurs with 20 cm to 40 cm telescopes can contribute, but for the observations to be used they need to cover the whole campaign from early July to 30th September 2018. This campaign is monitoring the 3 red dwarfs GJ 887 at V magnitude 7.54, GJ 1061 at V magnitude 13.07 and GJ 54.1 (YZ Ceti) at V magnitude 7.54.

How to find Planets and Black Holes with Microlensing Events

Lukasz Wyrzykowski explained how any compact object, be it a planet, neutron star, or black hole can act as a gravitation lens. If such a lens passes in front of a background star this gives a very characteristic brightening, with the light curve enabling the parameters of the lens to be determined. These are very rare, only one in a million stars being lensed. Though large surveys like OGLE, cover large areas of the sky enabling the detection of lensing events. It is just becoming possible to perform astrometric lensing with Gaia, where the background star is distorted at the milliarcsecond scale. When a star with planets act as a lens, then the light curve can show multiple peaks. This type of microlensing event is sensitive to planets in wide orbits, with periods of many Earth years.

This is a great opportunity for amateurs to contribute. To properly analyse the microlensing events continuous coverage is needed, which can be provided by amateur astronomers. The Cambridge Photometry Calibration Server (CPCS) allows amateurs to upload their observations, and it will automatically perform photometric transformations. By combining Gaia data with ground based amateur observations it is hoped that the first lone black hole will be discovered in the Milky Way by 2024.

Short Period Eclipsing sdB Binaries and the claims for Circumbinary Objects

George Faillace introduced a research project on short period sub-dwarf eclipsing binaries (sdB) searching for circumbinary objects, being carried out by G. Faillace, D. Pulley, D. Smith, A. Watkins, and S. von Harrach. In eclipsing binary systems, any change to the predicted time of eclipse can indicate the presence of a third body or an astrophysical change within the system. Monitoring eclipse timings forms the basis of a powerful astrophysical research tool which is commonly used by professional astronomers and can equally be used by amateurs. The group is using this technique to investigate whether seemingly periodic variations in seven short period (2-3 hours) sdB systems could indicate the presence of circumbinary objects, such as planets or brown dwarfs. Following 246 new observations made between 2013 September and 2017 July using a worldwide network of telescopes, they found some systems did not follow predictions, showing possible cyclical variation over the short term. Observations over a very long timescale are needed to discover if these variations are due to circumbinary objects, and this is where amateur astronomers can make a significant scientific contribution.

Full details can be obtained from their paper "The quest for stable circumbinary companions to post-common envelope sdB eclipsing binaries? Does the observational evidence support their existence?" in the March 2018 Astronomy &Astrophysics Journal, freely available via the arXiv portal (https://arxiv.org/abs/1711.03749).

Williamina Paton Fleming's "Un-named" Variables and the AAVSO: A Scientific and Historical Perspective

Kristine Larsen, the AAVSO President, gave a review of the 'un-named' variables discovered by Williamina Paton Fleming (b. 1857, d. 1911). Fleming ran the Henry Draper Memorial Project of Spectral Classification. Over her career she discovered, or oversaw the discovery, of 10 novae, about 50 nebulae, and around 300 variable stars.

Twenty years ago, a JAAVSO article by Dorrit Hoffleit brought attention to the fact that fourteen of the nearly 300 variables discovered by Fleming or her team at the Harvard College lacked permanent designations in the General Catalogue of Variable Stars (GCVS). Raymond Berg found three of the stars to show no variation in his paper of 1999, though since then at least two have been found to be variable. This is due to the short time period over which he observed the stars. Between 1997 and 2010, seven were given variable star designations. Since 2010 our understanding of these stars has grown, and most have now received variable star designations.

This evolution of knowledge provides a valuable series of snapshots in time of the state of variable star astronomy over more than a century and illustrates the ongoing and significant impact of the AAVSO and its observers on the field.

Sunday Afternoon BAA-AAVSO Joint Session 5

Cataclysmic Variables as Universal Accretion Laboratories

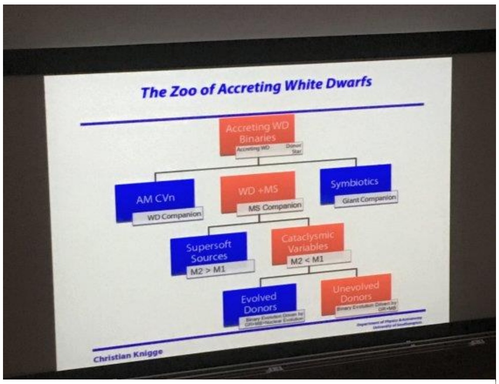

Photo: Gary Poyner

Prof Christian Knigge (University of Southampton) introduced a new angle on cataclysmic variables (CVs), as laboratories exhibiting the full range of accretion-related phenomenology. CVs are binary systems composed of a white dwarf (WD) accreting matter from a companion star. While these were subject to intense research in the 1980's and 1990's, more recently accreting neutron stars (NS) and black holes (BH) have been the focus of accretion research.

There is a whole zoo of accreting WDs. The companion star can be a main sequence star, a red giant, or another white dwarf. The magnetic field strength of the WD affects whether the accreting matter forms a disc or falls directly onto the magnetic poles of the WD.

Cataclysmic variables are numerous, bright and nearby, making them excellent laboratories for the study of accretion physics. Since their accretion flows are unaffected by relativistic effects or ultra-strong magnetic fields, they provide a crucial "control" group for efforts to understand more complex/compact systems, such as accreting NS and BH.

The WD accretion mechanics that are seen in CVs, share a common structure with accretion onto NS and BH. An accretion disc may form along with a disc wind, and bipolar jets may expel material at high speed from near the WD. The side of the companion star facing the WD may be subject to UV and X-ray heating. While NS and BH systems show the same general structure, each component of the system will typically emit radiation at shorter wavelengths compared to a WD system. The other key difference is that NS and BH systems will be subject to relativistic effects, while these effects will be absent in lower mass of WD systems. In other words, WD systems are simpler laboratories from which to study accretion physics.

There has been a recent insight into the outburst events that occur in accreting NS and BH systems, using what is termed a 'disc-fraction/luminosity' diagram (DFLD). This a plot of X-ray luminosity increasing along the vertical axis, versus X-ray hardness on the horizontal axis, with soft X-rays (longer wavelength and lower energy) to the left and hard X-rays (shorter wavelength and higher energy) to the right. Outbursts are observed to follow a hysteresis loop. The system starts in the bottom right at low luminosity with hard X-rays. When at outburst occurs the system switches to high luminosity with hard X-rays. Then it moves to the left, remaining at high luminosity but moving to soft X-rays. Next the system reduces in luminosity, generally emitting soft X-rays but with a lot of variation in the hardness of the X-rays. As the system dims, but before it reaches its pre-outburst luminosity, it eventually moves across to the right, emitting hard X-rays once more. Then finally it returns to its starting point, at low X-ray luminosity and emitting hard X-rays. While this behaviour is observed in all BH outbursts it is not properly understood. It is thought that when the system is emitting hard X-rays the accretion disc is truncated, and when it is emitting soft X-rays the accretion disc reaches closer to the central compact body. When the disc is truncated there is a corona of diffuse hot material which contributes to the hard X-rays, while the disc contributes softer X-rays.

It is now thought that this behaviour may also apply to active galactic nuclei (AGN), which contain a supermassive black hole at their centres, and vast accretion discs. A similar pattern is seen when plotting luminosity versus variability. When the systems are in a hard (X-ray) state they exhibit larger variability on short timescales, and when they are in a soft (X-ray) state the variability is much reduced. Interestingly jets are only seen in the hard (X-ray) state. When the system transforms into the soft (X-ray) state something mysterious happens which shuts off the jets and the final gasp of the jets sends out material ballistically. The disc winds, which are like a more conical outflow, are only seen when the system is in a soft (X-ray) state. The relation between disc winds, jets, and hard versus soft states is not yet understood.

Although CVs have been observed for over 100 years, Prof Knigge could not find any reference in the literature to colour evolution, which is the meaning of the transition between hard and soft X-ray states. The simple test is to observe a CV in a Colour-Magnitude Diagram (CMD), like V magnitude versus V-B colour, to see if it exhibits hysteresis over an outburst cycle. In 1980 Bailey observed a hysteresis curve for SS Cyg in a U-B versus B-V colour-colour diagram, but it has not been discussed since. Plotting a V versus V-B diagram for SS Cyg shows a hysteresis curve, but the direction of travel is in the opposite sense to that seen in the NS and BS systems. McGowen et al. 2004 looked at SS Cyg in X-rays. Translating their work into a modern DFLD plot, the same hysteresis behaviour is observed in SS Cyg, with the same direction of travel as NS and BH systems.

Another common property between CVs and relativistic systems is they all show flickering on very short time scales, with relativistic systems showing flickering on shorter timescales than CVs. This is a strong indication that the same physical processes are involved. The CV community considered the flickering as annoying noise. The NS and BH researches discovered that if you plot the strength of the variability against the brightness of a system, then you always get a straight line. The flickering contains a wealth of information, allowing certain models of the system to be excluded. This same relation is seen in CVs and means the favoured model for the flickering in CVs of little shocks and explosions cannot be correct.

When you get two periods in oscillations, it was discovered that the ratio between the two periods falls on a straight line. When the same analysis is performed on CVs, they also fall on a straight line, but even more interesting, the CVs, NS and BH systems all fall on the same straight line. This implies the same physics is involved, and this could not be relativistic since the WD in CVs are too low a mass for relativistic effects.

It had been thought that CVs did not drive radio jets. A campaign involving the AAVSO was organised to check for radio jets. AAVSO observers monitored SS Cyg for an outburst, and when an outburst was detected then radio observations were immediately triggered to search for a radio flare indicative of jets. The radio flare was discovered, and so it is now thought that CVs do in fact drive radio jets. By analysing spectra of SS Cyg, a disc wind is seen when the system is in a high ‘soft’ state, again analogous to the NS and BH systems.

Given this rich set of shared behaviour, it is reasonable to hope that much of accretion physics is universal. CVs hold great promise in this context as observational testing grounds for attempts to model and understand this physics.

RZ Cas: light curve and orbital period variations

Geoff Chaplin has performed detailed analysis of electronic observations made by BAA and AAVSO members of the semi-detached Algol-type binary star RZ Cas. This is a binary system where the physically larger secondary star has filled its Roche lobe and is passing matter onto the primary star. The orbital period of the binary is about 1.195 days.

To model the RZ Cas system requires parameters for the geometry of the system, reflection effect where light from the hotter brighter star illuminates one side of the fainter star, limb darkening, radii, masses, temperatures, and the shapes of both stars. A model was fit to the primary minimum giving an inclination of 82.9 degrees, a radius of 1.57 solar radii for the primary star, a temperature of 8700 K for the primary star, and a temperature of 4900 K for the secondary star.

Some eclipses show flat bottoms, which are indicative of a total eclipse, but not all eclipses show a flat bottom. It also shows an indication of short term delta Scuti variability on the time scale of 22 minutes.

An observed minus calculated plot (O – C) of the changing time of minima shows that overall the period is increasing, but not uniformly. It is possible to fit 4 different periods covering different time intervals which give a better fit to the plot. The intervals where the period increases can be explained by mass loss. Causes for period decreases are less clear but may be electromagnetic interactions known as the ‘Applegate mechanism’.

A fresh look at the data is being carried out using ‘singular spectrum analysis for time series’. This is a data driven technique, rather than Fourier analysis techniques which are model driven. Applying the technique reveals a newly detected 23-year period, that could be due to a 1.2 solar mass object. However, the period and peak strengths are not constant, contrary to what you would expect for a third body in the system. So, it is more likely to be the ‘Applegate mechanism’

rho Cas - an update

Des Loughney, the BAAVSS Eclipsing Binary Secretary, has been monitoring rho Cas using DSLR photometry over the period 2007 to 2018 and onwards. The star is naked eye at magnitude 4.6 and circumpolar from Des’ location in Edinburgh. Its semi-regular variability was discovered by L D Wells in 1900. With a radius about 500 times that of our Sun, it is one of the largest known stars in our galaxy and is frequently referred to as a hypergiant. It has a mass of around 30 times that of our Sun and is about half a million times more luminous.

Des uses a Canon 550D DSLR with a 100mm canon lens to make his photometric observations. He takes a series of 5 second exposures at F4.0 and ISO 400. He has found that precision photometry requires at least 30 images, and under reasonable conditions will give a standard deviation of 0.02 magnitudes.

In 2001 to 2002 rho Cas exhibited an outburst to magnitude 4.1, followed by a fade to magnitude 5.4. During this event its surface temperature dropped by 3000 K and it is thought to have ejected 0.03 solar masses, a huge mass loss for such a short timescale. This was thought to happen every 50 years or so, and it was then expected to revert to its standard pattern of semi-regular variations. The measurements between 2007 and 2013 seemed to confirm this as the star varied semi-regularly between 4.5 and 4.9 magnitudes. Then, in 2013 an event occurred which heralded a new pattern of behaviour. The star brightened to 4.3 and faded to magnitude 5.0. A different pattern of mini outbursts emerged, with 3 recorded between 2013 and 2018. The outbursts, which are usually explained by mass ejections, are occurring more often and suggest the dynamics of the star have changed.

American Medical Association statement on street lighting

Mario Motta, MD, FACC, was on the Council on Science and Public Health at the American Medical Association (AMA) for 8 years. The AMA has adopted an official policy statement about street lighting and the use of low blue LED’s, with Dr Motta as the principle author. He gave this presentation to the Illuminating Engineering Society (IES), who make the streetlight standards in the USA, and hopes for a change in their recommendations soon.

The LED street lighting that the industry had originally proposed and are still suggesting is too harsh and bright for optimum safety and health. A report that outdoor lighting at night, particularly street lighting, should have a colour temperature (CT) of no greater than 3000K, was unanimously adopted by the AMA House of Delegates at its annual meeting in 2016. Higher CT (4000K) generally means greater blue content, and the whiter the light appears.

A white LED at CT 4000K contains a high level (over 30%) of short wavelength, blue light. These overly blue harsh lights are damaging to the environment and have adverse human health effects. In some locations where they were installed, such as the city of Davis, California, residents demanded a complete replacement of these high CT street lights for lower CT lighting. Cities that have followed the AMA recommendations and adopted 3000K or 2700K, have seen much greater acceptance of LED lighting. The much lower blue content is better for human and environmental health, reduces glare and is thus safer for driving.

The AMA has made three recommendations in its policy statement:

First, the AMA supports a “proper conversion to community based Light Emitting Diode (LED) lighting, which reduces energy consumption and decreases the use of fossil fuels”.

Second, the AMA “encourage[s] minimizing and controlling blue-rich environmental lighting by using the lowest emission of blue light possible to reduce glare”.

Third, the AMA “encourage[s] the use of 3000K or lower lighting for outdoor installations such as roadways. All LED lighting should be properly shielded to minimize glare and detrimental human and environmental effects, and consideration should be given to utilize the ability of LED lighting to be dimmed for off-peak time periods.”.

<u>Attendees Sunday July 8th</u>

Photo: © Jack Martin

FR: Des Loughney, Mike Poxon, Kristine Larsen, Andy Wilson, Robert Stephens

2R: Stella Kafka, Geoff Chaplin, Lukasz Wyrzykowski, Graham Darlington, Robin Bold, Ian Miller, Andrew Smith, David Smith, Jeremy Shears, Andrew Crossland

3R: Norman Walker, Gordon Myers, Ken Menzies, Diane Menzies, Bill Stein, Susan Michelson, Pierre de Ponthiere, ?, John O'Neill, Sara Beck, Seiichiro Kiyota, Philip Jennings

4R: Erwin Van Ballegoij, Robin Leadbeater, Geert Hoogeveen(?), ?, ?, Beverly Hudson, Ken Hudson, Peter Lythgoe(?), Thomas Morris, Tonny Vanmunster, Josch Hambsch

5R: John Fairweather, ?, Tony Vale, Kathy Griffiths, Kevin Gurney, Ken England, ?, ?, Stephen Futcher, ?, Patrick Wills, Tim Withers, Charles Galdies, ?

6R: Francois Cochard, Arto Oksanen, Tony Rodda, Heinz-Bernd Eggenstein, David Conner, David Boyd, Forrest Sims, Heidi Thiemann, Andrew Norton, ?, David Salmon, Stephen Brincat

7R: ?, Nick Atkinson, ?, Stuart Eves, George Fleming, Christian Knigge, Roger Pickard, Mario Motta, George Faillace, David Pulley, Ann Davies, Gary Poyner, Pavol Dubovsky, Ray Pearce

BR: ?, Richard Miles, Americo Watkins, Richard Fleet, John Toone, ?, ?, ?

Editor's note: We wish to apologise to those few attendees who have not yet been recognised. If you would like to contact the editor identifying yourself in the photograph, we will include a complete updated list in a future VSSC.

A Zooniverse project to classify periodic variable stars from SuperWASP

Andrew Norton,
School of Physical Sciences, The Open University

Introduction

As is well known to the readers of the BAA VSS circulars, stars are the building blocks of the Universe and determining stellar parameters is a cornerstone of astrophysics. Periodic variable stars are the key to this, as their time domain signals may be used to probe the dynamics or structure of stellar systems. The first step in such research is to identify and classify samples of variable stars, and that is the purpose of the Zooniverse project described here.

Of course, classification of periodic variable stars based on the shape of the photometric variability displayed in their folded light curves is not always a conclusive way of uniquely determining their type. However, it can at least give a good indication of the possible type of variable star and identify candidates that are suitable for follow-up investigations.

SuperWASP

Figure 1 SuperWASP

The Wide-Angle Search for Planets – SuperWASP – is the world's leading ground-based survey for transiting hot Jupiter exoplanets (Pollacco et al. 2006). Based at two sites in La Palma, Canary Islands and Sutherland, South Africa, it used off-the-shelf Canon lenses, backed by high quality CCDs, on a fast robotic mount, to monitor the sky. The lenses are Canon 200 mm focal length, f/1.8 telephoto lenses giving an angular scale of 13.7 arcsec per pixel on the Andor CCDs which are 2048 pixels square with 13.5-micron pixels. With 8 cameras on each mount, the total field of view of each instrument is around 500 square degrees. A broad-band filter spanning 400 nm to 700 nm is used to give white light photometry.

Operating between 2004 and 2013, the project accumulated over 16 million images from 2833 nights of data, comprising around 580 billion data points from over 31 million unique objects. The whole sky has been surveyed, excluding the Galactic Plane where the stellar density is too high to resolve individual objects, given the large pixel scale. To date, the project has announced the discovery of around 150 transiting hot Jupiter exoplanets, including many keystone systems, such as the extreme object WASP-12b (Hebb et al. 2009).

Previous variable star research with SuperWASP

It rapidly became apparent that the SuperWASP data provided a unique archive for variable star research. Combining both short cadence and long baseline and covering all stars away from the

Galactic Plane between about magnitude 8 to magnitude 15, it offers great opportunity for studying both large classes of objects and for discovering rare individual systems.

An initial period search, using only the first few years of data, yielded hundreds of thousands of potentially periodic objects amongst the SuperWASP light curves. Following this, a preliminary machine learning investigation attempted to classify the folded light curves using a neural network (Payne, 2012). This was only partially successful, but nonetheless these early analyses enabled us to investigate subsets of the data.

On this basis, we have spent the last decade carrying out a range of research projects focusing on the variable star content of the SuperWASP archive. Highlights have included: identifying 140 short-period eclipsing binaries, so increasing the number of main-sequence systems known close to the period cut-off by an order of magnitude (Lohr et al. 2013); discovery and characterisation of the first doubly-eclipsing quintuple system (Lohr et al. 2015a); measuring period changes in 14,000 eclipsing binaries which may indicate the presence of third-bodies in up to ¼ of the systems (Lohr et al. 2015b); studying period changes in a sample of eclipsing subdwarf B star post-common envelope binaries to search for circumbinary exoplanets (Lohr et al. 2014); the discovery and characterisation of a high amplitude δ Sct star in an eclipsing binary (Norton et al. 2016); and studying around 5,000 RR Lyrae stars, including the identification of the Blazhko effect in 800 systems, most of which are newly identified (Greer et al. 2017).

Period searching

In an attempt to further this research, now that the observational phase of SuperWASP has completed, we recently performed a complete re-analysis of the entire archive of 31 million light curves. The period searching used a combination of CLEANed power spectrum analysis (Lehto 1993) and a phase dispersion minimisation folding analysis (Davies 1990) to identify likely periods in each light curve. The search was sensitive to all periods between about 1 hour and 1 year. It was run on the Open University Linux cluster and took around 100 CPU years over the course of almost 2 calendar year to run.

As a result of this we identified around 8 million potential periods in about 3 million objects (10% of the total). However, significant numbers of these potential periods are close to integer fractions or multiples of a sidereal day or lunar month, and so are most likely to be spurious and caused by systematic errors in the data. Omitting these "flagged" periods leaves about 1.6 million periods in around 0.8 million unique objects. It is only these latter "unflagged" periods that are the subject of the Zooniverse project described below.

Since the flagged period ranges occupy about 20% of the logarithmic period range, and all periods in this logarithmic range from 10^4 sec to 10^7 sec are approximately equally likely, the actual number of likely periods is around 2 million periods in total from 1 million objects. The multiple periods detected per object will usually be harmonics of a single base period, except in rare cases where a single object contains two periodic phenomena.

Based on eye-balling samples of a few thousand unflagged period-folds, about 80% of the unflagged periods are still apparently the result of noise or junk, and only 20% are likely "real". So, the likely number of real periods in the archive is 400,000 periods from 200,000 objects. Hence about 0.6% of the SuperWASP objects are likely to be detectable as genuinely periodically variable.

The Zooniverse project

The Zooniverse project originated with the Galaxy Zoo initiative of Chris Lintott. It is now a multi-disciplinary citizen science portal, hosting numerous projects to identify and classify different phenomena, across all areas of science. Recently, the Zooniverse team instigated a project-builder interface allowing anyone to build their own Zooniverse project. This is what we have now done, using images of the folded SuperWASP light curves as the classification objects.

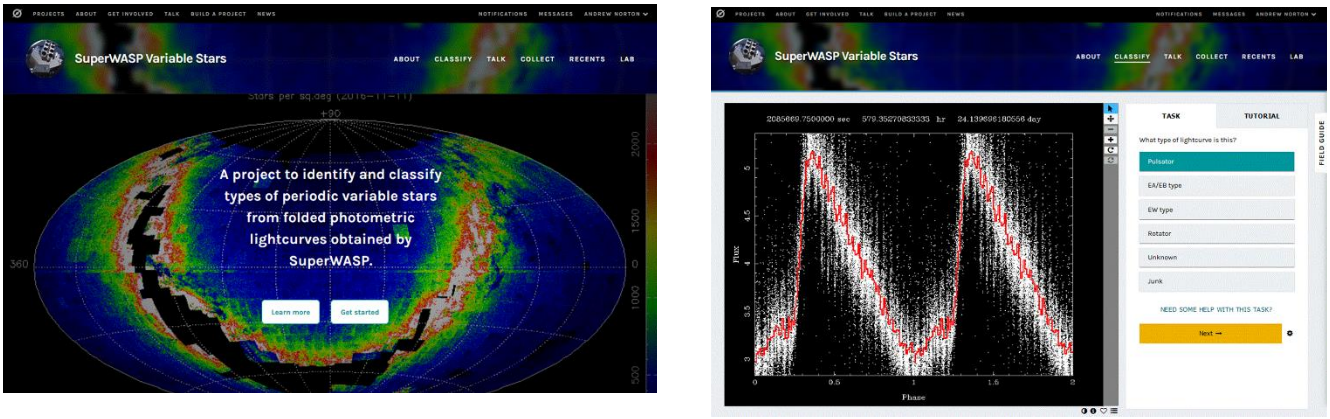

Figure 2 The Zooniverse interface for the SuperWASP variable stars project

Because the Zooniverse projects are genuine citizen science projects that are open to everyone, the classification tasks must be straight-forward and not depend upon subject-specific knowledge. Consequently, we have devised a simplified scheme to identify and classify SuperWASP folded light curves. When users visit the project at:

https://www.zooniverse.org/projects/ajnorton/superwasp-variable-stars

they can first read about SuperWASP and about the different classes of variable stars in general. They are then presented with a Tutorial that guides users through the classification process; a Field guide is also available which presents a sample of light curves of each type. The classification task asks users whether each folded light curve resembles that of an EA or EB type eclipsing binary; an EW type eclipsing binary; a pulsating star; or a generic rotational modulation. Options for unknown variable types or merely junk are also available – a lot of the folded light curves will be classified as junk. In particular some end-of-night effects can mimic eclipses and other noise features can mislead the automated period searching into identifying false periodicities.

In the case of eclipsing binary light curves, often the period at which the data are folded will be *half* the genuine period (particularly in the case of EW systems). Furthermore, in both eclipsing systems and pulsating systems, sometimes the period found is clearly incorrect. Consequently, a subsequent question following the initial classification, asks the user whether they believe the period is correct, half the true period, or incorrect.

The Zooniverse interface also provides a Talk board for users to discuss their findings, and a facility to highlight users' favourite objects and place them in Collections.

Members of the BAA VSS are strongly encouraged to sign up to Zooniverse and assist in the classification of the 1.6 million SuperWASP folded light curves.

Future work

Once the light curves have all been classified (by at least 5 people per image), we shall construct catalogues of the various classes of object, which can then be refined further by subsequent cross-correlation with other catalogues and visual inspection if necessary. This will allow the range of observational parameters (periods, amplitudes, etc) for each class to be identified, and also allow the discovery of individual “keystone” objects with unique features. We shall then follow them up with further photometry and spectroscopy to allow detailed modelling of their parameters (masses, radii, ages, metallicities, rotation rates, magnetic fields, etc). Topics for investigation may include: (a) exploration of the evolution of stellar system architectures through the identification of potential mergers and hierarchical multiples; (b) investigation of the rotational braking law for field stars and the use of differential rotation to study starspot cycles; (c) identification and analysis of the largest samples of pulsating stars in eclipsing binaries and Blazhko effect RR Lyr stars; (d) the use of light travel time effects to search for circumbinary objects and companions to pulsating stars and (e) the identification of unique and extreme objects such as very short or very long period contact binaries, eclipsing binaries in highly elliptical orbits, or extreme amplitude pulsators.

Acknowledgements

This Zooniverse project on SuperWASP Variable Stars is led by Andrew Norton (The Open University) and builds on work done with his former postgraduate students Stan Payne, Les Thomas, Marcus Lohr and Paul Greer, and current postgraduate student Heidi Thiemann. Other members of the SuperWASP project with an interest in this area who have contributed to the work include Pierre Maxted and Barry Smalley (Keele University), Pete Wheatley and Richard West (Warwick University) and Simon Hodgkin (Cambridge University).

The SuperWASP project is currently funded and operated by Warwick University and Keele University, and was originally set up by Queen’s University Belfast, the Universities of Keele, St. Andrews and Leicester, the Open University, the Isaac Newton Group, the Instituto de Astrofisica de Canarias, the South African Astronomical Observatory and by STFC.

References

- Davies, S.R., 1990, MNRAS, 244, 93.
- Hebb, L. Collier Cameron, A., Loeillet, B., et al. 2009, ApJ, 693, 1920.
- Greer, P.A., Payne, S.G., Norton, A.J., et al. 2017, A&A, 607, A11.
- Lehto, H.J., 1993, in Proceedings of “International conference on applications of time series analysis in astronomy and meteorology”, ed. O. Lessi, University of Padua Press, 99.
- Lohr, M. E., Norton, A. J., Kolb, U. C., et al. 2013, A&A, 549, A86
- Lohr, M. E., Norton, A. J., Anderson, D. R., et al. 2014, A&A, 566, A128
- Lohr, M. E., Norton, A. J., Gillen, E., et al. 2015a, A&A, 578, A103
- Lohr, M. E., Norton, A. J., Payne, S. G., et al. 2015b, A&A, 578, A136
- Norton, A.J., Lohr, M.E., Smalley, B., et al. 2016, A&A, 587, A54.
- Payne, S.G. PhD thesis, Open University, 2012.
- Pollacco, D. L., Skillen, I., Cameron, A. C., et al. 2006, PASP, 118, 1407

Eclipsing Binary News

Des Loughney

Astronomers detect a doubly eclipsing quadruple star system

Using the quality Kepler data astronomers have detected [1] a doubly eclipsing quadruple star system. Taken from their paper is a diagram (below) illustrating their distinctive light showing the two sets of eclipses and the way the light curves interfere with each other.

4 *Borkovits et al.*

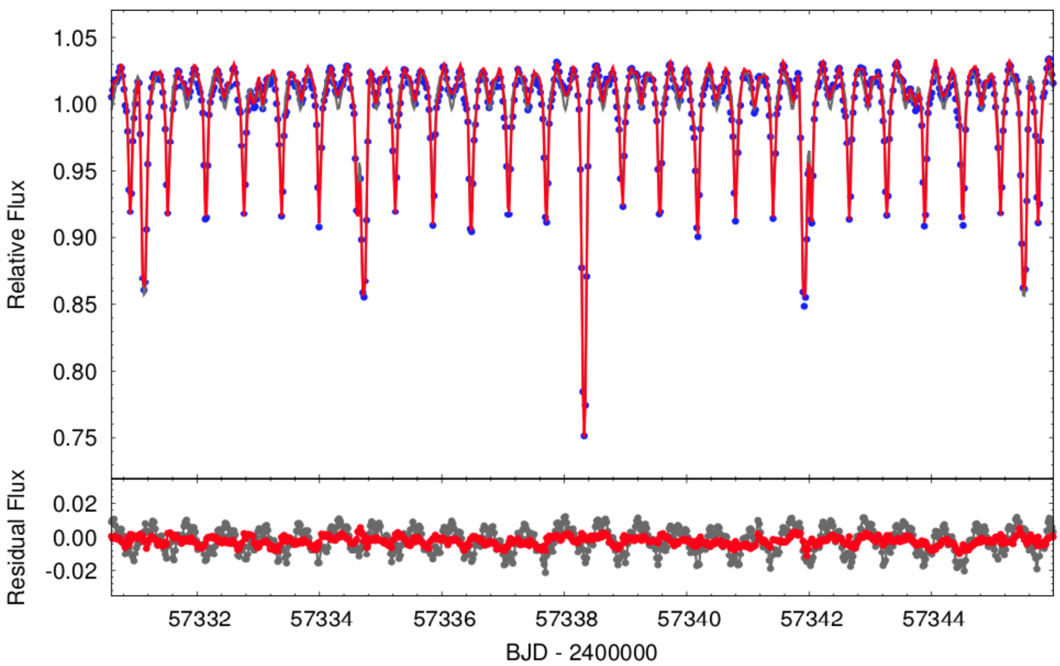

Figure 1. A zoomed-in ~ 14-day segment of the K2 flux data showing the superposition of the eclipses of the A and B binaries. The data are shown in blue, the gray curve is a pure, double, blended eclipsing binary model fit, while the red curve is the net model fit taking into account both the binary and the other distortion effects (see text for details). The residuals of the data from the two models are shown in the bottom panel.

The magnitude of the system is around 13. One eclipsing binary (EPIC 219217635A) has a period of 3.595 days and is thought to be an Algol type system (EA). The primary is 1.2 solar masses and the secondary 0.68 solar masses. The other eclipsing binary (EPIC 219217365B) has a period of 0.618 days and is thought to be a beta Lyrae type system (EB). The primary is 1.3 solar masses and the secondary 0.41 solar masses.

The paper states that it is possible that the two systems, which are thought to be 2 Angstrom Units apart, are gravitationally linked. This will only be confirmed following further observations over the next few years. They predict a 15-minute shift in eclipse times.

MN Cassiopeiae

This is a system with a period of 1.91692787 days and a maximum magnitude of around 10.10V. The depth of both eclipses are about 0.5 magnitude in depth. The stars are of equal luminosity.

Both the GCVS and the Krakow databases classify the system as EA/DM. However [2] describes a partially eclipsing system in which the stars are highly distorted being nearly in contact. The system is, according to [2] more properly classified as an EB, beta Lyrae, system. A system where the stars are in such close proximity is worthy of further study.

QX Cassiopeiae

This is also a system which the GCVS and Krakow classify as an EA/DM eclipsing binary. When the system was discovered in 1954 the eclipses were of equal depth, 0.5 magnitude. In 1969 the eclipses were around 0.3 depth. The secondary minimum occurred at phase 0.37 indicating a moderately eccentric orbit.

An article in the 2012 JAAVSO June by Ginan, Bonaro, Engle and Prsa, describes that the system has ceased to be an eclipsing binary. It may resume eclipsing at some stage so is still worthy of study.

Four winters of photometry with ASTEP South at Dome C, Antarctica.

Eclipsing binaries (and other variable stars) are being discovered in some unusual places [3]. Dome C in Antarctica offers exceptional conditions for making observations. It has a continuous night for six months and very favorable atmospheric conditions. Dome C is situated on a summit of the high Antarctic plateau at an altitude of 3233 meters, 1100 kilometers from the coast. 47 eclipsing binaries (19EA, 10EB and 18EW) have been discovered.

(1) EPIC 219217635: A Doubly Eclipsing Quadruple System Containing an Evolved Binary, arXiv:1805.09693 [astro-ph.SR] arxiv.org/abs/1805.09693.

(2) 'Eclipsing Binary Star MN Cassiopeiae' JS Shaw, AD Grauer, 1977, AJ, 82, 290-292.

(3) arXiv:1807.10807 [astro-ph.IM] (or arXiv:1807.10807v1

Autumn Eclipsing Binaries

Christopher Lloyd

In the second article on the BAAVSS eclipsing binary stars we have moved round the sky to the autumn stars, those between 0 and 6 hours. The eclipsing binary list has 85 stars that are accessible to observers with small telescopes or DSLR cameras, or even binoculars. However, if you are considering making eclipse timings please use a DLSR or a set up with a small telescope and CCD, like the Somerby Observatory for example, and archive your observations with the BAA or AAVSO or other accessible repository. For the complete listing see Lloyd 2018 (VSSC 176, 39) which also contains links to other resources. Most of the stars were originally selected as binocular variables and have magnitudes of 7 – 10 with a handful of bright, well-known classics and a few fainter stars. The periods are short, half have P < 2 days with the shortest at 0.27 days and only 8 have P > 5 days, again with a few long-period curiosities. Many of the stars have eclipses that are short enough to be observed in a single night – and this is the preferred way to make timings – but others may need the light curve or at least the eclipse to be built up over some weeks or even the whole observing season.

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.

TW Andromedae 00 03 18.23 +32 50 45.1

The classical Algol system TW And has a deep primary eclipse of $2.^{m}0$ from a maximum of V = 9.0 making it one of the fainter stars of this group at minimum. The system contains an F0 V primary which is totally eclipsed at primary minimum, and a K1-3 III-IV secondary. The secondary eclipse is very weak, ~ $0.^{m}1$. Times of minima are available for over a century, but these are relatively sparse, and the system has only been observed consistently with modern detectors since the turn of this century. Consequently, the period behaviour, although clearly variable at a low level, is not well defined. The behaviour is probably best explained by a combination of a secular period increase and a periodic component due to a third body with the period of 50 years (see Figure 1). This is a system which deserves to be monitored more closely. The recent ephemeris of primary minima is

$$HJD_{MinI} = 2455486.7364(11) + 4.1227265(34) \times E$$

TV Cassiopeiae 00 19 18.74 +59 08 20.6

TV Cas is a classical Algol system with components of B9 V and G5 IV-III, where the secondary fills its Roche lobe. The primary eclipse is deep, $1.^{m}0$ from V = 8.2 but the secondary is weak, only ~ $0.^{m}1$. The historical O-C diagram (see Figure 2) reaches back to the beginning of the last century and is apparently dominated by a single change between two nearly constant periods. However, it is best described by a combination of a secular decrease in period and the effect of a third body with a period of 65.7 years. However, the recent data reveal additional small-scale oscillations that are currently unexplained. In other similar systems this type of behaviour is related to variations in the mass-transfer rate from the secondary to the primary but in this case, it is not defined well enough to draw any conclusions. The complexity of the variations and the uncertainty in the behaviour make TV Cas a high priority target. The current ephemeris of primary minimum, which covers the recent constant interval, is

$$HJD_{MinI} = 2453290.2049(10) + 1.8125919(7) \times E$$

DS Andromedae 01 57 46.05 +38 04 28.4

DS And is one of the fainter stars in this group with a range of V = 10.4 -10.9 and although it is listed as a classical Algol-type its short period, at just over one day, means that the light curve is continuously variable. The most recent light curve and photometric solutions consider it as an RS CVn system. The primary is an evolved F3 IV-V star nearly filling its Roche lobe and the secondary is a solar-type star, so clearly not a classical Algol. It is a member of the intermediate-age open cluster NGC 752 and lies at the main sequence turn off. The eclipse timings have been well covered for the past ~ 20 years with a scattering of PEP and photographic values before that. The eclipse timings can be determined with some accuracy but there are an uncomfortable number of discordant measures. However, there is some suggestion that the recent timings have a different alignment to the earlier ones even though the formal errors do not support a period change (see Figure 3). Nevertheless, this is one to watch. The ephemeris of primary minima from JD = 2450000 is

$$HJD_{MinI} = 2451397.1951(7) + 1.01051971(17) \times E$$

AB Cassiopeiae 02 37 31.51 +71 18 16.3

With a range of V = 10.1 - 11.8 AB Cas is one of the fainter systems in the group but it is a classical Algol-type with a deep primary eclipse and is well observed. Eclipse timings date back for almost a century and reveal complex variations in period. Although the historical O-C diagram (see Figure 4) is dominated by sparse photographic, and visual timings at critical times, detailed analysis shows a large secular increase in period and the presence of a third body with a period ~ 40 years. The recent behaviour shows little variation over the past 15 years, but this is due to the combined effects of the secular and periodic variations cancelling each other out, but this should change as the effect of the third body becomes more pronounced. The current ephemeris is of primary minimum is

$$HJD_{MinI} = 2452140.4870(7) + 1.36689167(36) \times E$$

AB Cas is a complex system that deserves to be observed as its behaviour is based on very old material. The only complication is that the primary is a multi-periodic delta Scuti variable with a dominant period of 0.058 days and a semi-amplitude of $0.^{m}03$. From the scatter of the times of minimum this additional variation does not seem to have a significant impact on the eclipse timings provided enough of the eclipse is observed.

Z Persei 02 40 03.24 +42 11 57.7

Z Per is a classical Algol-type system with a deep primary eclipse containing an A0V primary and a G0 IV-V secondary. Times of minima have been recorded for over a century and show a substantial secular decrease in period upon which are superimposed irregular changes (see Figure 5). The period has been constant for the past decade, but it may recently have undergone another irregular change. The current ephemeris is of primary minimum is

$$HJD_{MinI} = 2454008.8682(13) + 3.0562360(22) \times E$$

DO Cassiopeiae 02 41 24.16 +60 33 11.8

DO Cas is a contact binary with a large temperature difference between the components. The period is one of the shortest in this group at 0.68 days and the range is V = 8.4 - 9.0 with a secondary eclipse of ~ $0.^m2$. The O-C diagram (see Figure 6) shows a nearly sinusoidal variation with a semi-amplitude of 0.005 days and a period of 18 years although there are inconsistent points and some significant gaps in the coverage. Given the poorly defined variations in the O-C diagram DO Cas should be considered a high priority target. The current ephemeris is of primary minimum is

$$HJD_{MinI} = 2437960.5081(6) + 0.684666122(37) \times E$$

RZ Cassiopeiae 02 48 55.51 +69 38 03.4

While RZ Cas is a classical Algol system it is also the prototype of an increasingly recognised subclass of oscillating Eclipsing Algol's (oEA) where the primary component is accreting mass and shows delta Scuti-like variations due to its position inside the instability strip. The system contains an A3 V primary with a K0 III Roche-lobe filling secondary and shows deep primary eclipses with a range of V = 6.2 - 7.7. The delta Scuti-like variations have a principal period of 0.016 days and a semi-amplitude of ~ 0.01_{mag}, both of which are variable. The historical O-C diagram is well covered back to the start of the previous century and it shows relatively small, but almost continual changes in period. A more detailed view of the recent behaviour in Figure 7 suggests that there are intervals of up to 10 years when the period is probably constant, but the variations are very complex. It seems most likely that the period changes are due to episodic variations in the mass-transfer rate related to magnetic cycles in the secondary and that these are also responsible for the changes in the delta Scuti-like behaviour of the primary. Although the system is relatively well observed it does need to be intensively monitored to track the subtle changes in period. The recent mean ephemeris of primary minimum, which is reliable enough to identify the eclipse, is

$$\mathrm{HJD}_{Mini} = 2445000.3373(8) + 1.19525524(13) \times E$$

beta Persei 03 08 10.13 +40 57 20.4

Not many stars give their name to a major class of variables, but Algol is one of them. The system contains a late B-type star with an early K-type subgiant which fills its Roche lobe. The system also contains a third body in a 680-day orbit around the close pair. Because the system is so bright the times of minima have been mostly visual, and it is only within the last decade that modern detectors have been used routinely. The period behaviour is very complex, although not particularly large, and is probably best represented by discrete period changes, both positive and negative, between constant periods (see Figure 8). This is most likely due to changes in the mass transfer rate. The most recent period change occurred in 2011 and the current ephemeris of primary minimum is

$$HJD_{MinI} = 2455063.5787(18) + 2.8673286(29) \times E$$

RW Tauri 04 03 54.31 +28 07 33.5

RW Tau's main claim to fame is the prodigious depth of its primary eclipse, $3.^m6$ from a maximum of V = 8.0. The secondary eclipse is weak at $0.^m07$. The system is a classical Algol with a primary of B8 Ve and secondary of K0 III-IV which fills its Roche lobe and completely obscures the B star at primary eclipse. Reliable eclipse timings have been made since the 1880s photographically, visually and using modern detectors, and they reveal a complex range of period variations which are not adequately explained by the usual secular and light travel time arguments. The O-C diagram is best described as a series of constant periods with discrete period changes both positive and negative. The mechanism producing this is not clear and RW Tau is a complex system with a Be primary, a circumstellar disc and gas stream. Despite the obvious activity of the system eclipse recent timings are relatively sparse (see Figure 9) so better coverage is required. The period has been effectively constant for the past decade and ephemeris of primary minimum is

$$HJD_{MinI} = 2454023.7189(6) + 2.7687937(9) \times E$$

HU Tauri 04 38 15.83 +20 41 05.0

HU Tau is one of the brighter stars in this group with a range of V = 5.9 - 6.7. It is a classical Algol system with a late B-type primary and an early G-type secondary which is over luminous for its mass and fills its Roche lobe. The secondary eclipse is very shallow, < $0.^m1$, which means that the secondary is unusually faint. From the O-C diagram in Figure 10 modern PEP and CCD minima are relatively well determined and while they do not show any substantial period change there is a suggestion of a cyclic behaviour with a period of ~ 70 years and a semi-amplitude of 0.006 days. Unfortunately, barely one cycle has been covered so far and there are some discordant points, so the behaviour is not clear. HU Tau should be considered a high priority target in order to define this variation. The current ephemeris of primary minimum is

$$HJD_{MinI} = 2440981.2677(16) + 2.05630398(42) \times E$$

ER Orionis 05 11 14.50 -08 33 24.7

At 0.42 days ER Ori is the shortest period system in this group and is an over-contact W UMa variable containing two similar stars with equal depth eclipses. The range is V = 9.3 -10.0 and the system is well observed. The O-C diagram shows complex variations which can be interpreted in terms of a secular increase in the period and the light travel time introduced by a third body with a very eccentric orbit and a period of ~ 54 years (see Figure 11). The current ephemeris of primary minimum is

$$HJD_{MinI} = 2456239.70372(32) + 0.42340615(15) \times E$$

SX Aurigae 05 11 42.93 +42 09 55.3

SX Aur is a shallow-contact system on the border of the beta Lyrae and W UMa stars. It is a massive system containing components of spectral types B3 and B5 and has a range of V = 8.4 - 9.1, with the secondary eclipse $0.^{m}5$ deep. The historical O-C diagram (see Figure 12) shows a small but significant secular change which may be made up of constant-period segments. The recent data appear relatively constant and the current ephemeris of primary minimum is

$$HJD_{MinI} = 2453082.37038(47) + 1.21008312(24) \times E$$

IM Aurigae 05 15 29.74 +46 24 21.4

The complex period variations of IM Aur have been known for some years although the amplitude is low. The O-C diagram (see Figure 13) shows a relatively short-period ripple and a small secular decrease in the period of the close binary. The system is a classical Algol type containing a late B-type primary and an F-type secondary. The third body is probably a mid A-type star and produces a 0.006-day semi-amplitude variation in the O-C diagram with a period of 1372 days, very much shorter than the typical multi-decennial periods. Clearly this behaviour needs to be more intensively monitored than it is currently. The current ephemeris of primary minimum is

$$HJD_{MinI} = 2450123.4040(10) + 1.24728553(35) \times E$$

IU Aurigae 05 27 52.40 +34 46 58.3

IU Aur is a massive short-period binary containing two early B-type stars. The range is V = 8.2 - 8.8 with the secondary eclipse at $0.^{m}5$ deep. The system is well known for the very short period, 293 days, variation introduced by a third body. The recent O-C diagram shown in Figure 14 is dominated by the high frequency scatter introduced by the third body and there is also a small secular increase in period. The ephemeris of primary minimum from recent data is

$$HJD_{MinI} = 2450380.5840(11) + 1.8114770(5) \times E$$

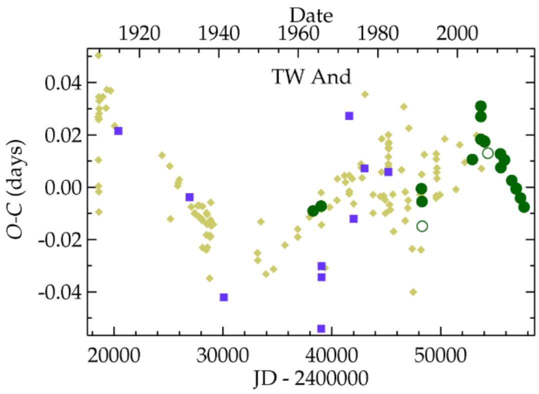

Figure 1:

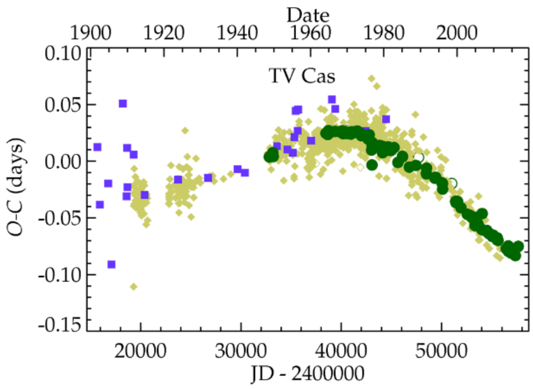

Figure 2:

Figure 1: The historical O-C diagram of TW And showing a nearly sinusoidal variation with a period ~ 50 years consistent with the effect of a third body and a secular increase in period. Symbols are as before.

Figure 2: The historical O-C diagram of TV Cas. Despite appearances the period is continuously decreasing but that is masked by the light-travel time effect of a third body. Squares are photographic, diamonds are visual, and circles are modern, PEP, CCD and DLSR. Open symbols are the secondary eclipse.

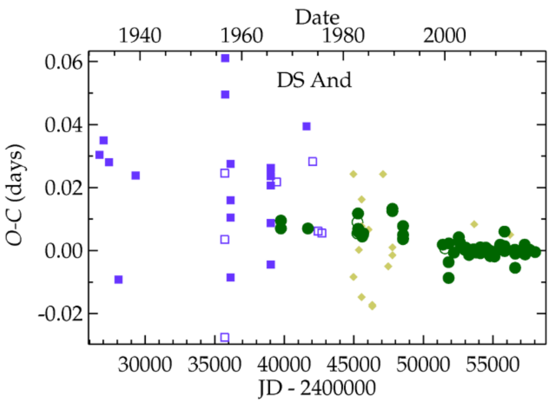

Figure 3:

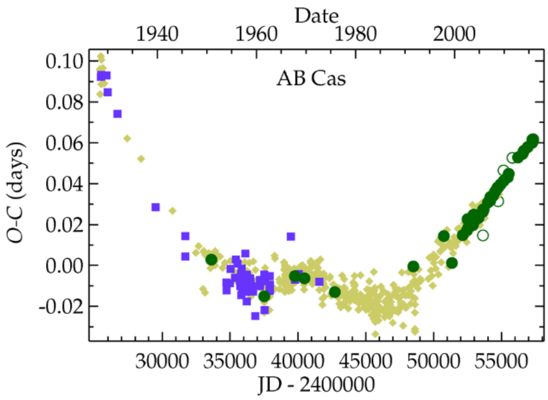

Figure 4:

Figure 3: The O-C diagram of DS And showing a possible secular increase in period. Symbols are as before.

Figure 4: The historical O-C diagram of AB Cas. The variation can be described by a combination of a large secular increase in period and the effect of a third body with a period of ~ 40 years. Symbols are as before.

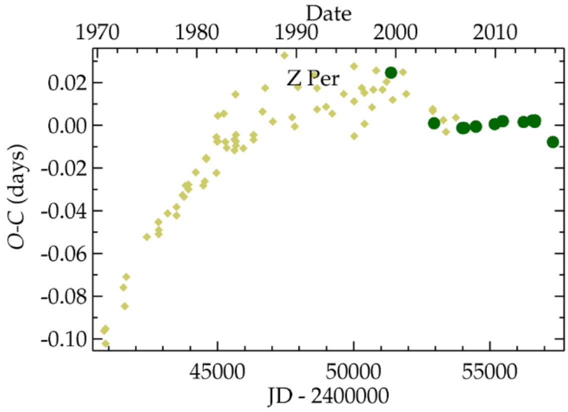

Figure 5:

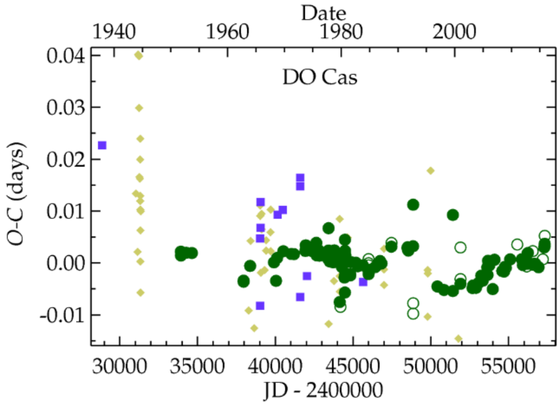

Figure 6:

Figure 5: The historical O-C diagram of Z Per showing a large secular decrease in period and other irregular changes. Symbols are as before.

Figure 6: The O-C diagram of DO Cas showing a low amplitude nearly sinusoidal variation with a period ~ 18 years, consistent with the effect of a third body. Symbols are as before.

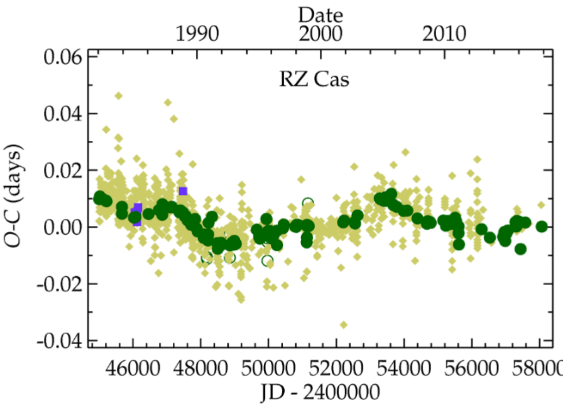

Figure 7:

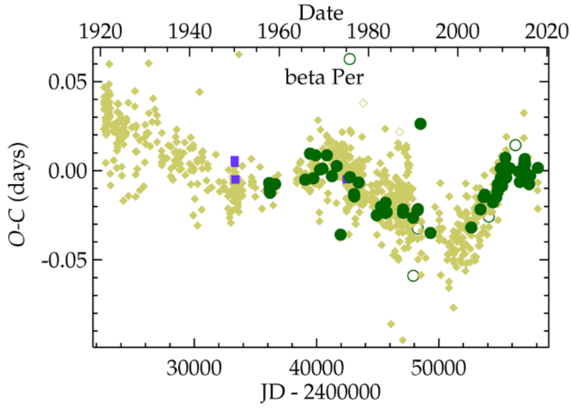

Figure 8:

Figure 7: The recent O-C diagram of RZ Cas small complex variations between approximately constant periods. Symbols are as before.

Figure 8: The O-C diagram of beta Per for the last century. The variation is complex, and the period appears to switch between values and remains approximately constant for 10 - 30 years. The recent period change occurred in 2011. Symbols are as before.

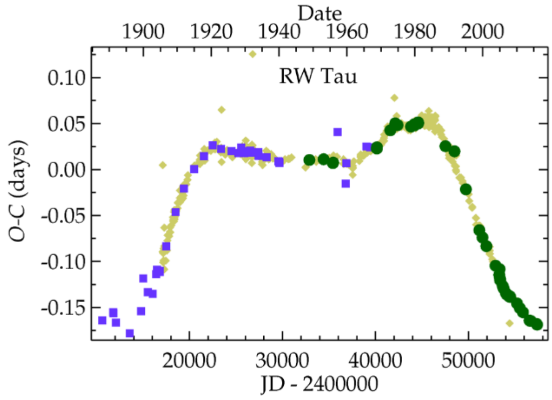

Figure 9:

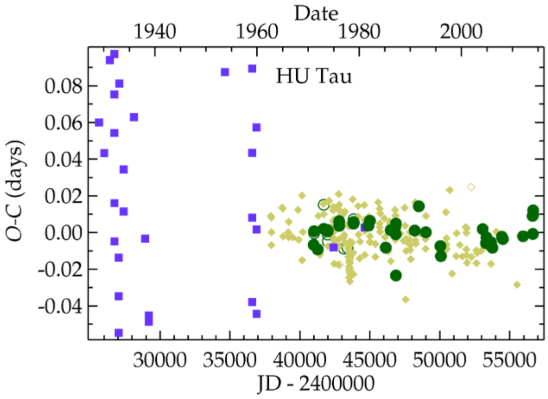

Figure 10:

Figure 9: The historical O-C diagram of RW Tau shows large and complex variations that are difficult to model with the usual secular change and light travel time arguments. Symbols are as before.

Figure 10: The historical O-C diagram of HU Tau showing a nearly sinusoidal variation with a period ~ 70 years consistent with the effect of a third body. Symbols are as before.

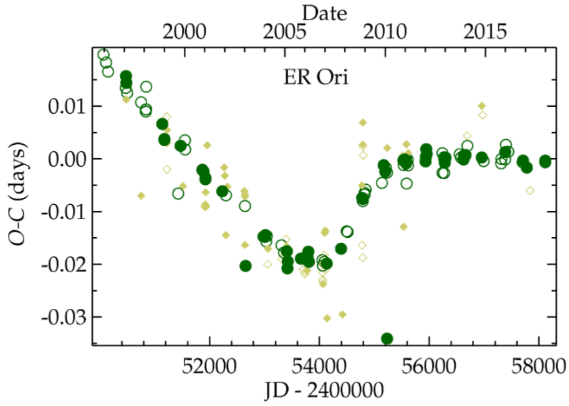

Figure 11:

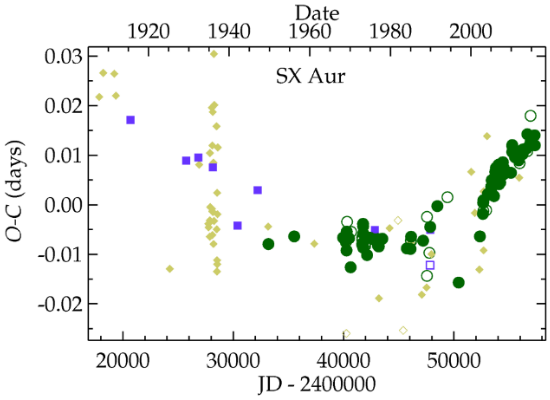

Figure 12:

Figure 11: The recent O-C diagram of ER Ori showing the variation produced by a combination of a secular increase in period and the effect of a third body. Symbols are as before.

Figure 12: The historical O-C diagram of SX Aur shows a small but significant secular change which may be made up of constant-period segments. Symbols are as before.

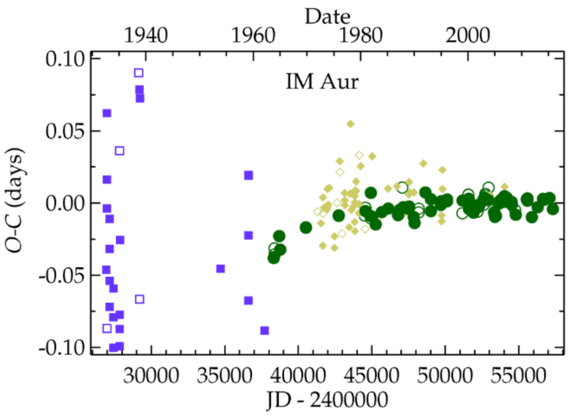

Figure 13:

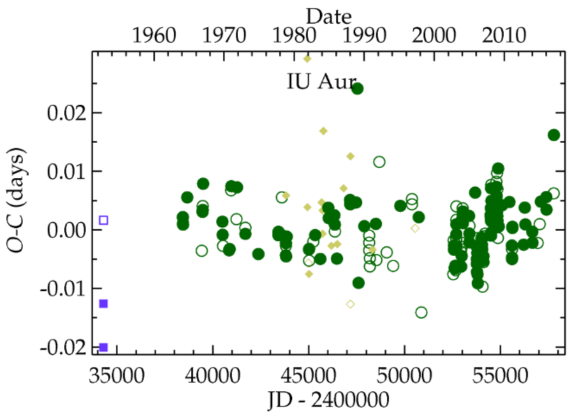

Figure 14:

Figure 13: The recent O-C diagram of IM Aur is dominated by the high frequency scatter introduced by the third body and there is also a small secular increase in period. Symbols are as before.

Figure 14: The recent O-C diagram of IU Aur showing the apparent scatter produced by the 293-day light travel time variation and a small secular increase in period. Symbols are as before.

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Section Officers

Director
Roger Pickard
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Hillside View, 17 Ashdale Road, Cressage, Shrewsbury SY5 6DT
Tel: 01952 510794   E-mail enootnhoj@btinternet.com

Pulsating Stars Co-ordinator
Shaun Albrighton
4 Walnut Close, Hartshill, Nuneaton, Warwickshire CV10 0XH
Tel: 02476 397183   E-mail shaunalbrighton93@gmail.com

CV's & Eruptive Stars co-ordinator, Circulars Editor & Webmaster
Gary Poyner
67 Ellerton Road, Kingstanding, Birmingham B44 0QE
Tel: 07876 077855   E-mail garypoyner@gmail.com

Nova/Supernova Secretary
Guy Hurst
16 Westminster Close, Basingstoke, Hants RG22 4PP
Tel: 01256 471074   E-mail guy@tahq.demon.co.uk

Eclipsing Binary Secretary
Des Loughney
113 Kingsknowe Road North, Edinburgh EH14 2DQ
Tel: 0131 477 0817   E-mail desloughney@blueyonder.co.uk

Database Secretary
Andy Wilson
12, Barnard Close, Yatton, Bristol BS49 4HZ
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