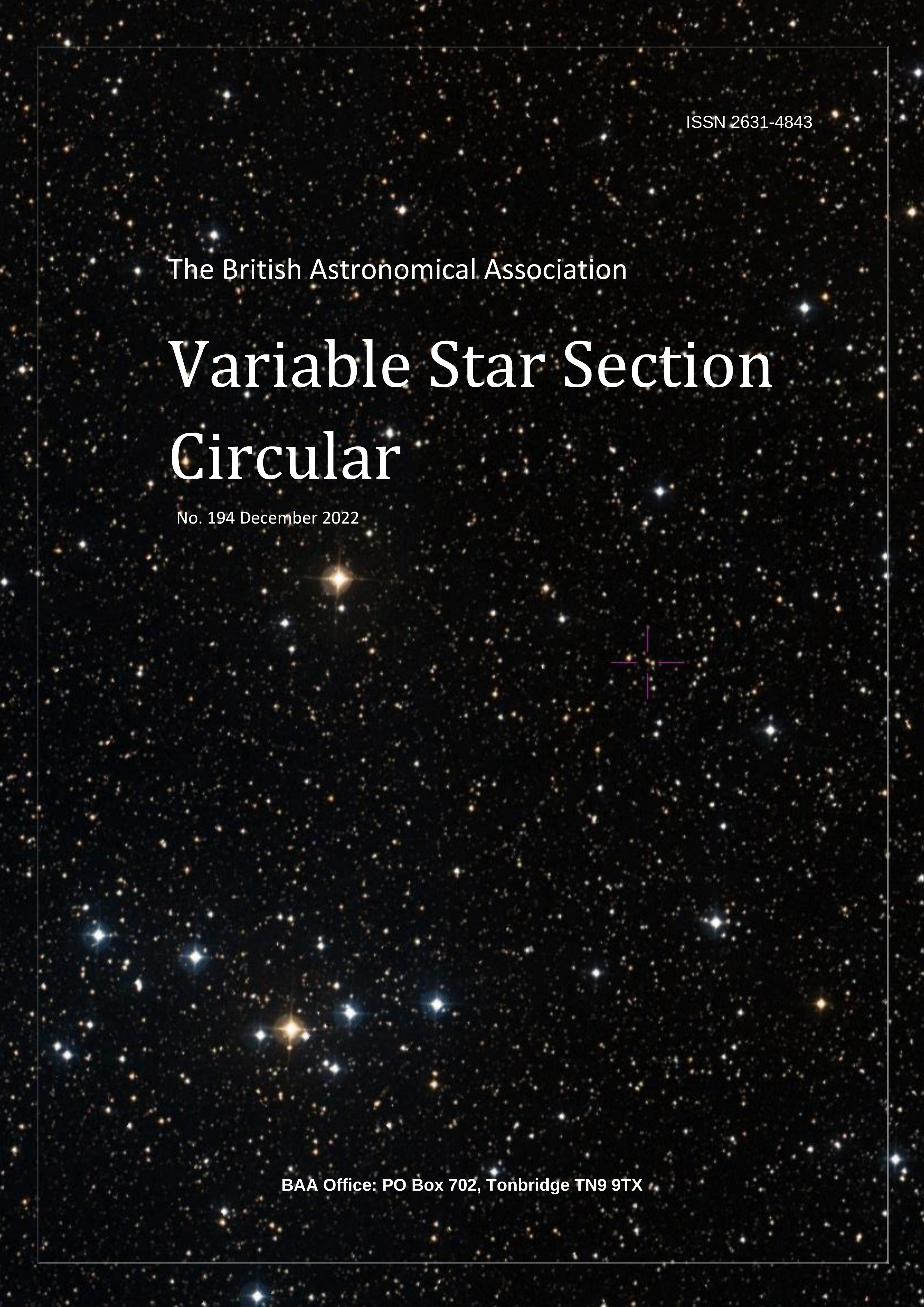

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Variable Star Section Circular

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Cover Picture

The field of DY Per
Digitized Sky Survey

Aladin sky atlas developed at CDS, Strasbourg Observatory, France
2000 A&AS..143...33B and 2014ASPC..485..277B.

Section meeting on 2023 September 2

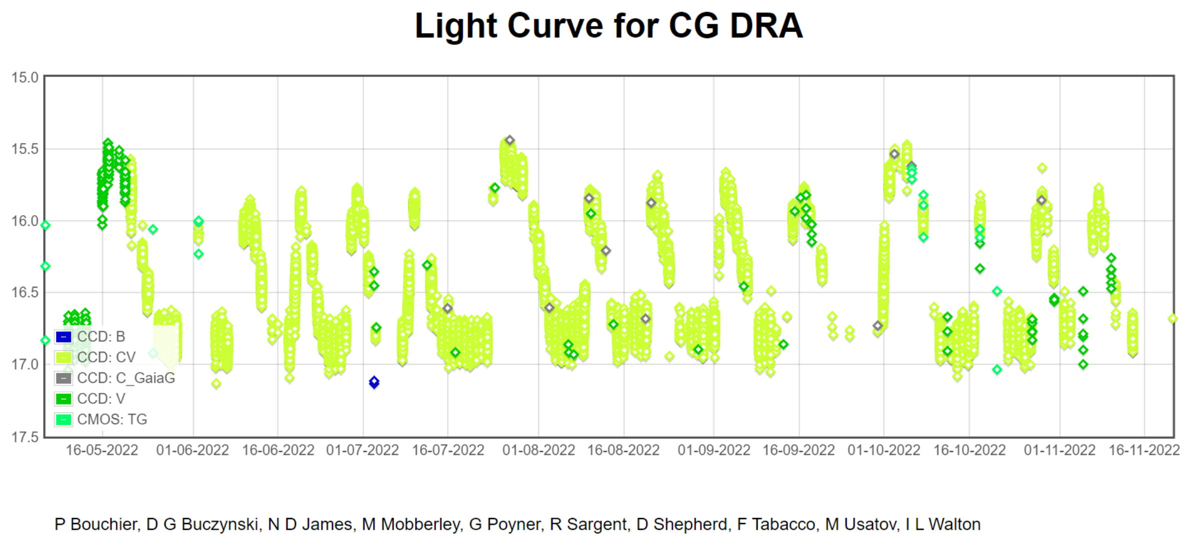
I am delighted to give advance notice that a full day Section meeting will take place on Saturday September 2, 2023 at the Humfrey Rooms in Northampton, courtesy of the Northamptonshire Natural History Society. We had hoped to hold a meeting in this venue in 2020, but the pandemic meant it was cancelled, so it will be wonderful to gather in person once again.

Further details will be available early next year. In the meantime, please put the date in your diary.

Gary Poyner and I will be putting the speaker programme together. We'd like to have a range of talks from members, so please give some thought if you would like to give a talk.

Campaign to observe CG Dra

Please continue to observe CG Dra as it sinks into the evening sky at this time of year. This year's coverage has been very intensive as shown by the VSS light curve below, covering 2022 May 1 to November 21:



Many thanks to all our observers, including Maxim Usatov whose long-term coverage from his remote observatory has been remarkable (and the subject of frequent discussion on the BAA Forum).

Professor Tom Marsh

Section members will no doubt have been saddened by the recent tragic death of Professor Tom Marsh during a visit to the European Southern Observatory at La Silla, Chile. Tom was founding professor of the Astronomy and Astrophysics group at the University of Warwick and a great friend of the VSS. In 2018, he won the RAS Herschel Medal, which is awarded for investigations of outstanding merit in observational astrophysics. The Herschel Medal recognised Tom's pioneering research on binary star systems. Our heartfelt condolences go to his wife, son and daughter.

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New AAVSO Executive Director

Dr. Brian Kloppenborg has recently taken up the position of Executive Director of the AAVSO. On behalf of the VSS, I have written to Brian to congratulate him and wish him well in his tenure. We have resolved to continue the spirit of fruitful cooperation between the two organisations that extend back well over a century.

2023 beckons

I'd like to take this opportunity of wishing all Section members a Merry Christmas and clear skies in 2023.

WINTER MIRAS

M = Max, *m* = min.

R And	M=Dec/Jan
R Aql	M=Jan
UV Aur	M=Jan
X Cam	*m*=Jan/Feb
SU Cnc	*m*=Jan/Feb
RT CVn	*m*=Nov/Dec
Omicron Cet	*m*=Feb
W CrB	M=Jan
chi Cyg	*m*=Dec
R Cyg	M=Jan/Feb
S Cyg	M=Jan
V Cyg	M=Jan
RU Her	M=Dec
SS Her	*m*=Nov/Dec
	M=Jan
SU Lac	M=Jan/Feb
RS Leo	M=Dec
X Lyn	M=Nov/Dec
X Oph	*m*=Feb
U Ori	*m*=Dec/Jan
T UMa	M=Jan/Feb

Source BAA Handbook

Chart News

John Toone

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Some minor changes have been implemented to sequences on the pulsating star programme, and as a consequence the following updated charts have been posted to the VSS web site:

035.03 W And
The gap between comparison stars K & L was previously too narrow so comparison stars L & N have been amended to adopt SRO values.

030.03 R Aql
Comparison star D has been amended from a V value on account of its red colour. Also, the sequence was previously calibrated too faint at the lower end so comparison stars W, X & Z have been amended to adopt HCO & APASS values.

104.03 RV & RW Boo
Comparison star E has been amended to provide a gap of 0.4 magnitude with comparison star D.

039.04 omicron Cet
Comparison star X has been amended from a V value on account of its red colour.

225.03 RY Dra
The sequence now adopts Hipparcos Vj values rather than Tycho Vj. The only impact is to comparison star C, which is red compared to comparison stars B, E & F.

106.04 AH Dra
Comparison star 1 has been amended to adopt a HD value to ensure a gap of 0.3 magnitude with comparison star 2.

224.03 g Her
Comparison star D has been amended from a V value on account of its red colour.

324.02 OP Her
Comparison star A has been amended from a V value on account of its red colour.

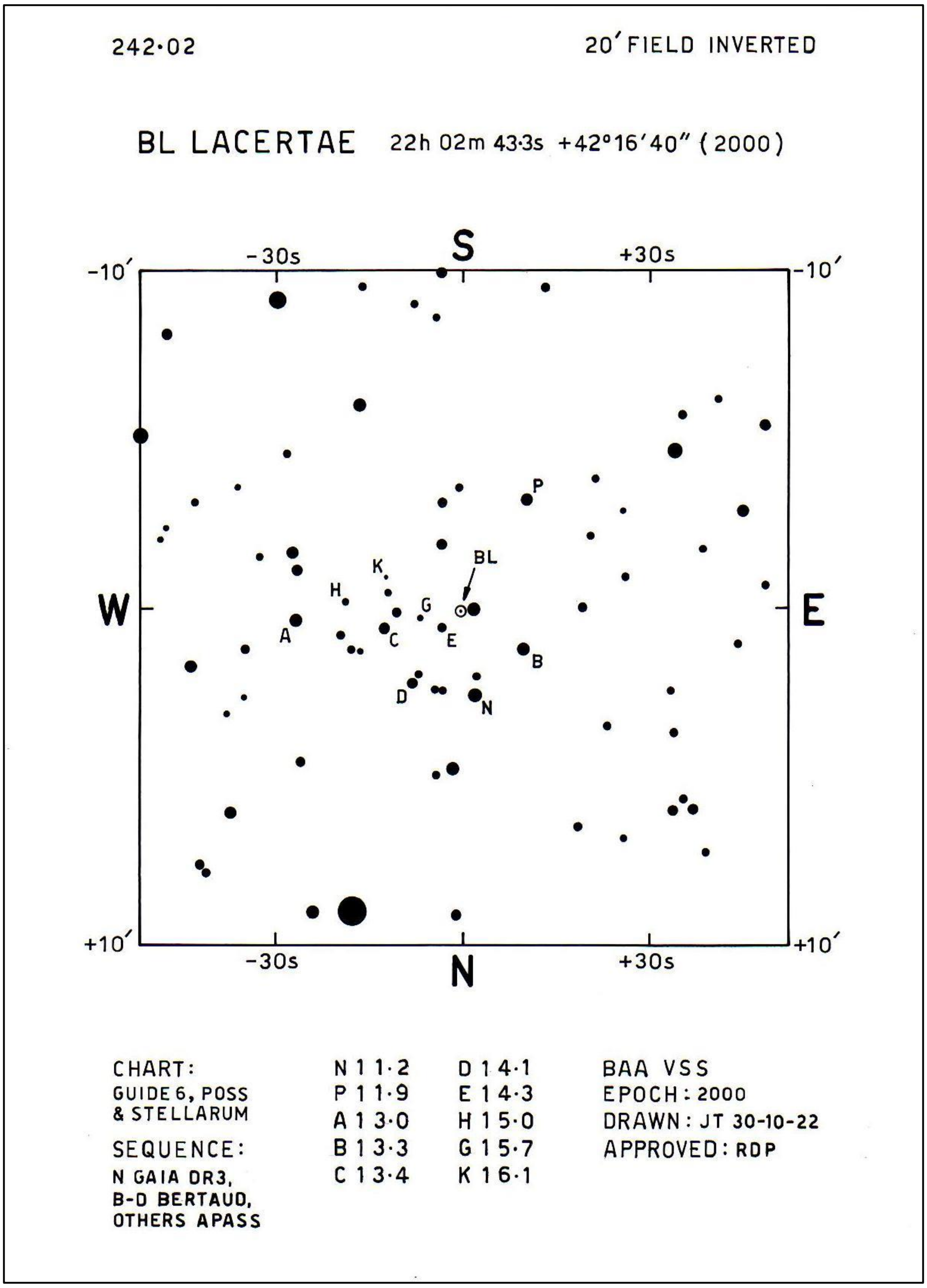
218.03 U LMi
The gap between comparison stars F & G was previously too narrow so comparison star G has been amended to adopt a APASS value.

033.03 R Ser
The gap between comparison stars L & N was previously too narrow so comparison star L has been amended to adopt a GSC value.

101.04 V UMi
Comparison star D has been amended from a SAO value to better represent the gap with comparison star E.

242.02 BL Lac

With BL Lac exhibiting bright optical flares in 2021 and 2022 the sequence on chart 242.01 was in need of extension. Therefore, the following update to the chart has been undertaken. Comparison stars N, P, H & K have been added to extend the sequence at both the bright and faint ends. Comparison star F has been dropped on account of photometric scatter and colour. The value of comparison star G has been amended from 15.48 to 15.7.



If observers have any comments relating to either charts or sequences, please contact the Chart Secretary.

Categorising Variable Stars, a short historical review

Shaun Albrighton

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This article takes a look at various proposals for the classification of variable stars and the characters behind the proposals.

If we exclude the sudden appearance of 'New Stars', novae and supernovae, which were observed sporadically throughout history, then the first authentic case of a periodic variable star is Mira, omicron Ceti. Not counting possible sightings by Chinese, Korean and Greek astronomers, it was David Fabricius, who in August 1596 noted the presence of a third magnitude star in the constellation of Cetus, which he could not find in any catalogue. The star was observed to fade over the following few weeks. Then in 1603 Bayer, unaware of the star's previous appearance, recorded the star as omicron Ceti. It was not until 1638, that Holwarda, observing the star himself, connected it to previous observations [1].

One would think that with the advent of the telescope, more variables would have been discovered, but this was not the case, in fact it is best to describe it as pedestrian. The second star Algol, or beta Persei, was discovered in 1667, by Montanari, who described it as being fainter on some nights than others. He also stated that the dimming could not be attributed to anything in the terrestrial atmosphere. During the next hundred years only two more variables were discovered, chi Cygni (Kirch 1686) and a star now known as R Hydra (Maraldi 1704) both Mira variables. Then, in the 1780's four more were added to the list, R Leonis (Mira), beta Lyrae (eclipsing) and a new class of variable in delta Cepheus and eta Aquila were discovered.

In 1795 three unusual types of variables were noted, alpha Herculis (William Herschel), R Coronae Borealis and R Scuti. So, by the end of the 18th century, 16 variables, including novae, were known. Over time further variable stars, including a different class of variable, SS Cygni and U Geminorium, were discovered visually and then increasingly, by photographic and spectroscopic means. The table below gives a snapshot, illustrating the progress made in the discovery of variables [2].

Year	Authority	Variables
1786	Pigott	12
1844	Argelander	18
1866	Schoenfeld	119
1896	Chandler	393
1907	Cannon	1425
1920	Müller & Hartwig	2054
1930	Prager	4611
1936	Prager	6776
1941	Schneller	8445

Numerous attempts were made to try and classify variable stars, perhaps the most famous of which was that in 1881 by Edward Charles Pickering (1846-1919). Pickering is often regarded as the founder of variable star observing in the U.S. and is perhaps best known for employing female 'Calculators', including Annie Jump Cannon, Henrietta Swan Levitt, Antonia Maury and Florence Cushman. Together they made several important discoveries, including that by Leavitt's of the period-luminosity relationship for Cepheids, published by Pickering. He initially proposed five groups:

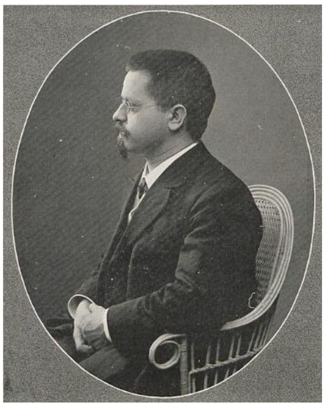
Edward Charles Pickering
(Public Domain)

I	Novae	IV	Short periods
II	Long-periods	V	Algols
III	Irregulars		

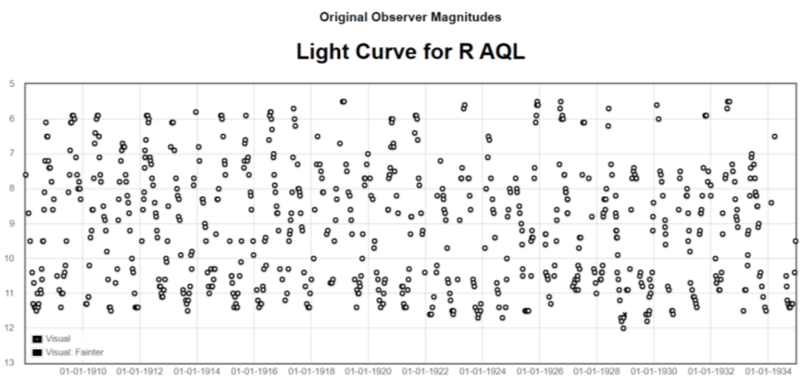
Pickering later divided Class II into three groups, IIa, Mira stars, IIb, U Geminorum or SS Cygni stars; and IIc, R Coronae Borealis stars. It was later realised that IIb and IIc should not have been classified with the long-period class, their demarcation purely being down to the time between successive maximum or minimum being rather long as against short. Class III variables was used as a dumping ground for those who did not appear to have any obvious period.

Pickering however was not alone, below are listed some of the other groupings;

Albertus Antonie Nijland (1868-1936). A Dutch astronomer and professor of astronomy at Rijksuniversiteit Utrecht. He is noted for his observations of variable stars, of which between 1906 and 1934, he submitted 18,370 observations of 27 stars to the BAAVSS [3]. Below is a plot of his observations of the Mira variable, R Aquila between 1908 and 1935.



Albertus A Nijland
(Public Domain)



Nijland is best known for his proposal that variables within each constellation be numbered V1,V2,V3… However due to the widespread use of the single/double letter system, his proposal was only adopted for numbers V335 onwards. His system for the classification of variable stars gave three groups, which were then subdivided.

I	Regular variation		
a	Algol	d	δ Cephei
b	β Lyrae	e	RR Lyrae
c	ζ Geminorum	f	S Sagittae

II	Semi-regular variation
a	Mira
b	U Geminorum
c	RV Tauri and η Geminorum

III	Irregular variations
a	Novae
b	Other irregulars (R Coronae Borealis and RX Andromedae)

Kasimer Graff (1878-1950). A Polish-German astronomer who worked as an assistant at Hamburg Observatory, then later professor of Vienna Observatory. When a Nazi government took over Austria in 1938, he was forced to retire, likely due to his family background and his rejection of the Welteislehre Theory. He did return in 1945 but retired three years later. Graff classified variables first by colour for Long-periods and Irregulars, then added Cepheids and Eclipsing stars:

I	Red Stars	II	Yellow stars
a	Mira	a	U Geminorum
b	μ Cephei	b	R Coronae Borealis
III	Cepheid stars	IV	Eclipsing stars
a	δ Cephei	a	Algol
b	RR Lyrae	b	β Lyrae

One of the most extensive classifications for its time came in 1928 by Hans Ludendorff (1873-1941). Ludendorff was a German astronomer and astrophysicist who became an observer at Potsdam Observatory in 1905, and then it's director in 1921, until he retired in 1938. In addition to his classification of variable stars (see below), he authored studies of the astronomy of Pre-Columbian Civilizations, in particular the Mayan culture [5].

I	Novae	VI	μ Cephei
II	Novae-like	VII	RV Tauri
III	R Coronae Borealis	VIII	Long-period Cepheids
IV	U Geminorum	IX	Short Period Cepheids
V	Mira	X	Eclipsing

For our final entry we look to that by Cecilia Payne and Sergei Gaposchkin in their 1938 book, 'Variable Stars'. Cecilia Helena Payne (1900-1979) was a British born American. Fascinatingly whilst studying at St Pauls School for Girls, no less than Gustov Holst urged her to take up a career in music. Her doctoral thesis proposing that stars were composed primarily of Hydrogen and Helium was initially rejected, although later Otto Struve described it as, "the most brilliant PhD thesis ever written on astronomy". Working with assistants they initially made 1,250,000 variable star estimates, with a further 2 million added later of stars in the Magellanic Clouds. Together with her husband they classified variables under four main headings:

A Geometrical variables, which include Eclipsing and Ellipsoid stars, as well as stars obscured by nebulae, but not involved in them.

B The intrinsic, or Great Sequence stars, which include Long-period, Semi-regular, Cepheid and Cluster-type stars, and Irregular Red variables.

C The Cataclysmic variables, which include Novae, SS Cygni, and R Coronae Borealis stars.

D Extrinsic, or Nebular variables; those involved in nebulosity.

I hope that this article has given some insight into the history of developments of variable star classification.

References

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3. https://britastro.org/photdb/observer_summary.php?obs_id=NI

4. "Why Hitler and other Nazis thought the world was really made of ice". Big Think. 20 February 2018.

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CV & E News

Gary Poyner

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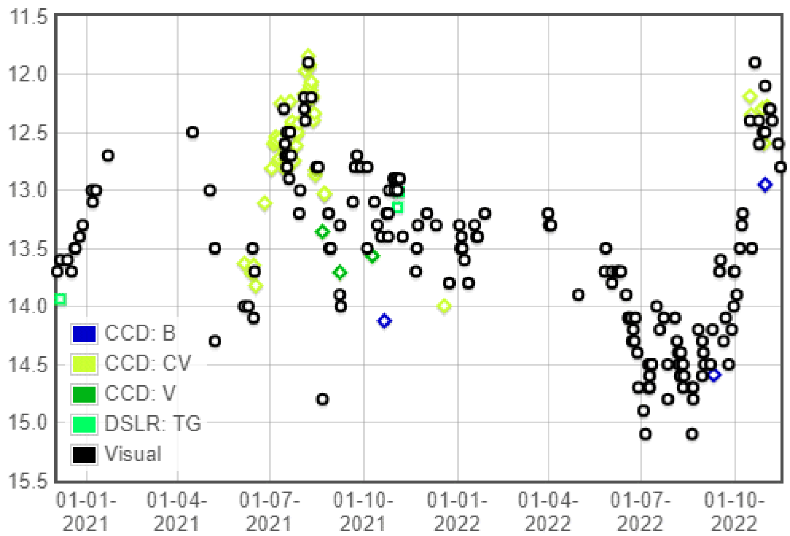
Further updates on CV&E programme stars BL Lac, V482 Cyg, AX Per, DY Per and MV Lyr are covered, including light curves from the BAAVSS database

BL Lac

Following on from the report in VSSC 189 (September, 2021), the AGN BL Lac continues its active state, with a second bright optical brightening occurring in October and continuing through November.



BL Lac, Jan 2021-Nov 18 2022. *BAAVSS database*

Following the historically bright state reached on August 7, 2021 where BL Lac surpassed magnitude 12.0, a slow somewhat erratic decline set in, ending with BL Lac reaching a mean value of 14.5 visual during July 2022. A rise in brightness then started in late September culminating in a visual magnitude of 11.9 on October 20 – equal to that of the historically bright flare in 2021. The optical brightening was announced on ATel 15725 on October 27, and on October 30, ATel 15730 reported a high X-ray flux state comparable to that of 2021.

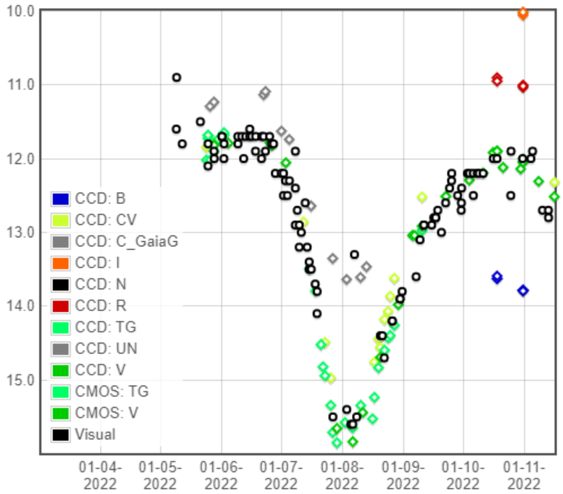
As I write this report (November 18), BL Lac has faded back to 12.8 visual. The field should be accessible in the western sky to the end of the year at least, and observers are asked to monitor as closely as possible over the coming weeks if possible.

With this current high activity in mind, a new chart with an extended sequence has been prepared by John Toone and is available for download from the BAAVSS web page here and page 6 in this circular.

V482 Cyg

In VSSC 193 (September, 2022) I reported on the rare fade of the RCB star V482 Cyg, detected by several observers during the Summer of this year. Minimum occurred during August at magnitude 15.7V, and after only 17 days V482 Cyg began to recover. By November 1st V482 Cyg had reached magnitude 12.0V, whereafter it has begun to fade slowly again. The last estimate I have (Nov 20) sees V482 Cyg at magnitude 12.7 visual. Multi-colour photometry by Denis Buczynski during late October showed that V482 Cyg becomes very red (not too much of a surprise for an RCB star) as it rises out of a deep fade, being one magnitude brighter in R, two mags in I and close to two magnitudes fainter in B.

Although the field is now getting low in the West (V482 Cyg lies some 1.3 degrees East of eta Cyg), observers are asked to monitor as closely and as frequently as possible in the evening sky (not forgetting the close 13.7 companion star), and to attempt morning observations in late Winter next year if possible.

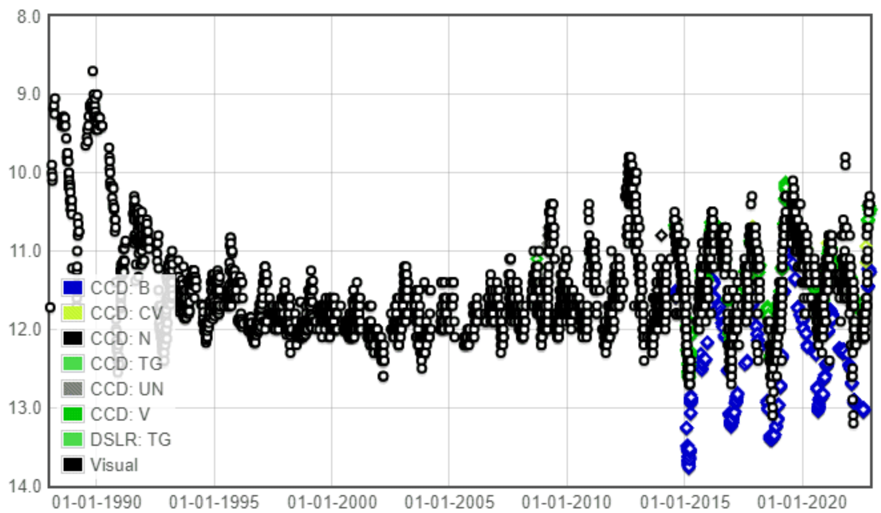


V482 Cyg, May 01-Nov 15, 2022. *BAAVSS database*

AX Per

AX Per is an eclipsing Symbiotic star with a catalogued range of 9.5V-12.8V and an orbital period of 680.83 days. Superimposed on the P_{orb} are periods where AX Per displays outburst activity. Major outbursts (to ~ magnitude 9.0V) have been recorded in 1888, 1925, 1950, 1978 and 1988 & 1989.

Since the *faint* outburst of 2012 (9.5mv), AX Per has shown intense activity where brightenings have exceeded magnitude 10.5mv on several occasions, and at the time of writing (Nov 20), AX Per is once again approaching magnitude 10.0mv. This current bright spell should be visible for some months, as the rise to previous bright phases have shown to be steeper than the decline, making AX Per an excellent target for small telescopes and indeed spectroscopy over the coming months.



AX Per, 1988-2022 showing increased activity since the outburst of 2012. *BAAVSS database*

DY Per

The prototype star of its class (DYPer), these stars are all hydrogen deficient stars which display fading events similar to RCB stars, although the decline is slower and the decline and recovery are quite symmetrical compared to RCB stars, of which not so long ago they formed a subgroup. Semi-regular type pulsation behaviour can be seen when the objects are not in deep minimum, and DY Per

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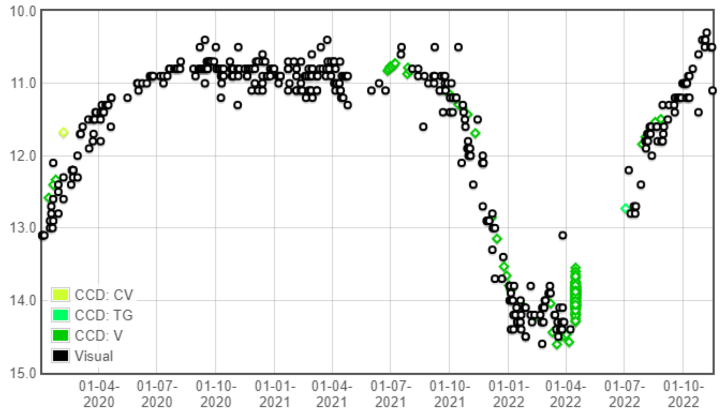


DY Per, January 2020-November 2022 showing the long 18 month maximum and current recovery. *BAAVSS Database*

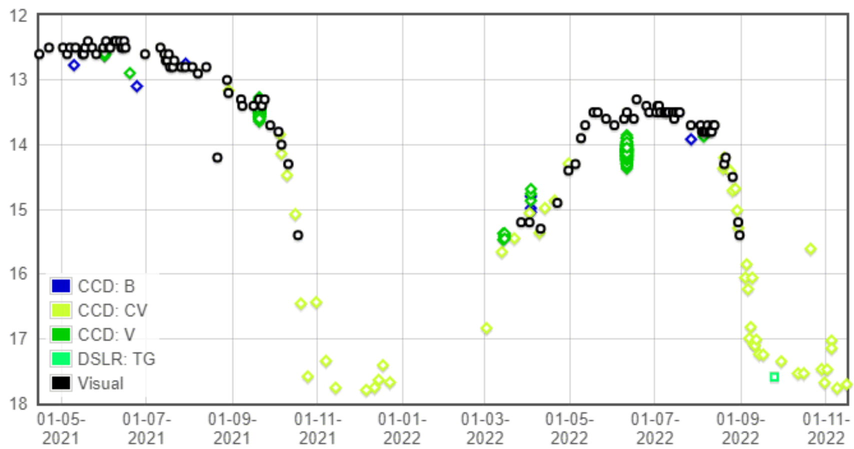
itself displays a nice 792d period. Amplitudes for declines are slightly less then RCB stars, although DY Per can drop by over 6.5 magnitudes.

At the start of the year, DY Per was at a fairly typical faint state of 14.5mv and receiving some good attention from VSS observers. The indication of a recovery was seen in late April - just before the 'seasonal' gap – where V observations had a rise to 14.0V mean. Observations were picked up again in early July where DY Per was recorded at 12.7 (V & mv), and by early November maximum brightness was reached at ~10.3 mean. Unlike RCB stars, DY Per doesn't spent too much time at maximum brightness, and it's likely than within a few months the star will be fading again. The longest period DY Per has remained at maximum brightness since observations began in 1992 has been 18 months from April 2020 to October 2021.

DY Per lies in a wonderful location of the sky – 20' NW of the open cluster Trumpler 2, and 2 degrees SE of the double cluster (*see cover*). A perfect target for the coming winter months with telescopes of all apertures.

MV Lyr

In VSSC 193 I reported some late news that the NL star MV Lyr had begun to fade for the second time in eight months, having failed to recover fully during its rise in the Summer of this year. The fade continued through August, and a minimum of 17.5Cv was reached during early September. There were indications of a recovery in mid-October when MV Lyr brightened from 17.54CV on Oct 15 to 15.61CV by the 20th, however by the 28th the star had faded again to 17.5CV. The last observation on Nov 15 shows it remains in deep minimum. Interested observers are requested to monitor into the western sky for as long as possible, and to attempt morning observations in the new year if able.



MV Lyr, May 2021 - Nov 2022 *BAAVSS Database*

IX Dra: an update on the supercycle period

Stewart Bean

sjbeanmail@aol.co.uk

This year's campaign season suggests a shortening for the supercycle period.

Introduction

Dwarf novae (DNe) are binary systems comprising a white dwarf with an accretion disc that is receiving matter from the second star. This flow of matter leads to a series of normal outbursts as the disc's temperature cycles. When the disc radius grows to a particular dimension, the disc becomes unstable and a long duration superoutburst, one magnitude brighter than normal outbursts, occurs returning the disc to its initial state. The sequence of normal outbursts then repeats. The time between superoutbursts is known as the super-cycle length P(sc). The Variable Star Index (VSX) [1] gives the following definition for the UGER stars:

ER Ursae Majoris-type subclass of UGSU dwarf novae. These stars typically spend a third of their time in super-outburst with a super-cycle of 20-90 days. Outside of super-outburst they typically pack in a rapid succession of normal outbursts.

UGER stars therefore offer the opportunity to monitor several superoutbursts per year and measure their P(sc) values. Reports on the supercycle period for IX Dra, ER Uma, RZ LMi and V1159 Ori have been published in previous VSSCs. In VSSC 187 a review of the supercycle evolution of IX Dra discussed the available data from discovery in 1995 to the 2020 December. This note extends the observation period until the end of 2022 October with data collected by BAA and AAVSO observers complemented by some TESS satellite observations (Reference 2 and VSSC 186).

The IX Dra light curve.

The AAVSO light curve for the period to date is presented over approximately 800 days in Figure 1 using 1949 observations from 19 observers of which nine are BAA-VSS members. Observations made prior to JD2459000 were too sparse to capture accurately the start of every superoutburst. Twelve superoutbursts are recorded characterised by their high brightness and long duration compared to the more frequent normal outbursts. We are fortunate that TESS recorded several of these superoutbursts including one that eluded the campaigners on JD2459853.

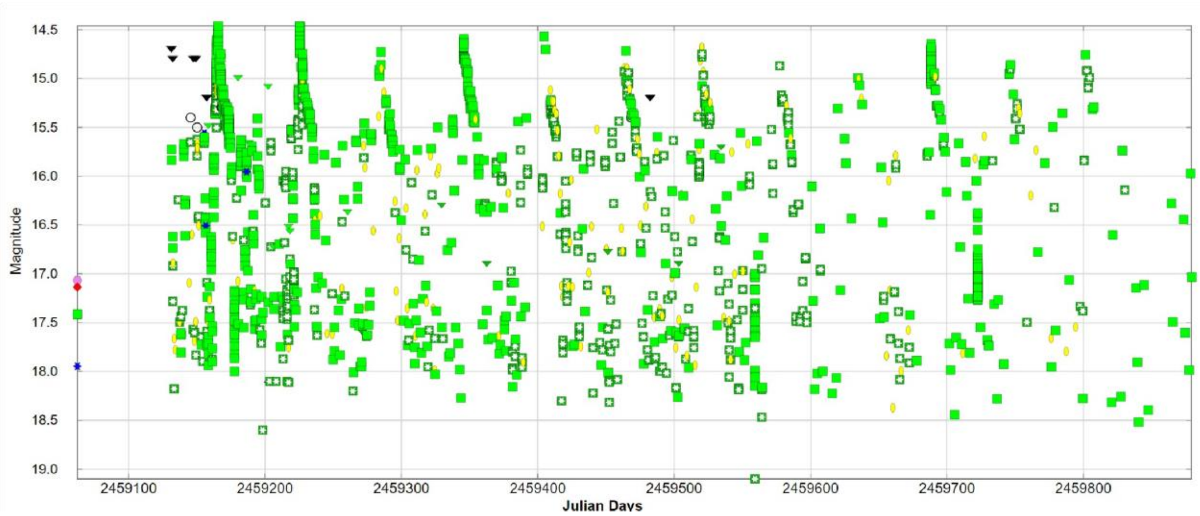


Figure 1. The AAVSO light curve covering the period of the present report.

The estimated start times of recent superoutbursts, not reported in VSSC 187, are presented in the table below. The uncertainty associated with the start of a superoutburst is probably +/- 1 day for the BAA and AAVSO observations, but less for the TESS results. This level of uncertainty is insufficient to influence the discussion of trends over a period of 800 days.

Start of outburst - JD	Supercycle period (days)
2459224	
2459283	59
2459344	61
2459403	59
2459463	60
2459520	57
2459577	57
2459632	55
2459688	56
2459745	57
2459801	56
2459853	52

The most recent superoutburst period is of particular interest as it is only 52 days. The confidence in this result is based upon the TESS light curve, presented in Figure 2, for the two superoutbursts at JD2459801 and JD 2459853.

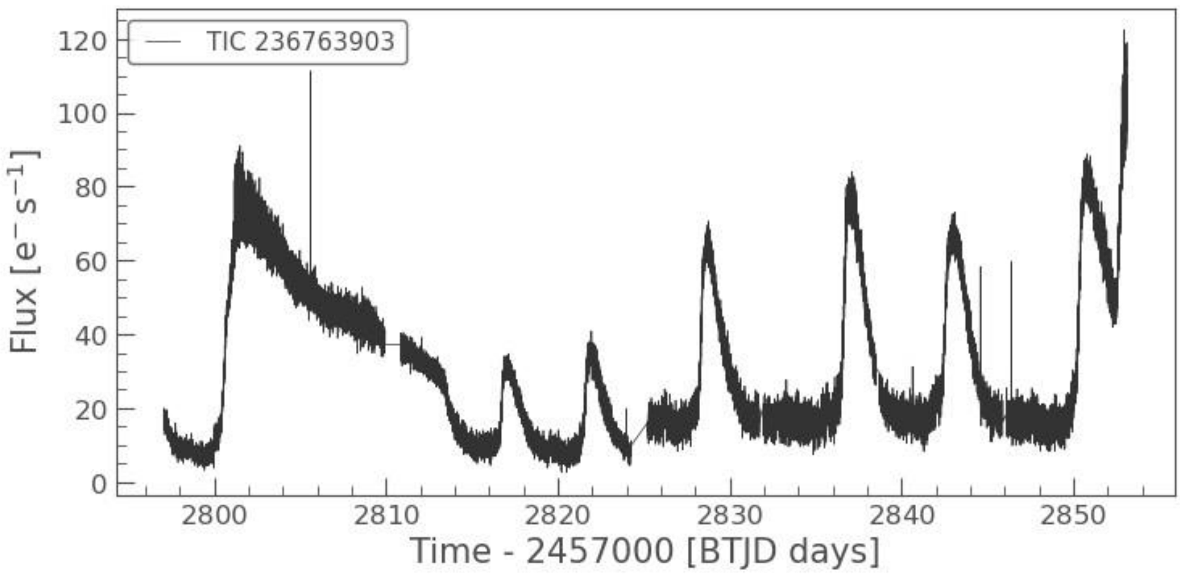


Figure 2. The TESS light curve for IX Dra that captures the start of the superoutbursts at JD 2459801 and JD 2459852.

Discussion

The reported supercycle periods from 1995 to 2022 October are presented below in Figure 3. Klose, S [3] reported 45.7 d and Ishioka et al [4] reported 53 d but neither gave an uncertainty analysis. Olech et al [5] reported 54+/-1 d whilst M. Otulakowska-Hypka [6] suggested 58.5+-0.5 d. In VSSC 187 the average over eight supercycles was found to be 60.5 d with low uncertainty. It can now be seen that with data from all 20 supercycle periods (including those reported in VSSC 187) there is a trend for the period to be shortening.

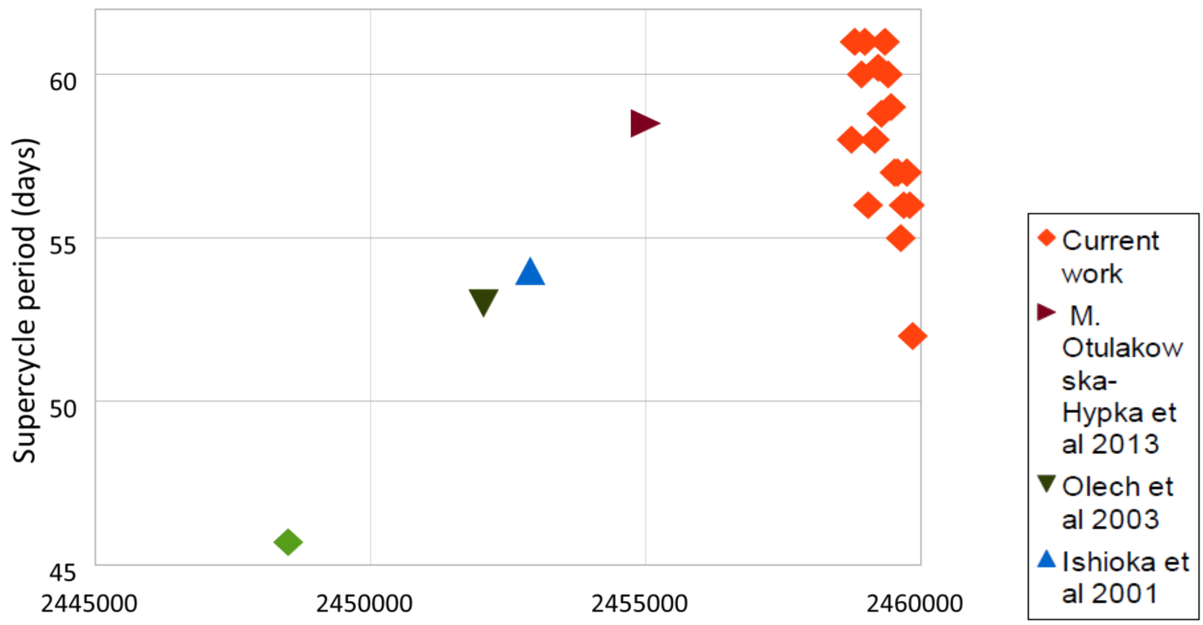


Figure 3. The evolution of the supercycle period from 1995 to the present.

The current work suggests that the supercycle period is trending towards the short period observed by Klose, S. [3]. Perhaps the supercycle period varies chaotically between an upper value of about 60 d and a lower value of about 46 d over a period of a few years. The more comprehensive data for ER UMa, presented in VSSC 188, also shows apparently chaotic variations between limits that may be a model for IX Dra

Future work

Further observations will clarify the evolution of this star along with other ER UMa class objects. Observations of IX Dra are being continued by BAA VSS and AAVSO observers and by the New Mexico AAVSOnet telescope. TESS continues to provide useful complementary observations during its extended mission.

I would like to express my appreciation to those contributing observations on IX Dra.

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2. TESS mission site is https://tess.mit.edu

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Eclipsing Binary News

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Zwicky Transient Facility (ZTF) (*From Wikipedia***)**

Observing in visible and infra-red wavelengths,[2] the Zwicky Transient Facility is designed to detect transient objects that rapidly change in brightness, for example supernovae, gamma ray bursts, and collision between two neutron stars, and moving objects like comets and asteroids. The new camera is made up of 16 CCDs of 6144×6160 pixels each, enabling each exposure to cover an area of 47 square degrees. The Zwicky Transient Facility is designed to image the entire northern sky in three nights and scan the plane of the Milky Way twice each night to a limiting magnitude of 20.5 (r band, 5σ).[3][4] The amount of data produced by ZTF is expected to be 10 times larger than its predecessor, the Intermediate Palomar Transient Factory.[5] ZTF's large data will allow it to act as a prototype for the Vera C. Rubin Observatory (formerly Large Synoptic Survey Telescope) that is expected to be in full operation in 2023 and will accumulate 10 times more data than ZTF.

ZTF J1813+4521 (1)

This is a binary star system including a sun-like star and white dwarf, co-orbiting every 51 minutes, about 3,000 light years away in the constellation of Hercules. It is considered a cataclysmic variable with the white dwarf pulling outer layers of hydrogen from the star onto itself. It has the shortest orbital period of all hydrogen-rich cataclysmic variable stars known. It is predicted that the orbital period will reach a minimum of 18 minutes within 75 million years as the system evolves. The system is destined to become a helium CV binary.

It was identified in 2022 by Kevin Burdge of MIT using a computer algorithm that searched over 1,000 images from the Zwicky Transient Facility, identifying stars that had brightness variability periods around one hour. Below is Figure 1 from the article in Nature [1]. It shows the light curve of the system in five different wavelengths. The eclipse profile varies with the wavelength because the white dwarf preferentially emits its radiation at shorter wavelengths than the cooler donor.

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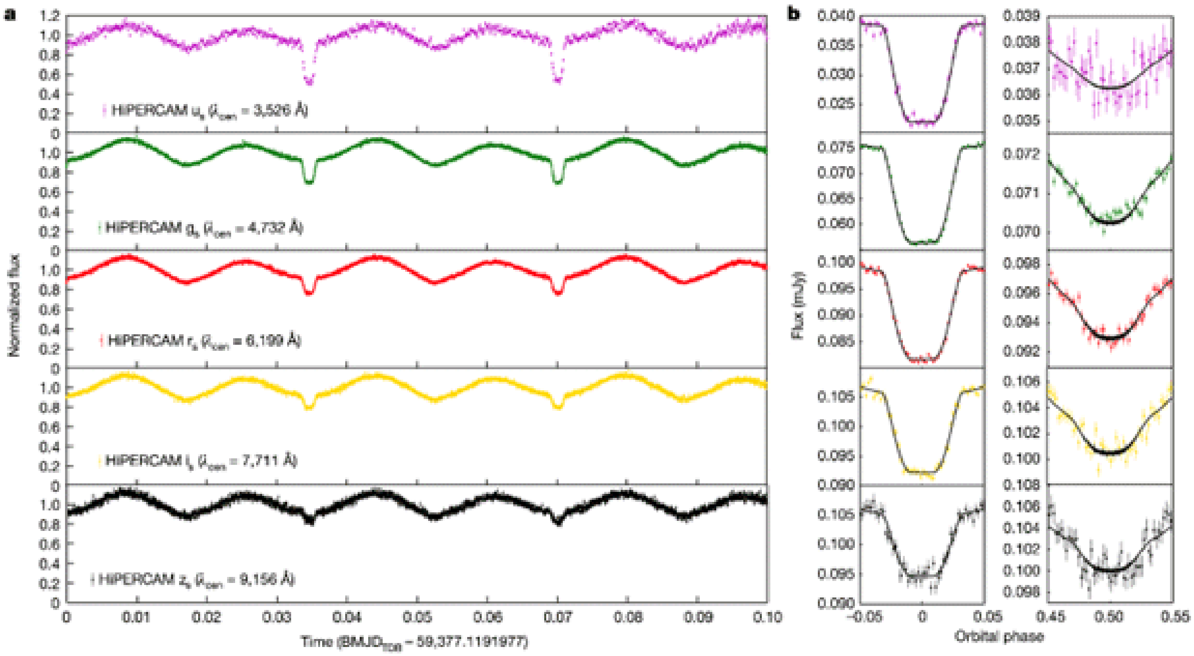

Figure 1. |Light curve of ZTF JI813+4251. **a** The five-colour HiPERCAMlight curve of ZTF J1813+4251, with filters us, gs, r, i, and z, arranged from top to bottom (where Mcen refers to the central wavelength of these filters). The object exhibits a strong sinusoidal component at twice the orbital frequency owing to the tidal deformation of the donor star. The system undergoes a full eclipse, in which the donor fully occults the accreting white dwarf. The timestamps of these lightcurves are given in barycentric modified Julian date, in bar centric dynamical time (BM]DDR). The depth of the eclipse varies dramatically with wavelength, with the white dwarf contributing half the luminosity in the us filter, and only about 10% in the z, filter, primarily because the white dwarf preferentially emits its radiation at shorter wavelengths than the cooler donor. **b**, Best-fit light-curve models of the primary and secondary eclipses of ZTFJ1813+4251. These models, combined with the spectroscopically derived radial velocity semi amplitude, allow us to robustly constrain the properties of both components in the system.

gamma Doradus Variables

The prototype star of this class of variable has an apparent magnitude of about 4.25. It is a pulsating variable that varies in brightness by less than a tenth of a magnitude owing to what is called non radial gravity wave oscillations. Four pulsational frequencies have been identified. The star is 1.6 times the mass of the Sun but is radiating seven times the luminosity of the sun. An infrared excess has been detected at multiple frequencies indicating that the star is being orbited by a pair of debris disks.

According to Wikipedia in its section on Asteroseismology the pulsations in this class of variables is driven by ‘**Convective Blocking**’. If the base of a surface convection is sharp and the convective timescales slower than the pulsation timescales, the convective flows react too slowly to perturbations that build up to large, coherent, pulsations.

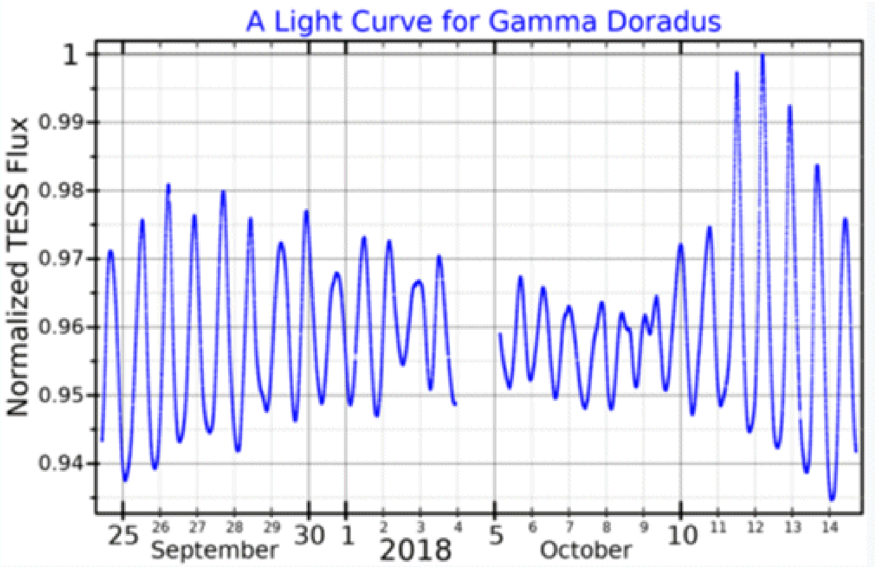

Figure 2. A light curve for gamma Doradus, plotted from TESS data. *Wikipedia*

Four bright eclipsing binaries with γ Doradus pulsating components: CM Lac, MZ Lac, RX Dra, and V2077 Cyg [2]

Analysis of these eclipsing binaries has been possible using TESS data. It has been possible to separate out the variations in magnitude due to eclipses and due to the Gamma Doradus variations.

CM Lac is an EA/DM system with a period of 1.6046916 days. The out of eclipse magnitude is 8.18. The secondary eclipse has a depth of 8.53 and the primary eclipse 9.15. This would be a good CCD/DSLR target with the challenge of picking up the Gamma Doradus pulsations.

MZ Lac is a more difficult target. It is a DA system. The out of eclipse magnitude is 11.2 and, apparently the two eclipse depths are 12.1. The period is 3.158795 days.

RX Dra is a EA/DM system. The out of eclipse magnitude is 10.0. The primary eclipse is of 10.5 depth, and the secondary 10.3. The period is 3.7863886 days.

V2077 Cyg. It is difficult to get information on this system. It is not listed on the Krakow data base. GCVS lists its variation as being from 9.16 to 9.31 but does not have a period nor does it specify its class of eclipsing binary

The best target for further study seems to be CM Lac which is circumpolar from the UK. I will be looking for three suitable comparisons to use with DSLR photometry.

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2. Four bright eclipsing binaries with gamma Doradus pulsating components: CM Lac, MZ Lac, RX Dra and V2077 Cyg. John Southworth and Timothy Van Reeth. MNRAS, 515, 2022, pp 2755 -2765. *Abstract* https://doi.org/10.1093/mnras/stac1993

A Period Study of the Hot Algol-type Eclipsing Binary TT Hydrae

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From 120 years of timing data, it is shown that TT Hya has shown two discrete period changes of +0.0001 d separated by about 60 years. The most recent change did not occur smoothly and there must have been some time when the system had a longer period before settling into the current one. The TESS data have been pivotal in demonstrating the movement of the secondary eclipse, and also a much smaller variation in the timing of the primary. The TESS light-curve also shows low-level oscillations in the gamma Doradus range during maxima.

In a paper on the long-period binary VV Cephei in the previous *Circular* Henshaw [1] showed a light-curve of the southern Algol-type eclipsing binary TT Hydrae that had been used as a 'technology demonstrator' or 'proof of concept'. TT Hya has a deep primary eclipse of nearly two magnitudes and this is very clear on the plot, but unfortunately the ingress is largely missing, however there is sufficient to suggest that the ephemeris used is not reliable for whatever reason. O–C diagrams from the Krakow and O–C Gateway eclipsing binary databases show that the period of TT Hya is not constant, and it will be shown that in the past 100 years the period has changed not once, but twice.

TT Hydrae is a bright star, out of eclipse $V = 7.3$, and it has been observed extensively. The system has a period of $6^{d}.95$ consists of a B9.5V primary with a K1II-IV secondary which fills its Roche lobe. Spectroscopically, emission can be seen from an accretion stream, an asymmetric accretion disc and a 'hot spot' (see Miller et al. [2]), and there is also evidence of a bi-polar outflow [3]. The components have masses of 2.77 $M_{\odot}$ and 0.63 $M_{\odot}$ and the secondary is transferring mass to the primary. It shares many similarities with the hotter, more massive, and longer period Algol system AU Mon [4], and a comparison of these with other similar systems is given by Richards et al. [5].

Photometrically, TT Hya presents as a typical Algol-type eclipsing binary with a deep primary eclipse of $1^{m}.8$ and a shallow secondary eclipse of $0^{m}.1$ in V, which are total. The catalogued period is $6^{d}.95342913$ with primary eclipse lasting for 16 hours and totality for 6 hours. It is a challenging object to observe partly due to the length of the eclipse, but also because the period is close to 7 days so it is not possible to build a complete light-curve in one observing season from one site. So, even given its brightness there are few photometric studies and very few eclipse timings. The Krakow database shows 16 timings over 120 years but unhappily does not provide the data nor references to the observations. The O–C Gateway provides a subset of eight of these, of which only six are made with modern detectors.

The variability of TT Hya was discovered by Wood [6] on a short run of plates taken with the Franklin-Adams camera at the Union Observatory, Johannesburg in 1926. The initial ephemeris was improved by Hertzsprung [7] using a long series of Harvard plates two years later, and it is this ephemeris that has survived, with small modifications, up to recently. The last correction to the period using photographic data was by Reilly [8] using data up to 1939, although the bulk of the Harvard data continued to 1952 with only a relatively small number of later observations.

The first photometric model based on modern data and still the most comprehensive light-curve is that by Kulkarni & Abhyankar [9] (and later papers) that was built up over four years from 1973– 1977 and has been re-used in many subsequent analyses. Their ephemeris is based on Hertzsprung's with a revised period, and this is perpetuated into more recent studies. More recent photometry of primary eclipse is provided by Kviz [10] in UBV and by Eaton & Henry [11] in *B* and *V*, and both note that the eclipse appears over an hour later than the Kulkarni & Abhyankar's ephemeris. The other photometric models are published by Etzel [12] and van Hamme & Wilson [13] (which includes a thorough discussion of the earlier work and the spectral types of the components) and uses the Kulkarni & Abhyankar ephemeris, as does Miller et al.'s spectroscopic tomography paper.

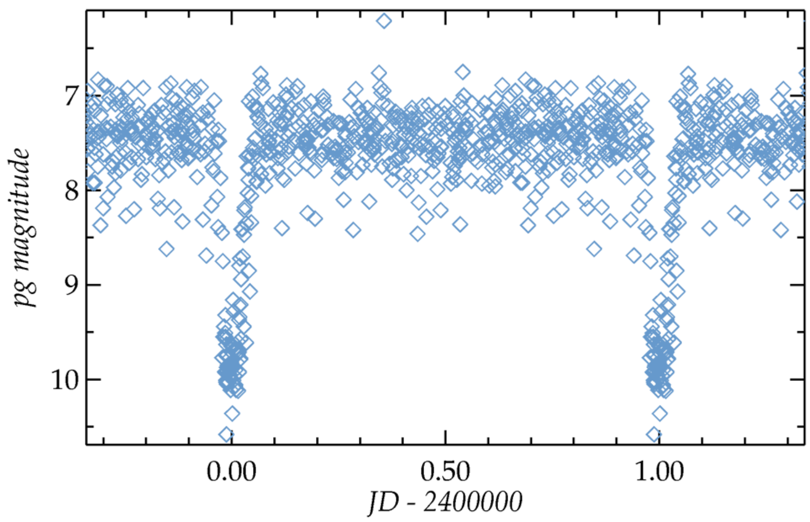

Figure 1: Phase diagram of the Harvard photographic data with errors < 0^m. 3 and most discordant data rejected.

In order to supplement the meagre timing data original observation have been sought from various sources. Wood provides measurements from the plates used so the times of the points within the primary minimum and fainter than m_{pg} = 10.0 have been used. The Harvard photographic data have been taken from the [Digital Access to a Sky Century at Harvard](#) (DASCH) archive. The observations were restricted to those with errors < $0^m.3$ and a high-order Fourier fit was used to weed out other discrepant points. After some iteration all the reliable times within the primary minimum have been identified. The phase diagram of the Harvard data is shown in Figure 1 folded on the photographic ephemeris determined later.

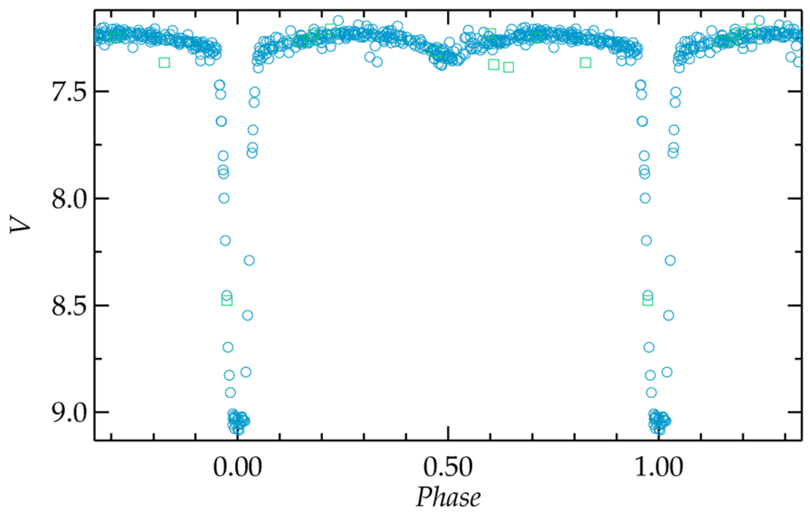

Figure 2: Phase diagram of the ASAS3 data folded on the central ephemeris determined later.

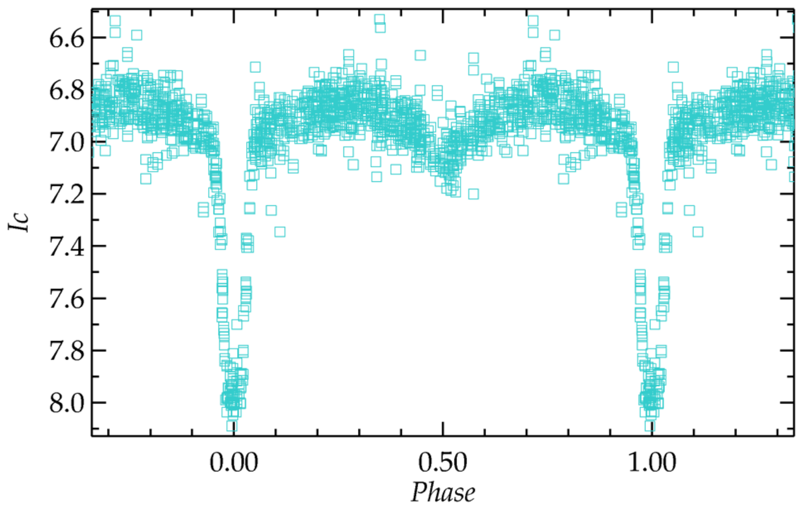

Figure 3: Phase diagram of the KWS data folded on the *TESS* ephemeris determined later.

The star was also observed by *Hipparcos,* but the ingress to primary eclipse is not well covered. Nevertheless, the folded light-curve is suitable for fitting with a simple Gaussian and this provides a surprisingly reliable time of minimum that replaces the value given in the O–C Gateway.

Data are available from the All Sky Automated Survey (ASAS3) [14] from late 2001 to early 2009 but during the middle year's observations covering ingress and egress are too sparse to be useful. Composite times of minima have been calculated from quadratic fits to the phase diagram of points that are clearly in the primary minimum for the years 2003, 2004, and 2007–2009, and these replace the single measurement for the early ASAS3 data made by Anton Paschke listed in the O–C Gateway. The phase diagram of the ASAS3 data is shown in Figure 2.

SuperWASP [15] observed several runs on TT Hya but none of these cover both the ingress and egress of primary eclipse. Ultimately five of the best runs were selected that covered a significant part of totality plus part of the rise or descent. It was necessary to align the runs on the level of totality which were then folded to complete the eclipse. The Kwee-van Woerden [16] method was used to measure the time of minimum. The optimistically small error has been arbitrarily increased by a factor of four to reflect the manipulation of the data.

More recent data are provided by the Kamogata/Kiso/Kyoto Wide-field Survey (KWS) project which observed TT Hya from 2014 to the present, but unfortunately the early years do not cover the primary eclipse well. Data from the pairs of seasons 2017–2018, 2019–2020 and 2021–2022 have been combined to give three composite timings by fitting a quadratic to the minimum as for the ASAS3 data. The Kwee-van Woerden method is not suitable here as the data are sparse, and the multiple exposures cause confusion. The KWS data are shown in Figure 3. There is also an isolated measurement by Cook [17].

TT Hya was observed by the Transiting Exoplanet Survey Satellite *TESS* [18] in 2019 (Sector 9) with the standard 30-minute cadence and 2021 (Sector 36) with the more recent 10-minute cadence. The data were extracted from the Full-Frame Images using the *Lightkurve* package [19]. The data were restricted to HARD quality in *Lightkurve* parlance, and the fluxes were measured using a custom aperture created within the routine. The aperture was chosen to be as symmetrical as possible while providing good signal to noise, and crucially, minimizing the flux gradient through the sector. The resulting light-curve is remarkably flat in the sense that no additional polynomial fitting is required to correct variation in level through the *TESS* orbit, as is often the case.

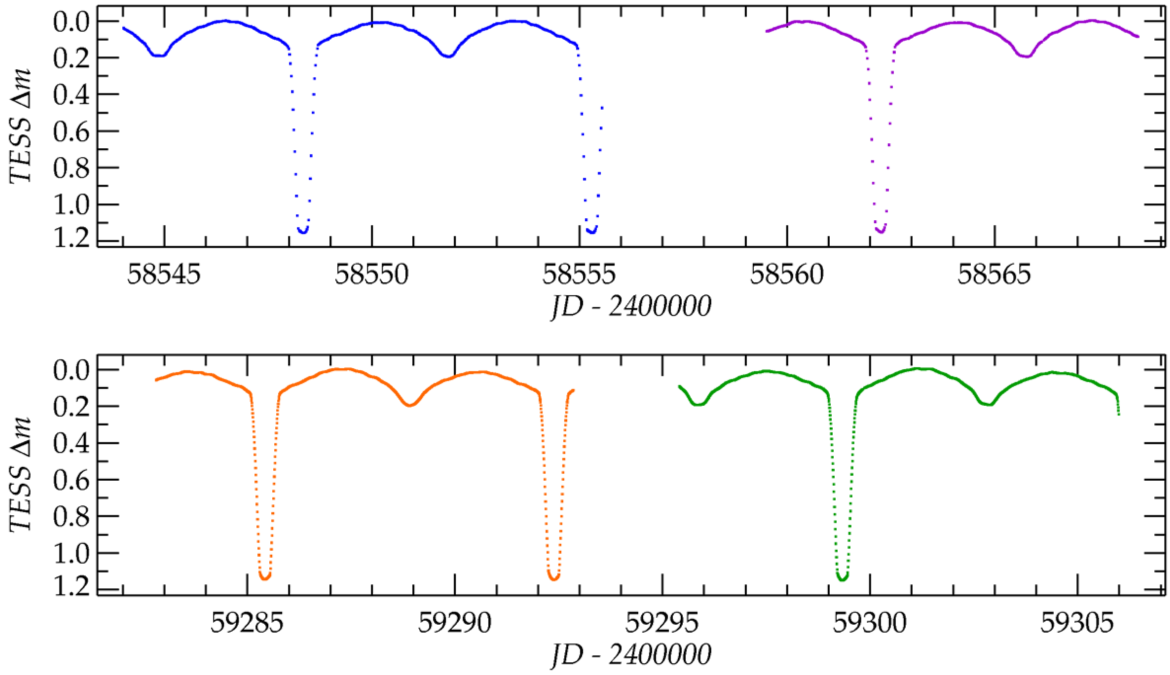

Figure 4: The *TESS* light-curve showing Sector 9 (top) and Sector 36 (bottom).

The *TESS* sectors naturally divide into two due to the 1–2 day break for the data downlink so the resulting light-curve comprises four sections of ~11 days of mostly continuous data. A high-order Fourier fit was used to remove any small offsets in level between the four different sections. The process to align the data will operate most effectively on the primary minimum where there is the steepest change so any other variations will be relative. The resulting light-curve is shown in Figure 4. *TESS* observed six primary minima, although one was not complete, and six secondary minima. The difference in coverage between the 30-m and 10-m cadence is obvious, particularly in the primary eclipse. The phase diagram in Figure 5 shows no major deviation from the mean light-curve but there are small variations throughout the cycle, particularly around the maxima.

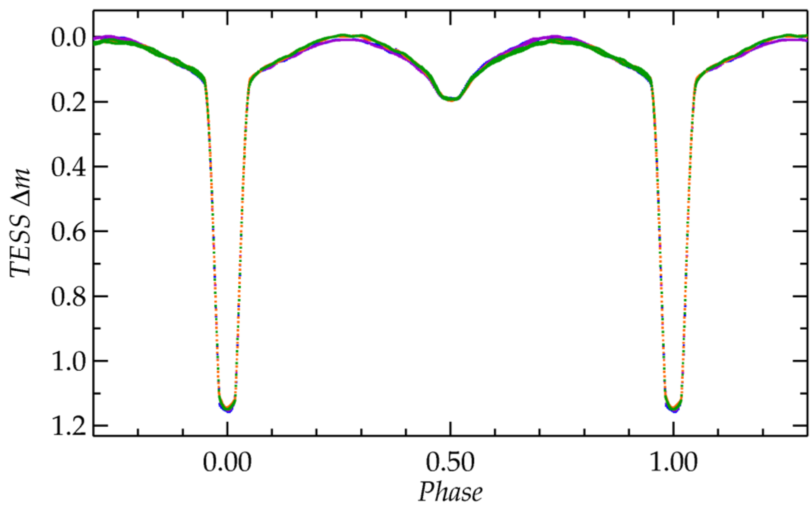

Figure 5: The phase diagram of the *TESS* data folded on the *TESS* ephemeris. The colour scheme is the same as in Figure 4

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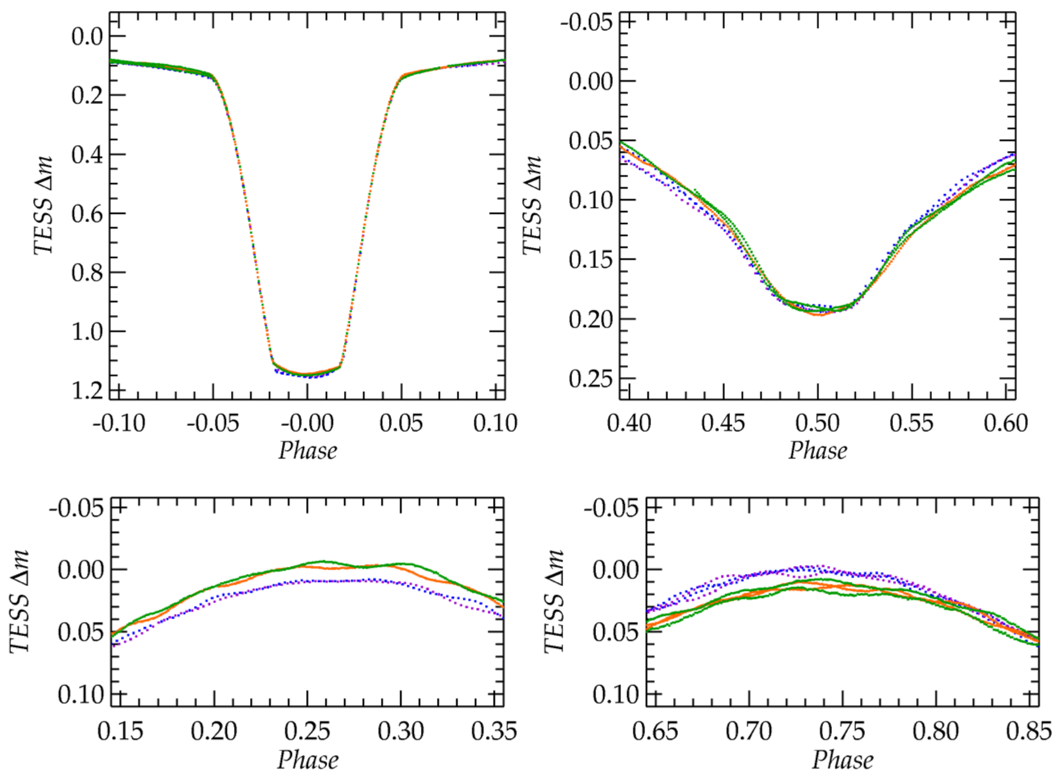

Figure 6: Detail from the *TESS* data around the primary and secondary minima (top) and the two maxima (bottom). Relative to the primary minimum plot the vertical scale of the other plots is factor of four larger. The primary minimum is very consistent with only small changes during totality and on the shoulders of the eclipse. The wings of the secondary eclipse show coherent movement early and late. The maxima show changes in maximum brightness between the two sectors and weak ripples. The colour scheme is the same as in Figure 4.

Detail of the eclipses and maxima is shown in Figure 6 where small, $\sim 0^m.01$, coherent changes can be seen in totality of the primary eclipse along with other small changes in the level and possibly shape of the shoulder of the eclipse. Similar amplitude changes are visible in the secondary eclipse but while the minimum is largely constant the wings show significant changes with the phasing of the Sector 9 data being clearly earlier than the Sector 36 data, indicating coherent movement of the eclipse. Larger changes, $\sim 0^m.02$, are visible in the maxima where the Sector 9 data are fainter at phase 0.25 and brighter at phase 0.75, both absolutely and relative to the Sector 36 data. The Sector 36 data show the reverse effect but the range is smaller at $\sim 0^m.01$. Under normal circumstances these variations would be interpreted as a weak O'Connell effect [20, 21], both positive and negative, but in such an active system with an accretion stream and asymmetric disc the origin is not clear. The *TESS* data also show what can only be described as ripples during both maxima that occur on a time-scale of $\sim 0^d.3$ with an amplitude of 5 mmag. It is possible that these are oscillations in the γ Doradus range emanating from the primary [22]. Both maxima are also displaced towards phase 0.5 relative to their nominal phases.

Times of minima have been measured from the eclipses using the Kwee-van Woerden method. For the primary minima measurements have been made at several different magnitude levels to test the symmetry of the eclipse and the repeatability of the timings. The bright limit of the measurements cover the range from magnitude 0.3 to 0.9 in $0^m.1$ steps. There is a surprisingly large difference in the

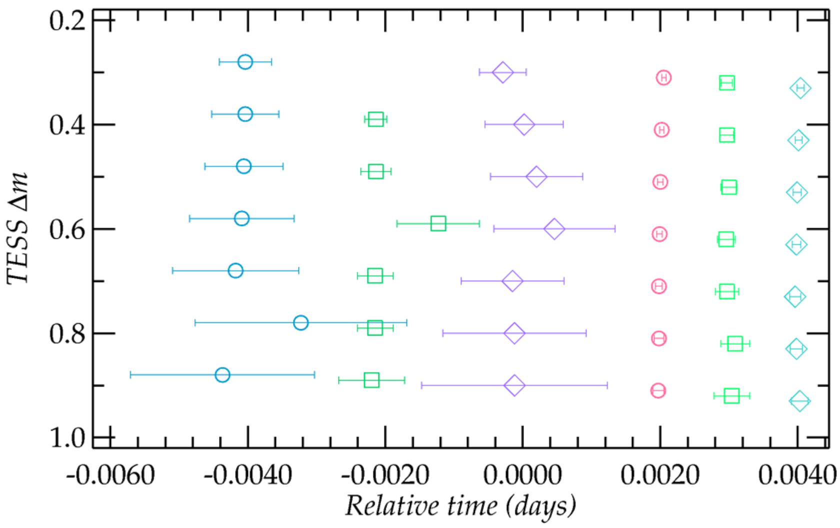

Figure 7: The results of the Kwee-van Woerden timing measurements of the primary eclipses with different bright limits. The data used cover the eclipse from the bright limit, which range from magnitude 0.3 to 0.9 in $0^m.1$ steps. Arbitrary offsets have been applied to the timings for each eclipse to allow them to be seen more clearly, and small offsets have also been made to the magnitude limits to avoid confusion with overlapping error bars. The eclipses are in date order and the earlier colour scheme does not apply. The first three eclipses have 30-m cadence data and the second eclipse is not complete so does not cover the full range.

reliability of the measurements between the 10-m and 30-m cadence data, but unsurprisingly those with the brighter upper limit are substantially more reliable. The results are shown in Figure 7 where arbitrary offsets have been applied to the timings for each eclipse to allow them to be seen more clearly. There is no significant asymmetry in the primary eclipses and the measurements are more consistent than their uncertainties would suggest. The bright limit used for the timings of the secondary minima was set at the change of gradient which occurs about magnitude 0.13.

The timings of the photographic eclipses and all the other measured primary minima are shown in the O–C diagram in Figure 8. The plot naturally divided into three sections. The first is the photographic data which clearly has a different period to the second section of modern data at about 2010 or JD 2455000, and the third section including the *TESS* data is different again. The central section is the only one that is obviously linear. The photographic data are poorly defined but there is no evidence to suggest that they are not linear. The section of recent data is too short to draw any conclusion. A quadratic fit to the data completely fails to follow the observed variation so there appear to be two changes between three apparently constant periods. The ephemeris of the photographic data is

$$HJD_{pg} = 2424615.384(10) + 6.953388(12) \times E \quad (1)$$

which uses the Harvard data and the points selected from Wood. The period derived in this way is $\sim 1\sigma$ shorter than Hertzsprung's period and $\sim 2\sigma$ shorter than Reilly's, which made full use of the eclipse. It can be seen in Figure 8 that the timings Reilly used up to 1939 are generally later than the following data so this will lead to a longer period. The post-photographic ephemeris has been calculated using the minima from Kviz [10], Eaton & Henry [11], *Hipparcos*, ASAS3 and SuperWASP to give

$$HJD_{central} = 2443918.1029(28) + 6.9534906(26) \times E \quad (2)$$

which covers the period from 1955–2008, and this has been used to construct the O–C diagram. The times of minima for the central section and their residuals from this ephemeris are given in Table 1.

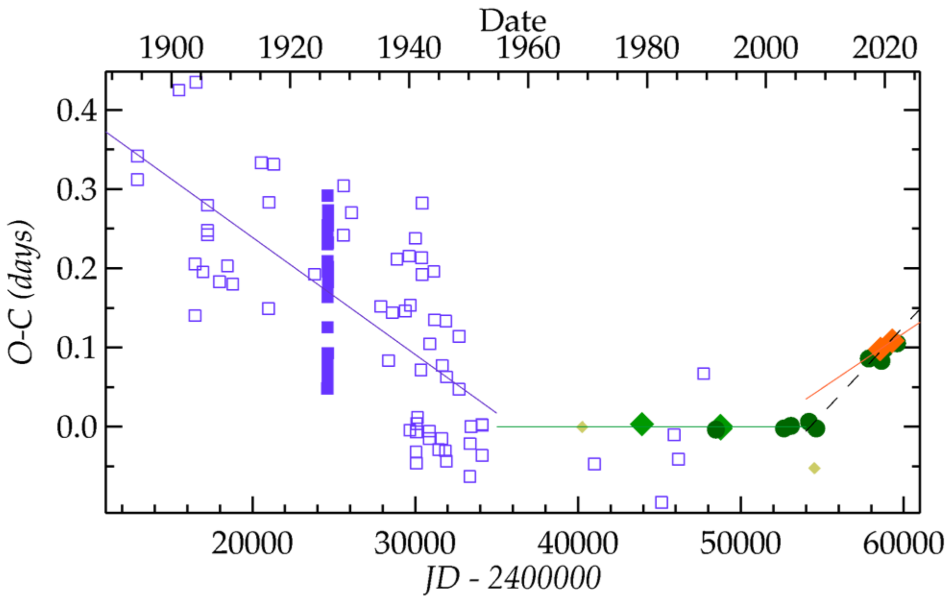

Figure 8: The O–C diagram of all the primary eclipses. The individual Harvard plates are shown as open squares and Wood's minima as filled squares. The pep timings of Kviz, and Eaton & Henry are shown as green diamonds, the *Hipparcos*, ASAS3, SuperWASP, KWS and the measurement by Cook as green circles and the *TESS* data as orange diamonds. In most cases the error bars are smaller than the symbols. The plot also includes two visual timings (small squares) provided by the O–C Gateway.

Unfortunately, there are no reliable timings near the intersection between this and the photographic ephemeris so there is no information on exactly when or how this transition occurred.

On the face of it the intersection between the central section and the recent data is apparently more secure, but this is not the case. A contrived ephemeris has been constructed by fitting the last two points from SuperWASP and the ASAS3 with the *TESS* primary data giving

$$HJD_{\text{contrived}} = 2458548.3415(23) + 6.953644(8) \times E \quad (3)$$

and this is plotted as the dashed line on Figure 8. The reason for showing this is because it is the shortest period the data allow in this section, but it is longer than the period for the *TESS* data

$$BJD_{\text{tess}} = 2458548.34488(14) + 6.9535871(13) \times E \quad (4)$$

which is the weighted fit to the *TESS* primary minima. The region around the recent data is shown in detail in Figure 9. The plot is constructed using just the *TESS* primary minima as these are by far the most reliable. The line plotted across the diagram is the contrived ephemeris from Figure 8, but this is obviously inconsistent with the *TESS* data, and marginally less consistent with the KWS data, although their uncertainties are much larger. Cook's point is equally adrift. Projected back to the central section the *TESS* ephemeris shows a clear discontinuity and suggests that the handover from one period to the next is not as simple and clean as may have been naively thought. There will be an opportunity to test the stability of the *TESS* period when the star is observed again in Sector 63 next year. The times of minimum and residuals from the *TESS* ephemeris are given in Table 2.

The discrete period changes between the photographic data, the central section and the TESS data are $+0^{d}.000103(12)$ and $+0^{d}.000097(3)$ and are consistent within the errors, further supporting the idea of coherent changes. Without the *TESS* data the similarity of these period changes would have been missed and the contrived ephemeris taken forward. Although the quadratic fit to the O–C residuals is a completely inadequate description it does provide a very general rate of period change

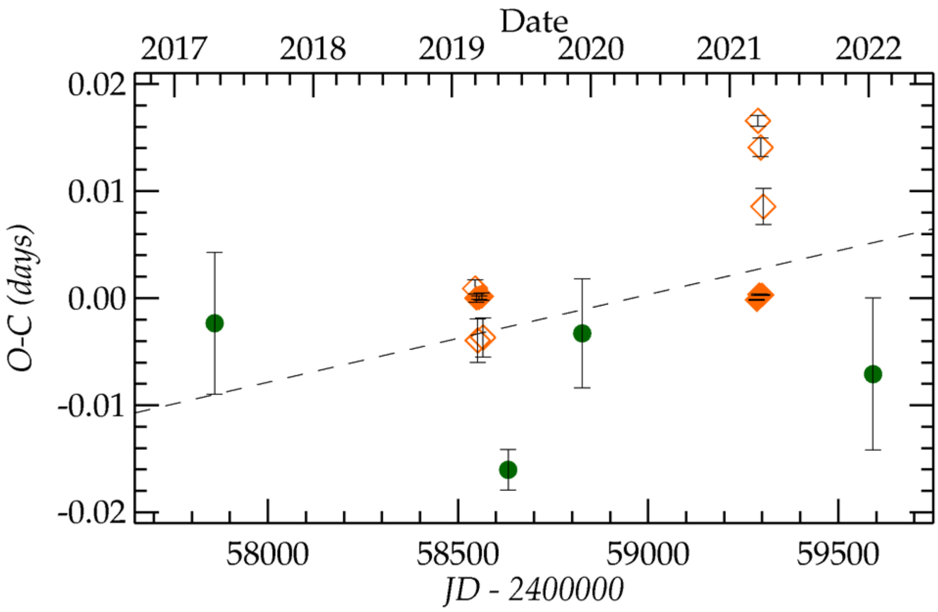

Figure 9: The O–C diagram of all the recent data which includes *TESS*, primary and secondary eclipses (open symbols), three KWS timings and the measurement by Cook. The plot is constructed using just the *TESS* primary minima and the line is the contrived ephemeris from Figure 8, which is a poor fit to the *TESS* and less so, the KWS data. The other interesting feature of the plot is the variability and dispersion of the *TESS* secondary minima. The symbols are as before.

over the past century or more. Both the weighted and unweighted fits give $P/\dot{P} \sim 7 \times 10^{-7}$ yr^{-1} which, under the unlikely assumption of conservative mass transfer, leads to a continuous rate of 2×10^{-7} $M_{\odot} yr^{-1}$, which is some three orders of magnitude larger than Miller et al's minimum observed mass transfer rate, but may point so significant mass loss from the system.

Table 1: *Times of minimum for the central section*

HJD	***Error***	***Min***	***Cycle***	***O–C (d)***	***Band***	***Observer/Source***
2443918.1060	0.0006	1	0.0	0.0031	*UBV*	Kviz [10]
2448465.6819	0.0027	1	654.0	−0.0038	*Hp*	Hipparcos (This paper)
2448743.8230	0.0040	1	694.0	−0.0023	*B*	Eaton & Henry [11]
2448743.8260	0.0040	1	694.0	0.0007	*V*	Eaton & Henry [11]
2452644.7312	0.0042	1	1255.0	−0.0023	*V*	ASAS3 (This paper)
2453068.8974	0.0028	1	1316.0	0.0009	*V*	ASAS3 (This paper)
2454181.4610	0.0010	1	1476.0	0.0061	*V*	SWASP (This paper)
2454626.4760	0.0044	1	1540.0	−0.002	*V*	ASAS3 (This paper)

The other feature revealed in Figure 9 is the range of variation of the *TESS* secondary minima, which appear displaced by up to $0^{d}.016$ or 0.0023 in phase from their nominal position and can also appear early and late. In this system these variations are probably related to circulation of the asymmetric disc. While not obvious, all of the primary minima from Sector 36, which have the smallest uncertainties, also show small but significant movement. Miller et al. claimed a small spectroscopic eccentricity for TT Hya but this was challenged by Eaton [23] on the grounds that the reversal of the mass ratio would have circularized the orbit, and that similar spurious eccentricities could be found for other Algol systems. An offset of the secondary eclipse could point to a non-zero eccentricity and a limit could be estimated from *e* cos *ω*, however, these systems have $\omega \sim 90^{\circ}$ so no displacement would be expected.

Table 2: *Times of minimum for the TESS and other recent data*

HJD	*Error*	*Min*	*Cycle*	*O–C (d)*	*Band*	*Observer/Source*
2457859.93740	0.00660	1	-99.0	-0.00234	*Ic*	KWS (This paper)
2458544.86899	0.00084	2	-0.5	−0.00090	*C*	TESS (This paper)
2458548.34488	0.00038	1	0.0	−0.00000	*C*	TESS (This paper)
2458551.81773	0.00203	2	0.5	-0.00395	*C*	TESS (This paper)
2458555.29851	0.00016	1	1.0	0.00004	*C*	TESS (This paper)
2458562.25221	0.00034	1	2.0	0.00015	*C*	TESS (This paper)
2458565.72518	0.00184	2	2.5	-0.00367	*C*	TESS (Tis paper)
2458631.77190	0.00190	1	12.0	-0.01603	*V*	S Cook [17]
2458826.48510	0.00510	1	40.0	-0.00329	*Ic*	KWS (This paper)
2459285.42496	0.00003	1	106.0	-0.00016	*C*	TESS (This paper)
2459288.91847	0.00050	2	106.5	0.16560	*C*	TESS (This paper)
2459292.37903	0.00008	1	107.0	0.00033	*C*	TESS (This paper)
2459295.86957	0.00086	2	107.5	0.01407	*C*	TESS (This paper)
2459299.33259	0.00005	1	108.0	0.00030	*C*	TESS (This paper)
2459302.81764	0.00169	2	108.5	0.00856	*C*	TESS (This paper)
2459591.37590	0.00710	1	150.0	-0.00710	*Ic*	KWS (This paper)

In conclusion TT Hya has proved to be a dynamic Algol-type binary with a significantly increasing period. It has shown two discrete period changes of $+0^{d}.0001$ separated by about 60 years. The most recent change occurred about 2010 but the migration to the current period did not occur smoothly and there must have been some time when the system had a longer period before settling into the current one. Discrete period changes point to episodic mass transfer and suggest that TT Hya is in a phase of evolution where it is (slowly) detaching. The *TESS* data have been pivotal in identifying the complex behaviour of the recent period change, and in demonstrating the movement of the secondary eclipse, and also a much smaller variation in the timing of the primary. The *TESS* light-curve also shows low-level oscillations or possibly *gamma* Doradus range pulsations visible during maxima. Simplistically, the overall rate of period change requires a mass transfer rate three orders of magnitude larger than the minimum rate observed and may indicate significant mass loss from the system.

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Post common envelope binary systems and their purported planetary systems

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Post common envelope binary systems, with their short orbital periods and well defined eclipse minima, are ideal observing targets for the non-professional astronomer. Comprising a very hot primary and cool secondary, these binaries came to the attention of the professional astronomer when it was noted their eclipse times varied in a quasi-periodic way suggesting the presence of circumbinary planetary bodies. If these planets exist, when they were formed and how these binary systems evolved, remain unanswered questions.

Current status

A brief introduction to post common envelope binary (PCEB) systems was outlined in a recent Variable Star Section circular [1], noting these binaries were referred to as HW Virginis systems, designated from the prototype system, HW Vir, and first reported by Menzies & Marang (1986) [2]. HW Vir systems are non-contact binaries comprising of a very hot primary component, often a subdwarf B (sdB) star with temperatures in excess of 30,000K, and a secondary M dwarf or brown dwarf companion with temperatures of 3,500K or less. The separation between the two components is usually less than one solar radius, causing the secondary to be heavily irradiated by the primary star and giving rise to significant amounts of orbital phase dependent reflected energy from the secondary. The small separation between the two binary components results in very short orbital periods, typically between 2 and 3 hours.

A model, approximately to scale, for a typical sdB system, HS0705+6700, is shown in Fig. 1 and its light curve in Fig. 2 where the rising and falling shoulders between the primary and secondary eclipses is indicative of the reflected energy from the secondary as its phase changes with its orbit around the primary. Similar systems are found with the much hotter, ~45000K, white dwarf (WD) primary but here, and because of the compact nature of a WD, the eclipse ingress and egress are very much steeper with durations of less than 90 seconds. The light curve for a typical WD primary, in this case RR Cae, is shown in Fig. 3.

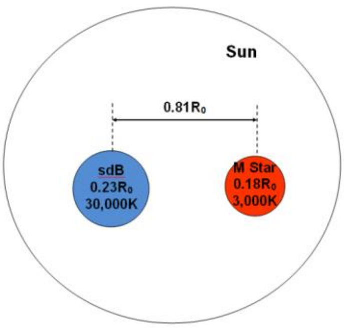

Fig. 1. The compact structure of HS0705+6700. The close proximity of the very hot sdB star to the cool secondary results in energy reflected from the secondary and may be the reason behind the complex ETVs seen in this and similar systems. The Sun is shown to scale.

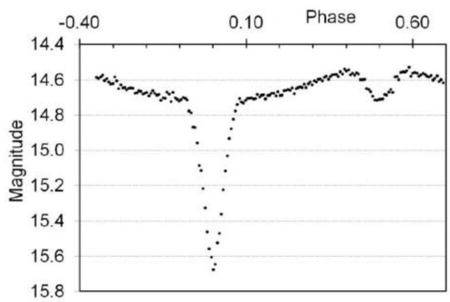

Fig. 2. Full light curve for HS0705+6700 showing the falling and rising shoulders between eclipses formed from the primary components light reflected off the secondary dwarf M star. Observations Ian Sharp, Ham Observatory; filter IRB.

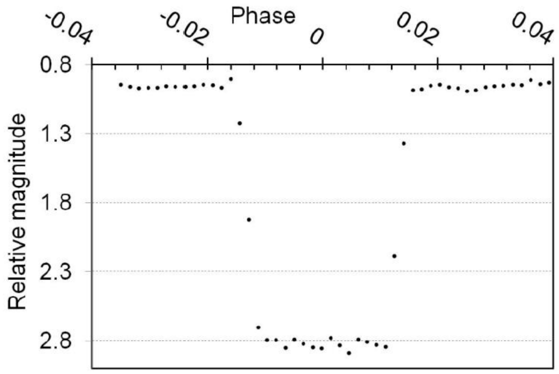

Fig. 3. The primary eclipse for the white dwarf binary, RR Cae. The steep ingress and egress are typical of WD PCEBs. The eclipse duration is approximately 15 minutes. Observations David Pulley, Luminance, Dubbo, Australia.

HW Vir type system's compact structure, short periods and large temperature differences between the components, give rise to well defined primary eclipses allowing times of minima to be determined with high precision. Professional interest in these systems has grown rapidly over the past twenty years, particularly when it was noted that the observed eclipse times varied, referred to as eclipse time variations or ETVs, in a quasi-periodic way from the calculated or predicted eclipse times. The difference between the observed and calculated eclipse times, (O – C), provides a useful tool in understanding the underlying mechanics of these systems. Although not recent, good overviews of these systems are provided by Zorotovic & Schreiber (2013) and Lohr et al. (2014) [3,4]

Various evolutionary scenarios have been proposed for these systems but a definitive mechanism remains to be found. Favoured models suggest that when the more massive primary evolves to its red giant phase, it fills its Roche lobe and matter is transferred from the primary star to its secondary main sequence companion at a rate that cannot be accommodated by the smaller star. This unstable mass transfer from the primary forms a common envelope that surrounds the helium-burning core of the red giant primary and its companion. As a consequence, angular momentum is transferred from the binary system to the surrounding envelope, bringing the binary pair closer together and resulting in a short binary period of a few hours. Eventually the common envelope acquires sufficient angular momentum for it to be mostly ejected and so creating a planetary nebula surrounding a detached binary system.

As the common envelope phase is of short duration and the secondary is unable to accommodate the mass transfer, the mass of the smaller companion remains substantially unchanged. The remaining mass of the red giant, the primary star, is about equal to the mass of the core of the giant at the onset of mass transfer. This helium-rich primary forms an sdB (or possibly an sdO) star and is well on its way to becoming a white dwarf. Eventually, the loss in angular momentum will bring the binary pair into close proximity, producing a classic cataclysmic variable.

One of the first systems to be scrutinised in detail was HS0705+6700 (V470 Cam but the Hamburg-Schmidt survey name is generally the preferred designation) and reported by Drechsel et al. (2001).[5] For this system, the first ETV analysis was performed by Qian et al. (2009) and,[6] having eliminated possible causes of the observed ETVs of apsidal motion, Applegate (magnetic) type effects and angular momentum loss through gradational radiation or magnetic breaking, they concluded that the observed ETVs were caused by circumbinary objects, in this case probably of planetary mass. When these planets were formed remains an unresolved question; were they formed prior to the common envelope and survived the envelope's ejection or could they have formed in the short period after common envelope ejection?

Many of the claims for planets around HW Vir type systems have found their way into exoplanet databases e.g., the NASA Exoplanet Archive and the Extrasolar Planets Encyclopaedia, see Table 1. However further observations soon showed that the ETV's predicted by these models failed, within months, to match observations. An overview of many of these systems can be found in Pulley et al. (2022) [7] and one such example, Sale et al. (2020) [8], is shown in Fig. 4. This is one of seven

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circumbinary predictions made for HS0705+6700 over the past 13 years and, as with the other models for this system, all failed within a few months of publication.

Binary designation	RA	Dec	Mag. (Pre-eclipse)	Type	Circimbinaries (see notes)
EC10246-2707	10 26 56.6	-27 22 59	14.4	sdB+MS/BD	4
HS0705+6700	07 10 42.07	+66 55 43.6	14.5	sdB+MS/BD	2
HS2231+2441	22 34 21.481	+24 56 57.39	14.5	sdB+MS/BD	3
HW Vir	12 44 20.24	-08 40 16.8	10.6	sdB+MS/BD	1,2
J1938+4603	19 38 32.61	+46 03 59.14	12.7	sdB+MS/BD	1,2
J08205+0008	08 20 53.536	+00 08 43.50	15.2	sdB+MS/BD	4
NSVS 07826147	15 33 49.44	+37 59 28.2	13.0	sdB+MS/BD	3
NSVS 14256825	20 20 00.458	+04 37 56.50	13.5	sdB+MS/BD	1,2
NY Vir	13 38 48.14	-02 01 49.2	13.3	sdB+MS/BD	1,2
DE CVn	13 26 53.27	+45 32 46.69	12.6	WD+MS	**1**
NN Ser	15 52 56.131	+12 54 44.68	16.5	WD+MS	1,2
QS Vir	13 49 52.00	-13 13 37.00	14.4	WD+MS	3
RR Cae	04 21 05.56	-48 39 07.06	14.4	WD+MS	1,2

Table 1. Examples of sdB or WD PCEBs. sdB+MS/BD, primary an sdB and secondary a main sequence, usually dwarf M star or a brown dwarf. WD+MS, white dwarf primary and a main sequence, usually a dwarf M star, secondary. Note 1 recorded on the NASA Exoplanet Archive; Note 2 recorded on the Extrasolar Planets Encyclopaedia; Note 3 planets modelled but not on database; Note 4 No planets modelled

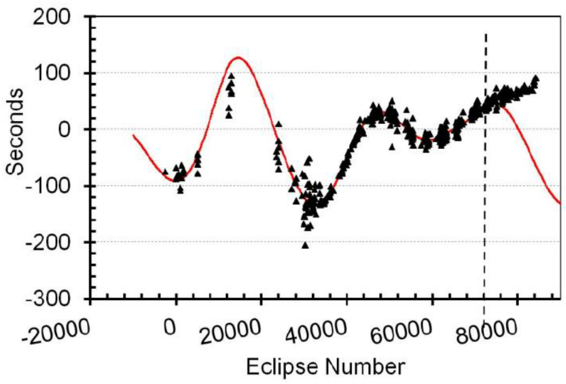

Fig. 4. (O – C) plot for HS0705+6700 based upon the model of Sale et al. (2020). Black triangles are historic data and red line is the Sale et al. model. Data points to the right of the vertical dotted line are data post the Sale model indicating their model fails soon after publication. One eclipse cycle is approximately 0.095647 days. The vertical axis is the deviation of the observed eclipse from it calculated or expected value in seconds.

As more data is accumulated, and for some systems there is now in excess of twenty years of observations, the quasi-periodic ETVs have become increasingly more complex requiring two or more circumbinary objects to explain the observations. However, in all cases, analysis of the orbital stability of these multi-planetary systems indicate that they have a lifetime of less than a few million years, strongly suggesting that these multi-planet solutions are not viable in the longer term.

With the failure of all circumbinary models, the driver behind the observed ETVs remains unresolved. Apsidal motion is an unlikely contender; the close proximity of the two binary components strongly suggests that their orbits would circularise very rapidly and monitoring the phase of the secondary eclipse does confirm this to be the case. Gravitational radiation and magnetic breaking produce a continuous loss in angular momentum with a corresponding continuous reduction in binary period. Neither of these effects will produce the quasi-periodic ETVs observed in these systems.

Whilst no single process can explain the observed variation in eclipse times, it remains possible that a combination of processes, for example the presence of magnetic effects and one or more circumbinary objects, could explain these observations. This, together with gravitational radiation or magnetic breaking to describe any time dependent binary period decrease, if present, may explain the observed ETVs. Magnetic interactions between two binary components were first proposed by James Applegate in 1992 [9] but analysis of the sdB binaries has always shown that there is insufficient energy in the secondary star to make this a viable option. However, subsequent researchers including Lanza (2020) [10] have modified this theory and whilst not providing a total solution, magnetic effects could provide a significant contribution to the observed ETVs.

Whilst it is possible to remove the predictable effects of gravitational radiation and magnetic breaking, magnetic effects are not fully understood nor are they predictable, for example the randomness of solar spots. Thus, to remove magnetic effects from the observed ETVs, so leaving quasi-periodic ETVs caused solely by circumbinary planetary motion, is likely to prove difficult for the foreseeable future.

Conclusion

sdB PCE binary systems, together with sdO and WD PCEBs, provide interesting observational targets for the professional astronomer. Many of these systems are bright with magnitudes of between 10 and 15 and together with their short binary periods, make them ideal observing targets for amateur observers. Whilst much data has now been accumulated on these objects, their formation remains unresolved. This, together with unexplained observed variations in eclipse timings, provides the observer with many interesting challenges.

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RZ Cassiopeiae light curves showing activity of the δ Scuti component

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This article discusses my observations of the eclipsing binary RZ Cassiopeiae, whose light curve is complicated by one of the components which is itself a pulsating variable.

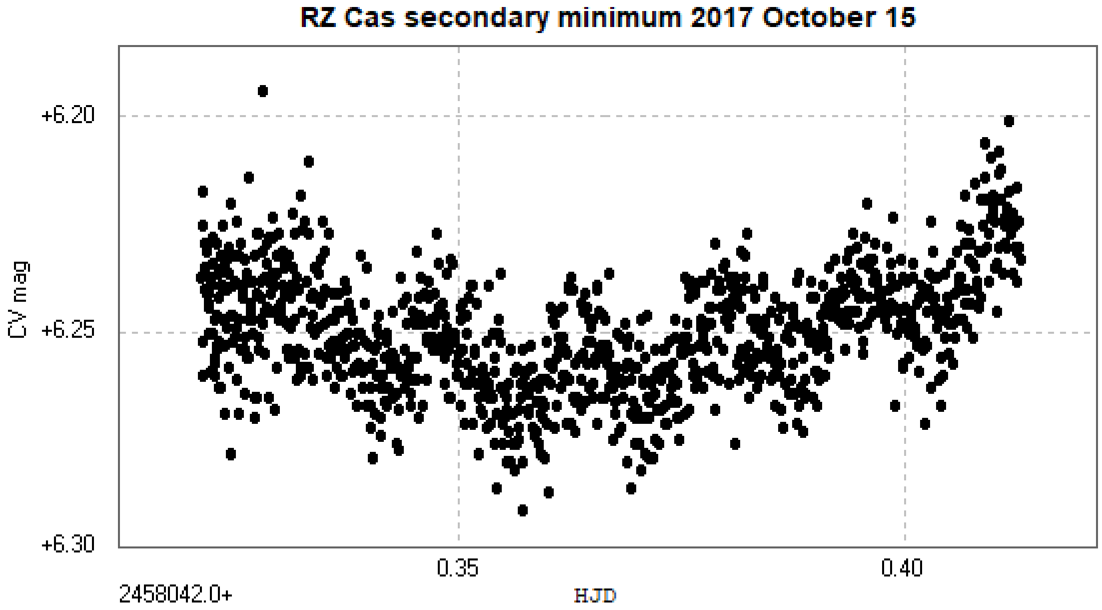
The following are some of my observations made of the eclipsing binary system RZ Cassiopeiae from the Somerby Observatory with the '2 inch Titan' – a 2 inch / 50mm aperture finder scope with the eyepiece replaced with an Atik Titan camera. All observations were unfiltered. Plots and analysis have been performed in Peranso.

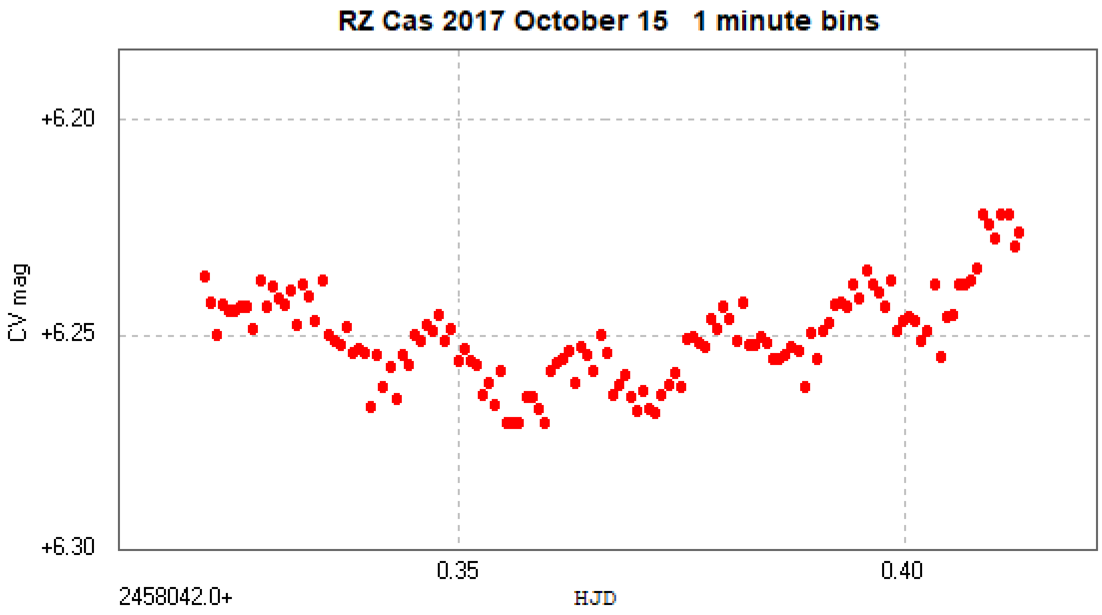
RZ Cas is catalogued as an EA+DSCT type system (AAVSO VSX) where one of the components, the A3V primary, is a pulsating star of the δ Scuti type. These are small amplitude (0.003 to 0.9 mag), short period (0.01 to 0.2 day) pulsating variables. The secondary is a K0III type. Originally thought of as 'noise' affecting my attempts at determining the times of eclipse minima of the system, subsequent analysis has shown that at least some of this noise was due to activity of the δ Scuti type component. A detailed discussion of timing issues caused by this activity in the light curve, '*RZ Cas lightcurve and orbital period variations'* by Chaplin, Samolyk and Screech, can be found in the 2018 June issue of the Journal of the BAA.

2017 October 15: secondary minimum

Due to the brightness of this system, these observations were made with the aperture stopped down to 30 mm to enable longer exposures to be used to reduce scintillation effects, 8 seconds in this case. The first diagram shows a plot of the individual magnitude estimates, while the second diagram consists of one minute bins of this plot.

Visual inspection of the plots suggests a semi-amplitude of approximately 0.01 magnitudes.

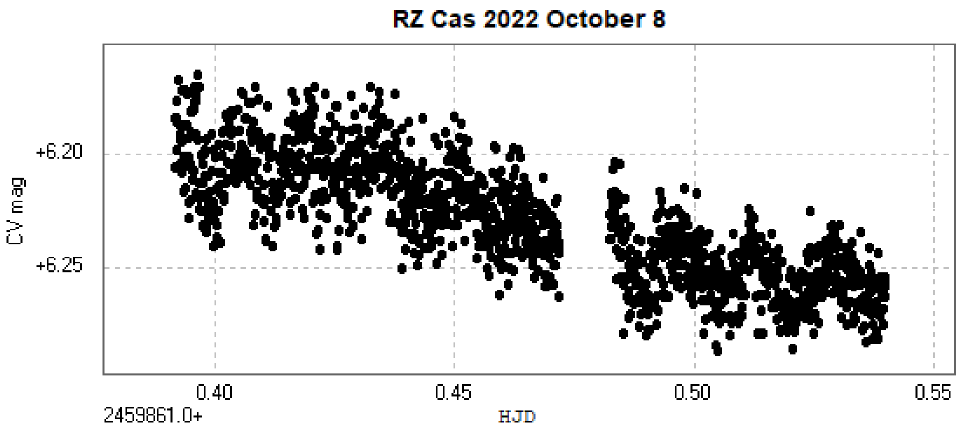


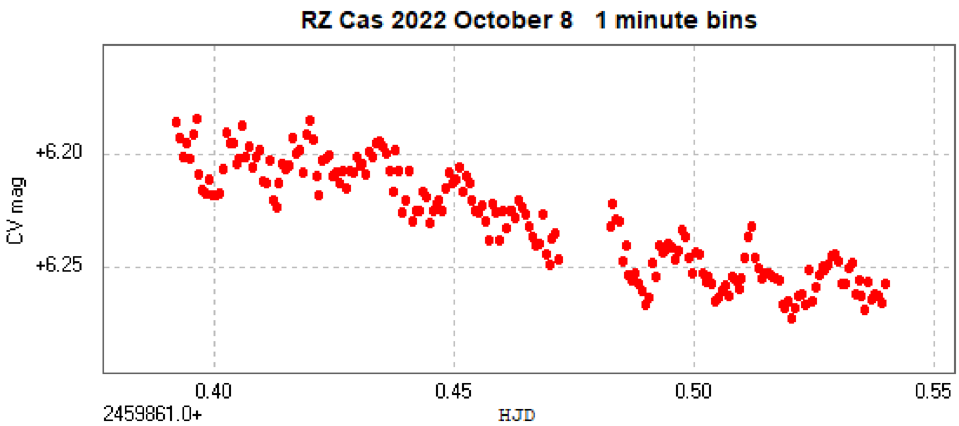


The period suggested by Peranso is 0.0156 days / 22.46 minutes.

2022 October 8

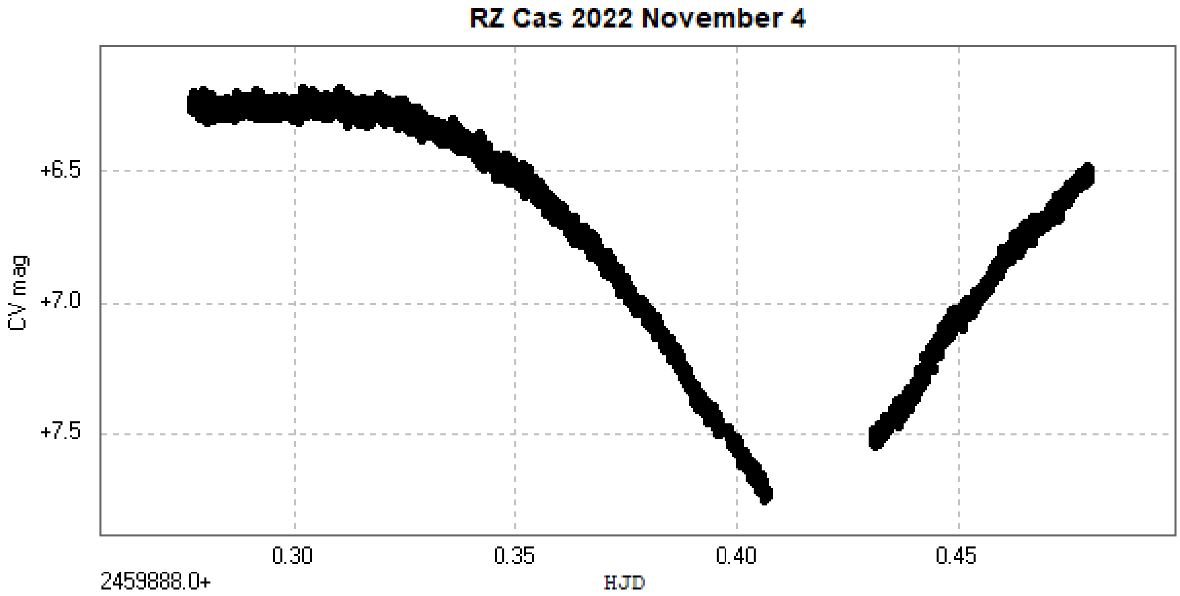
Ingress to secondary minimum from maximum. The gap is due to cloud, as is the lack of the rest of the minimum. Here, the period is again approximately 0.016 days, but the semi-amplitude is perhaps closer to 0.015 magnitudes.



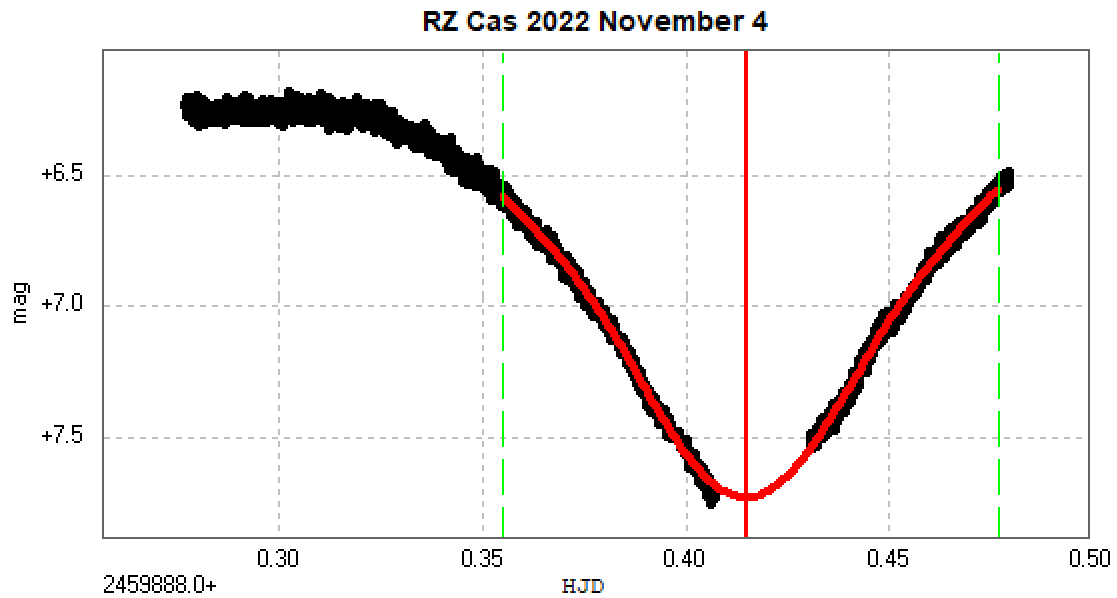


2022 November 4: primary minimum

This night was mainly clear, but a bright Moon was present. The full 50mm aperture was used, to collect as many photons from the system as possible, using exposures of 4 seconds. The prime objective was to obtain a timing of the primary minimum, which is shown below.

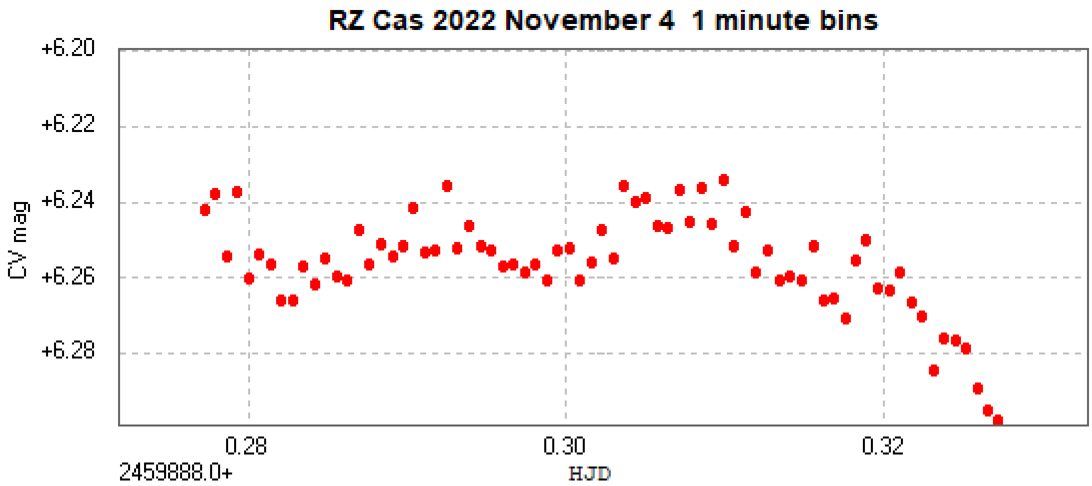


Further δ Scuti type variability was again apparent, not least in the ascending branch of the above light curve, which has a slight 'waviness' to it with a period of approximately 0.015 days. This is less conspicuous in the approach to minimum. The following diagram illustrates this where the red line is a polynomial of degree 8 curve plotted in Peranso.



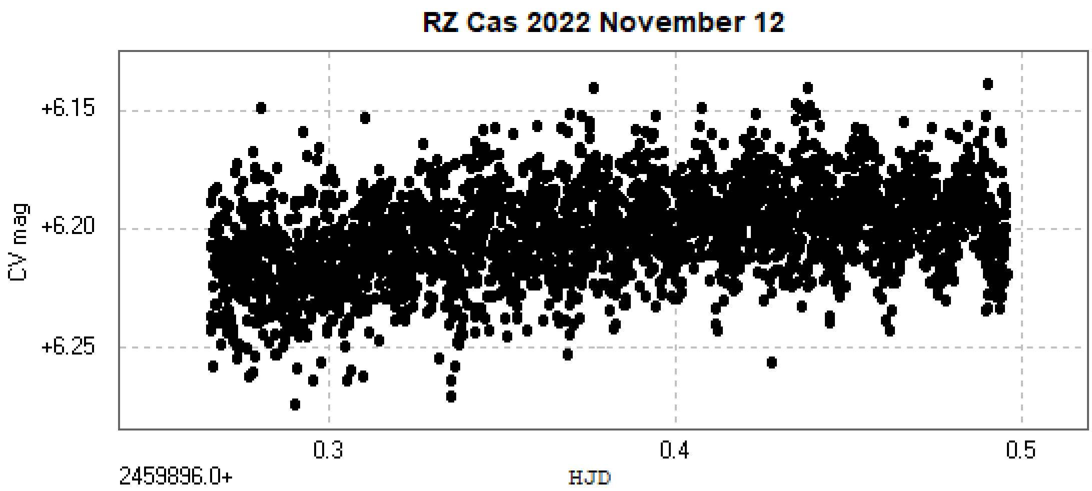
The calculated extremum is at HJD 2459888.414817 +/- 0.00049. However, given this asymmetry and lack of the actual minimum, the calculated error of +/- 43 seconds might be a little optimistic.

As before, δ Scuti type variability was detected in the maximum before the start of the eclipse, plotted below in 1 minute bins. Again, this has an approximate period of 0.015 days.

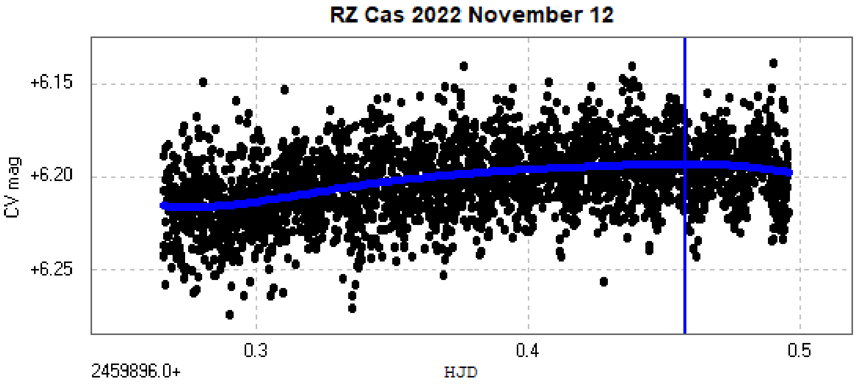


2022 November 12: maximum

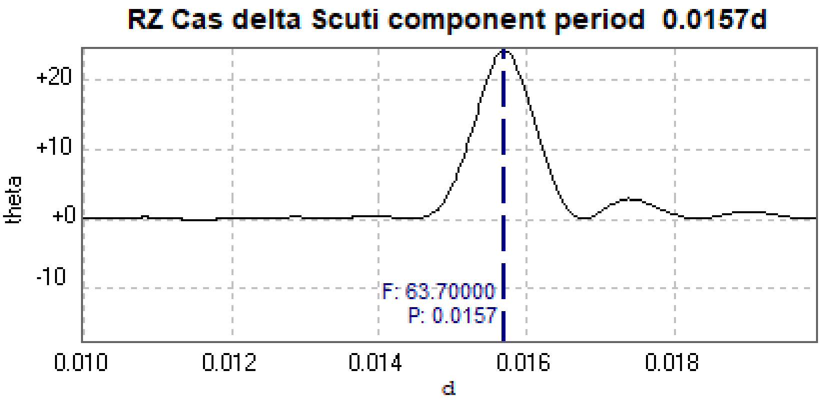
The maximum section of the light curve was observed, with the aperture reduced to 30mm in order to extend the exposures to 7s.



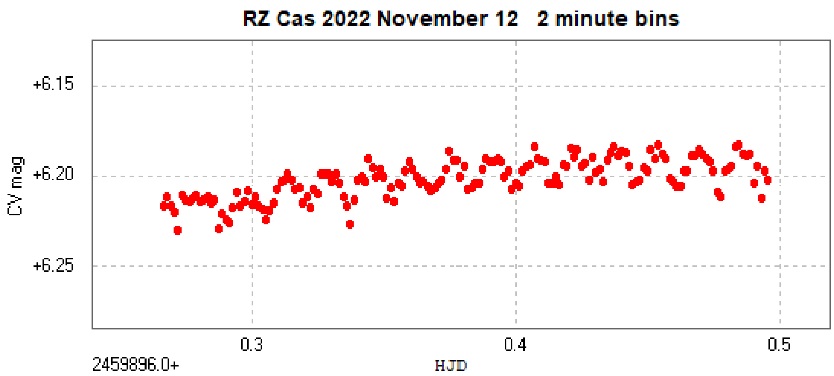
Fitting a polynomial of degree five curve to this, in blue, suggests an increase of approximately 0.02 magnitudes. The calculated extremum is at HJD 2459896.457628 +/- 0.01081. (This is approximately 6.73 periods after the November 4 primary minimum, i.e.moving from the secondary minimum to the primary minimum.)



Peranso/ANOVA suggests a period of 0.0157d for this activity.



The δ Scuti activity is clearer when the above is plotted in 2 minute bins, as below. Here, the semi-amplitude is again 0.01 magnitudes approximately.



Conclusion

This system generates a complex light curve. Not only are two light curves essentially superimposed on each other, but there are also interactions between the two components of the system. These affect the period of the binary system, generating substantial o-c activity (see Kreiner), as well as the period and amplitude of the δ Scuti activity. As suggested by Chaplin et al (*op cit*) this system is well worth continued monitoring. More information can be found on my website.

Observer Profile

Cledison Marcos da Silva

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My name is Cledison Marcos da Silva, I have a degree in physics with a specialization in teaching astronomy, as well as a degree in Pedagogy. I live in Brazil in a small town of less than 6,000 inhabitants called Luminárias. In recent years, light pollution has increased a bit here, as in many other small towns, and that has taken a toll on variable star observations. Not much, since the light pollution here is level 04 on the Bortle Scale, but as my house borders a wooded area, I can say I have a level 03.

I have been interested in astronomy since I observed a partial solar eclipse in 1994, I was 6 years old at the time. Over the years the interest only increased, but for financial reasons I did not have the opportunity to have a telescope from an early age, and bought my first telescope when I was 25 years old, a 114mm of the Greika brand. Unfortunately it was not the best and in the same year I exchanged it for another 114mm - a Celestron Astromaster, a very high quality piece of equipment that I still have and use sporadically. I also have a 200mm that I use when observing variables.

My story with variables started while I was attending a class by the late professor João Steiner about them and the interest was immediate. I started to search the internet and came across the AAVSO website. Reading about them, I decided to delve deeper into the study of these very interesting objects.

Over time I developed an interest in pulsating variables, especially Miras, as the first star I saw change in brightness more perceptibly was R Oph. Currently I dedicate myself to observing Miras, RV Tauris, R Coronae Borealis, Young Stellar Objects and some cataclysmic objects. I currently have a total of 1915 observations sent to the AAVSO (my observer code is DCMA). After having developed osteonecrosis on both sides of the hip I was able to make observations in 2022. Which is very good, I came to think that I would be negatively affected in this regard.

In the first years my observations were sporadic for reasons of work and studies. For a few years I observed independently, until I took over the coordination of the Variable Stars Commission of the Brazilian Union of Astronomy in December 2019. We have already started work with the historic event of the dimming of Betelgeuse. The commission currently has 46 members, including both experienced and novice observers.

Since the commission was created, with the reactivation of the U.B.A. we participate in target observation campaigns at the request of the AAVSO, and we also organize campaigns here in Brazil for some stars that we find interesting. Unfortunately, with few participants. But the trend is improving, at least for variable stars. I've noticed an increase in demand for them here, particularly in relation to visual observations.

We organized a 3-day workshop in 2021 and an introductory course to variable stars in partnership with the Clube de Astronomia de São Paulo, and with these events we were able to attract some people who are already making their observations in a satisfactory way.

I believe that with a little work and patience we will be able to increase the interest of the younger ones in variable stars. Many people are unaware that they are very important, and have already contributed to scientific advancement in many ways. In addition to being an aesthetically beautiful area, there is also the scientific value of their observations. You know you are doing something important for someone, even if you only observe the stars of your program, some student, teacher or even a professional astronomer will be able to use your observations for something.

I conclude by thanking John Toone for the space kindly given to me to write this short profile, and I hope to be able to continue contributing in some way in the future to an important institution such as BAA-VSS.

Below are two light curves of my favorite stars: U Mon and RU Lup. And also a picture of me (above) and my 114mm while observing some variables.

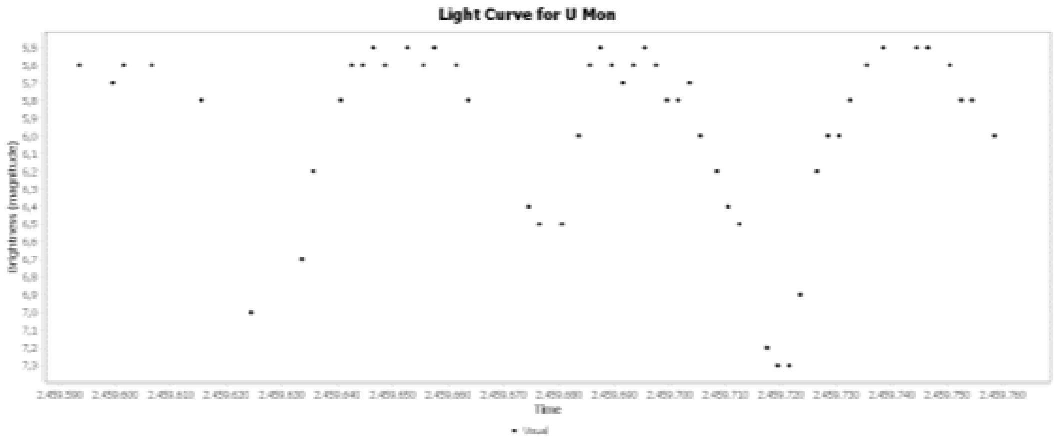

Figure 1 - U Mon light curve in the first half of 2022.

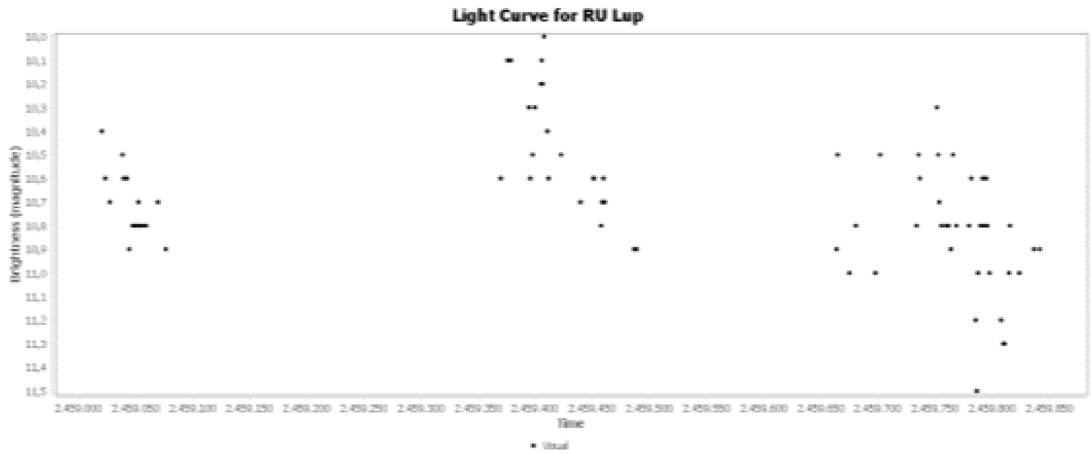

Figure 2 - RU Lup light curve from 2020 to present.

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Telephone Alert Numbers for Nova and Supernova discoveries telephone Guy Hurst. If answering machine leave a message and then try Denis Buczynski 01862 871187. Variable Star alerts call Gary Poyner or post to BAAVSS-Alert – **but please make sure that the alert hasn't already been reported**.

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