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Cover Picture

DQ Herculis Nova Shell

A false-colour image of the shell surrounding the nova DQ Her, made from three narrow band images:
Blue = 4800 angstroms, green = Halpha and red = [NII] at 6583
From https://en.wikipedia.org/wiki/DQ_Herculis
and originally
Angular Expansion of Nova Shells. Santamaria et al, ApJ 892:60, 2020

From the Director – *Jeremy Shears*

Michael Woodman to receive The Charles Butterworth Award

In recent VSSCs I have written about Michael Woodman who, at the age of 15, detected the eruption of **T CrB** in the early hours of 1946 February 9 from his home in Newport, South Wales.

I had the huge honour of visiting Mr Woodman, now 94, at his home in Sussex during September. He recalls the events surrounding his discovery with great clarity. The time and approximate magnitude help to constrain the light curve during the earliest stages of the eruption. There is a short write-up in the *Research Notes of the AAS*: Another Independent Discovery of the 1946 Eruption of the Recurrent Nova T Coronae Borealis - IOPscience

In recognition of his discovery, the BAA VSS Officers have agreed to award Mr Woodman the Charles Butterworth Award. This award was instituted by the VSS in 2004 for outstanding service in the field of Variable Star astronomy. Charles Frederick Butterworth was a Lancashire born amateur astronomer and the first person to complete 100,000 visual variable stars observations, in 1939.

I am very much hoping to present Mr Woodman with his award in person at the BAA meeting on Saturday January 18 at the Institute of Physics in London. During the meeting I will speak about Mr Woodman's discovery, and another independent discovery by VSS observer Frank Knight.

Might there be anyone else who can recall seeing the 1946 eruption of T CrB?

AAVSO Annual Meeting

I enjoyed attending the 113th AAVSO meeting in Huntsville Alabama in November. The location was superb, especially as a child of the Apollo era: the U.S. Space & Rocket Center, the official NASA Visitor Centre for NASA's Marshall Space Flight Center. The opening reception was held in the Saturn V Hall, where it is possible to walk underneath an original Saturn V rocket which was used at Huntsville for tests during the Apollo programme. The opening keynote was by Dr. John Blevins, the Chief Engineer for NASA's Space Launch System Program. As he presented, he had a background comprising the original Apollo 16 Command Module, complete with parachute, that had flown to the Moon and back in 1972 and a Lunar Module. Amazing!

I was made most welcome by Dr Brian Kloppenborg, Executive Director, Board members of AAVSO, and many others. There is much interest in furthering cooperation between our two VS organisations which goes back over 100 years. In my talk I conveyed best wishes from the VSS to the AAVSO. I mentioned the correspondence between Charles Lewis Brook (1855-1939) of the VSS and Leon

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Campbell (1881-1951), Recorder of the AAVSO in the early 1920s on what today might be called a campaign on SS Cygni.

Brook was keen that variable star observers around the world should pool their observations to allow a more complete analysis of the star: “owing to the peculiar character of the variation, it will be difficult for anyone to deal comprehensively with the problem of the star’s changes unless the fullest evidence is available.” He wrote to Campbell in 1921 with an offer for “the ASVSO [sic] and the VSS to compare notes and see if an agreed list of the maxima of this star since 1896 cannot be arrived at”. Campbell replied in positive terms, sharing some of the AAVSO conclusions.

Dr Andrew Wilson

Many will know that our Database Manager, Andy Wilson, has been pursuing research towards a PhD at the University of Exeter. The wonderful news is that Andy passed his PhD viva in September.

His thesis has the tile: “T-Tauri stars: Identification by explainable machine learning and investigation into the effects of starspots.”

In October, Andy began a 3-year Postdoctoral Research Fellowship in Astrophysics at Exeter. The topic is star formation. His fellowship will allow him to deepen his PhD research during which he identified candidate young stars, using photometry in the optical and infrared. The William Herschel Telescope will obtain follow-up spectra for several thousand of these candidate young stars. These spectra will allow him to confirm or refute their nature as young stars.

Congratulations, Dr Wilson, and good luck with your future research!

Chris Jones OBE

Section member, keen visual VS observer and Editor of the variable star column at TA, Chris Jones, received an OBE for his professional work in the waste management industry in October. Congratulations, Chris!

2025 beckons…

With the year end approaching very quickly, I’d like to take this opportunity of wishing all Section members a very Merry Christmas and clear skies in 2025. Don’t forget to observe the *Variable Star of the Year*, **GK Per**. See Gary Poyner’s article on GK Per in the 2025 BAA *Handbook*, also available here: https://britastro.org/vss/VSOTY%202025.pdf

CV & E News

Gary Poyner

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With the 90th anniversary of the discovery of Nova Her 1934 (DQ Her) by JPM Prentice occurring in December 2024, a description of the discovery, along with details of DQ Her itself is presented. The deep fade of the RCB star Z UMi along with a BAAVSS light curve and an update on T CrB is also included.

DQ Her

JPM Prentice 1903-1981. BAAJ 1982, 92, 3

December 2024 sees the 90th anniversary of arguably the most important Nova yet discovered – DQ Herculis (Nova Her 1934).

On the night of December 11/12, BAA Meteor section Director John P Manning Prentice was observing the Geminid meteor shower in cold and very clear conditions in Stowmarket. In JBAA Vol 45, No 3 he writes…

"The nights of December 11-12-13 are of course the maximum nights of the Geminid meteor shower, and I had arranged with my co-worker, Mr. Alcock, of Peterborough, for watch to be commenced in the early evening of December 12 in hope of getting some Geminids slowed down by atmospheric resistance, the radiant being then low. Watch was accordingly commenced at 5h 30m G.M.A.T. in a fairly good sky in strong moonlight, but this part of the programme was unsuccessful, only one meteor being seen in the two hours up to 7h 30 m, when I had to take other duties."

After resuming his watch at 09h 10m GMAT under excellent conditions, cloud developed at 11h 30m GMAT resulting in a two hour break in his observations. Not giving up, Prentice remained at his observing location until the sky cleared again at 13h 30m GMAT to leave the sky "marvellously clear". Continuing in his BAAJ report, Prentice writes…

"Turning towards the North-East, I had not taken more than two or three paces when I saw that there was something very definitely wrong with the head of Draco, and at once recognised the presence of a conspicuous Nova a few degrees following iota Herculis. I was rather surprised to see one in this position, as I had always believed that Nova appear on the borders of the Milky Way, whilst this was some way out; but it was undoubtedly a Nova. I made a careful estimate of its magnitude, and reckoned it at 1/2 β Dra t Her, which (neglecting absorption) works out at 3.4. As obviously the sooner its spectrum was photographed the better, I started up the car and drove down into the town to telephone the Royal Observatory, Greenwich, getting through about 17h. Having done this, work on the Geminids, was resumed from my observing station in Stow-market at 17h 10m approximately, and carried on until dawn at 18h 20m; 90 meteors being recorded in all in 8h 30m of effective watching"

Observing some miles from Prentice was “Mr Alcock” (George Alcock) who had agreed to help Manning Prentice in his meteor work. Alcock stopped observing at 01h 30m UT because he had his first job as supply teacher for ten months the following morning. In Alcock’s marvellous biography ‘Under an English Heaven’ written by Kay Williams [1], Alcock comments…

“*Manning was just stretching his legs, after a long spell observing in one position, when he spotted a bright Nova in the constellation of Hercules. It was a magnificent Nova – one of the best this century. If I hadn’t finished early that night, I would have seen it when it moved into my observing field.”*

The Nova peaked at magnitude +1.5 on December 22nd and remained visible with the naked eye until early April, 1935. From this point DQ Her faded to magnitude 13 by early May and recovered to magnitude 7 by July 1935. This is the (now) well known ‘dust dip,’ caused by dust forming as the nova shell expanded and cooled. A retrospective inspection of light curves of previous nova revealed that the very same phenomenon had occurred with T Aur (Nova Aur 1891), discovered by the Rev. Thomas Anderson. By 1960 the nova had returned to quiescence at magnitude 14.0 (Fig. 1). For the discovery of DQ Her, Manning Prentice was awarded the RAS Jackson Gwilt medal in 1953.

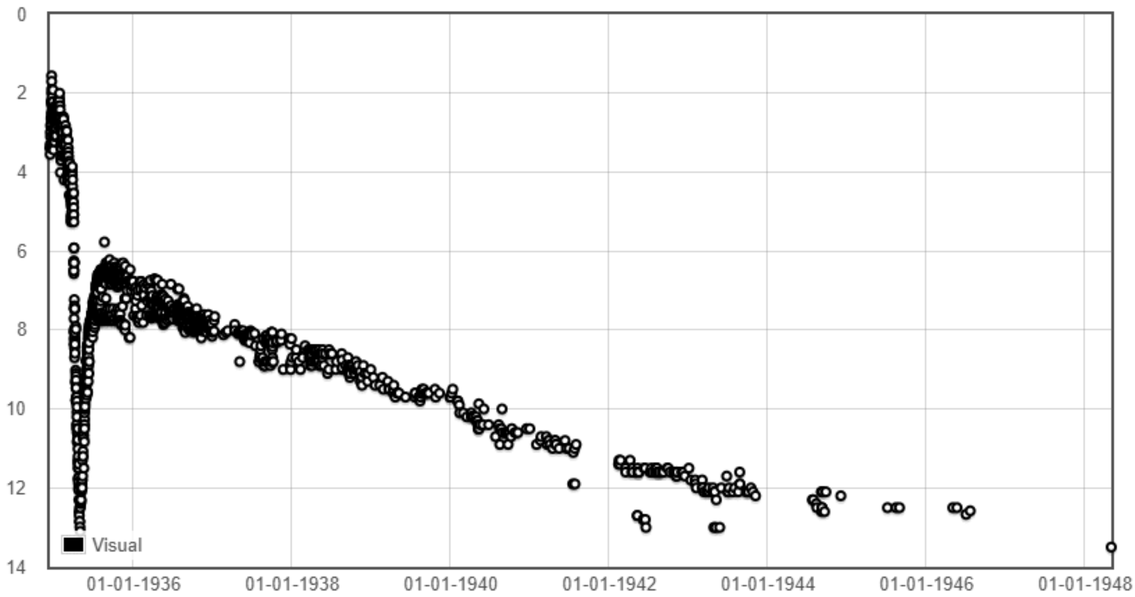

Figure 1. DQ Her 1934-1948 showing the well pronounced ‘dust dip’. *BAAVSS database*

During his programme of photoelectric observations of old novae in order to detect short term light variations which he carried out in 1954, American astronomer Merle F Walker made the remarkable discovery that DQ Her displayed eclipses every 4.65 hours. In addition to this he also detected a 71 second oscillation in the light curve. We now know this to be caused by the irradiation of the inner surface of the accretion disc by a spinning white dwarf X-ray beam. These discoveries, and others, led Robert Kraft to the conclusion in 1961 that all CV’s were in fact binary systems [2]. Our current understanding of these magnetic systems (DQ Her stars or Intermediate Polars) reveal a binary system consisting of a cool main sequence secondary star and a magnetic white dwarf. The magnetic field of the WD truncates the inner accretion disc from which material is accreted to the polar regions of the WD via the magnetic field lines. (Fig 2).

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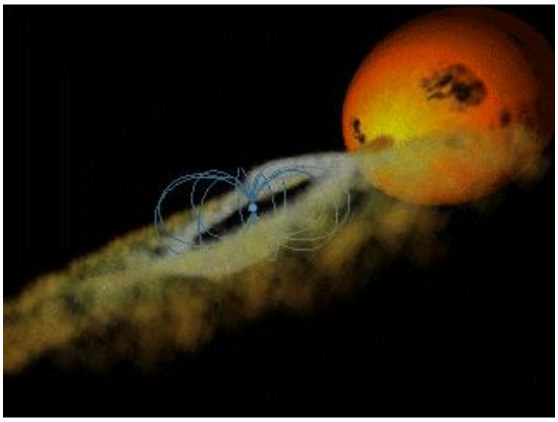

Figure 2. A DQ Her star (Intermediate Polar) showing the truncated inner disc. *Dr. Andrew Beardmore*

DQ Her displays a fine Nova shell (front cover and Fig 3), which is expanding at a rate of around 0.16 arc seconds per year [3]. During a talk on Novae which the author gave to West Yorks AS in April 2024, I mentioned DQ Her's shell and commented that I had never seen an amateur image taken of any nova shell, and that I didn't think that one existed at all (please correct me if I'm wrong). Within a few days, I had received an image from WYAS member Paul Wright of DQ Her and its nova shell taken with a relatively small telescope. (Fig. 4)

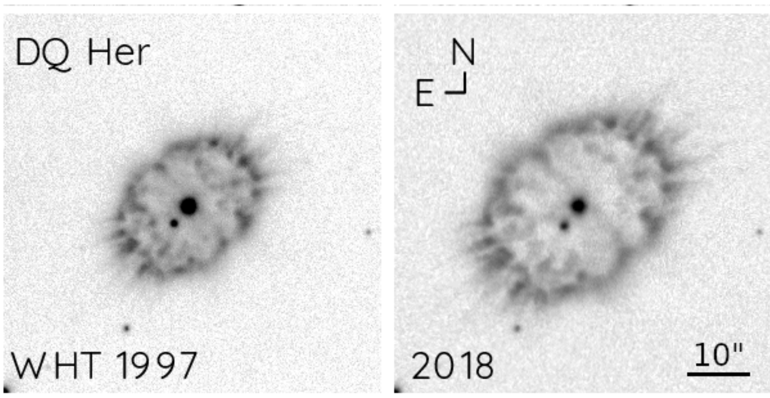

Figure 3. Expansion over 21 years. Hα filters, WHT (*left*) and Nordic Optical Telescope (*right*). [3]

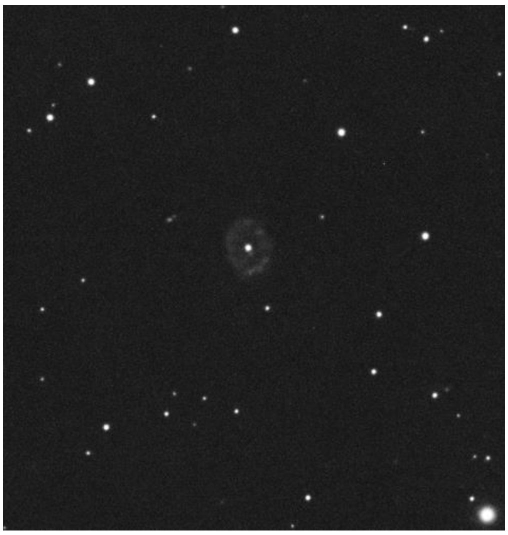

Figure 4. DQ Her Nova Shell. Paul Wright (WYAS). Cropped from original image obtained from 26x300s exposures using Sharpstar sca260 v2 260mm f5 aspherical Cassegrain, Ioptron CEM70, ZWO 294mm Pro, ZWO 174mm for guiding camera. ZWO EAF, ZWO EFW, ZWO off axis guider and Antlia 3nm filters.

I know Paul is looking to improve his image, and perhaps send a colour one too, but the weather in the UK is making things very difficult (and he is in Yorkshire). With the field now getting lower in the evening sky, it will probably be next year (2025) before he tries again.

The eclipses discovered by Merle Walker in 1954 can be monitored both visually (partially) and digitally. DQ Her lies just below magnitude 14 in quiescence, with the eclipses taking it to just below magnitude 17 every 4.6 hours. There are some eclipse observations in the BAAVSS database (Fig. 5) with the last data reported for DQ Her being in October 2023.

An eclipse ephemeris can be found in the AAVSO VSX, or from the epoch:

HJD 2434954.9431(16) +0.1936209154(30)

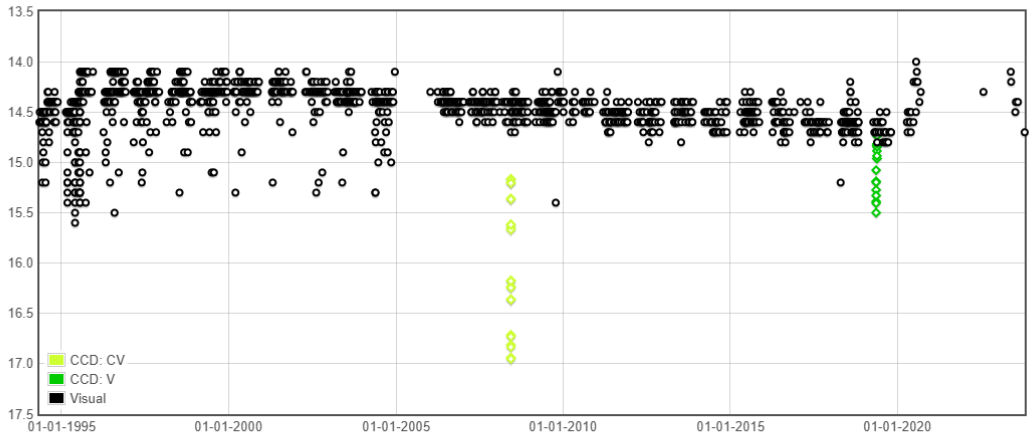

Figure 5. DQ Her with eclipses. 1994-2023. Observers CM Allen, JT Bryan, HW McGee, G Poyner, RH Tremblay, T Vale, IL Walton. BAAVSS Database

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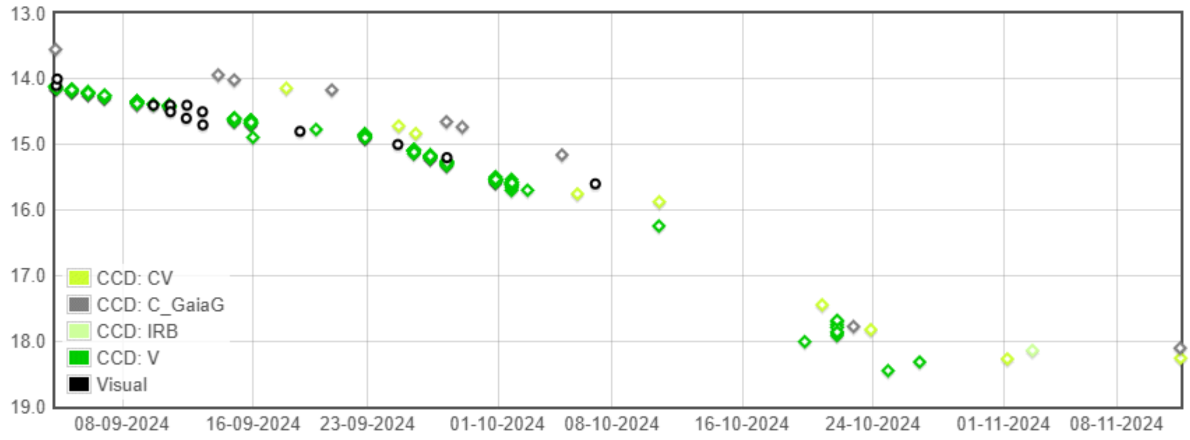
1: Under an English Heaven. Kay Williams. Genesis Publications, 1996

2: Binary Stars among cataclysmic variables. 1: U Geminorum stars (Dwarf Novae). Robert P Kraft 1962 ApJ 135 https://articles.adsabs.harvard.edu/pdf/1962ApJ...135..408K

3. Angular expansion of Nova Shells. Santamaria et al ApJ March 2020

Z UMi

In VSSC 201 news of a fade in the RCB star Z UMi was announced. The fade has proved to be a very deep one, reaching below magnitude 18.0V in late October, and steady there until mid-November (time of writing).

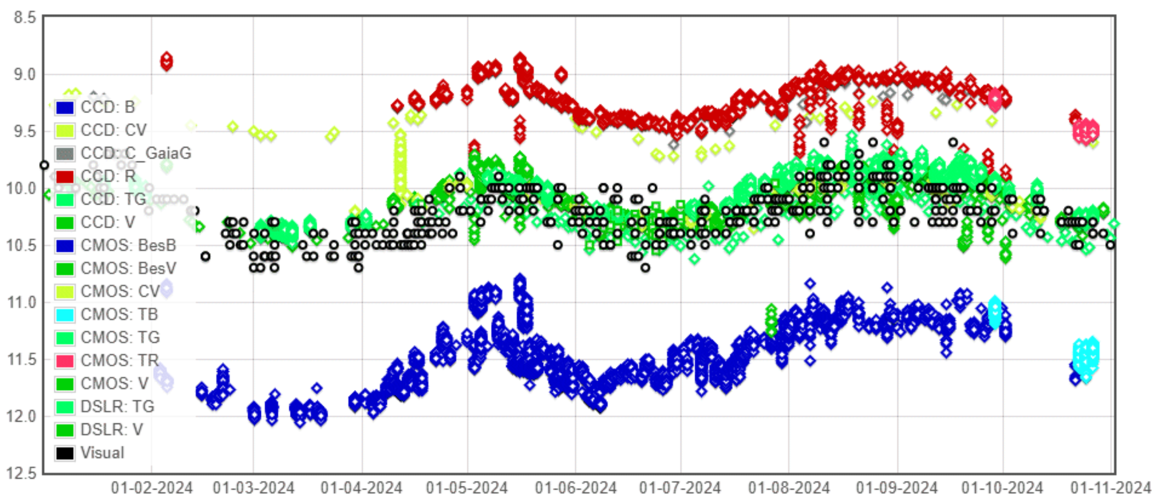


Z UMi: September 01 – November 17 2024. Observers ND James, M Phillips, G Poyner, GJ Privett, I Sharp, J Toone. *BAAVSS Database*

The deepest fade yet recorded started in January 2007 and reached minimum brightness of 19.1C on August 30th, so the current fade has nearly reached that level, but it does look at this time to have levelled off. The 2007 recovery was slow, reaching magnitude 16.0 by May, and eventually back to maximum brightness in August 2009, following a short one magnitude dip in March/April 2009.

T CrB

Well it hasn't happened yet. Despite several outburst predictions for 2024, T CrB continues to keep us all guessing! Details of recent spectroscopic changes from the ARAS group can be found on Atel#16912, and below is the BAAVSS light curve for T CrB in 2024 – January 1-November. Thanks to all observers for their observations, and please keep looking over the difficult winter months.



Observers: PG Abel, SW Albrighton, D Boyd, LK Brundle, DG Buczynski, M Finch, RK Hunt, ND James, PC Leyland, H Meyerdierks, A Miller, M Mobberley, P Mulligan, G Oska, W Parkes, R Pearce, M Phillips, G Poyner, AR Pratt, GJ Privett, JD Shanklin, I Sharp, D Shepherd, J Toone, M Usatov, T Vale, IL Walton, PB Withers. *BAAVSS Database.*

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AB Aurigae – The 2024 Fade

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A preliminary report of the 2024 fade of AB Aur, comparing it with previous fades and the overall variation recorded since 1978.

AB Aur is the Northern hemisphere's brightest Herbig Ae pre-main sequence star, normally fairly steady at magnitude 7 but with occasional dust obscuration events causing fades to magnitude 8. [1]

Photometric studies by professional astronomers in the modern era have recorded only minor light variations in AB Aur but that is due to the fact that they were short-term efforts which did not coincide with any fade events. Unlike the professional's, amateur astronomers don't have time constraints and are able to monitor variable stars unrestricted for many years. In the case of AB Aur, I have undertaken visual photometry on 2626 nights between October 1978 & May 2024 and the resultant light curve is reproduced in Figure 1. This light curve exhibits two clear forms of variation: 1) irregular long-term variation ranging between magnitude 6.7 & 7.3, and 2) short-term fades to below magnitude 7.5 at infrequent intervals. It would appear that the two fades recorded in 1997 & 2019 had a distinct impact on the mean brightness trend. In the case of the 1997 fade there was an immediate drop of 0.2 magnitude followed by a gradual additional fade of 0.3 magnitude over the next twenty years. This gradual fading trend was reversed following the 2019 fade event which instigated a recovery of 0.1 magnitude over the next four years. One could speculate that the short deep fades seen here are the leading-edge boundaries (perhaps involving clumps of materials) between differing densities of dust regions that are moving into the line of sight.

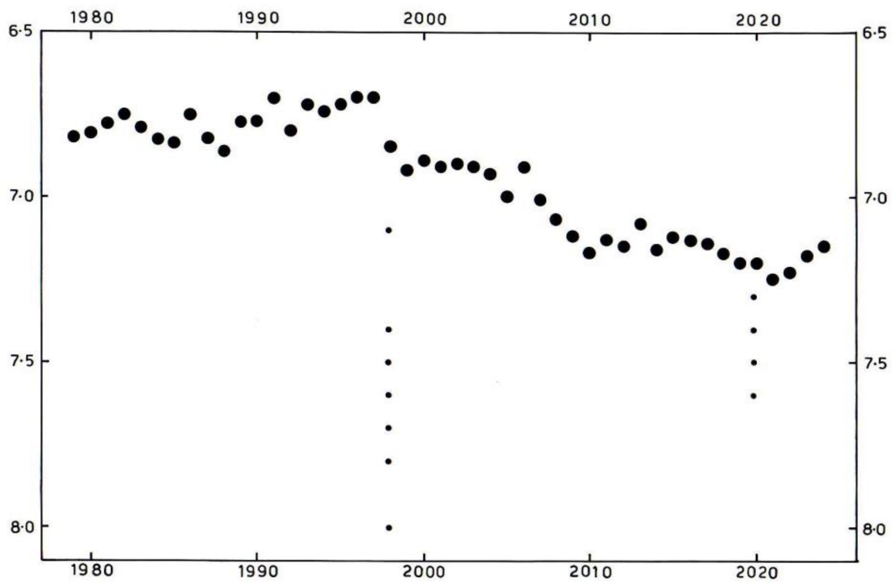

Figure 1**:** Light curve of AB Aur derived from 2632 visual observations by the author between October 1978 & May 2024. The large dots represent annual apparition (from July-May) means and the small dots represent individual observations obtained during fade events in 1997 and 2019. Note the impact that the two fade events appear to have on the long-term variation.

The three fade events reported in the last fifty years (in 1975, 1997 & 2019) have all been detected by visual observers based in the United Kingdom and have been previously described elsewhere. [2], [3] Each of those fades were very rapid and completed within three days.

A fourth fade detected by visual means has now occurred in 2024 with the first alert notice transmitted by me at 00:09BST on 16th September reporting AB Aur at magnitude 7.7. Three nights later (18/19th September) AB Aur had faded further to magnitude 8.0 and confirmation was received from Robert Fidrich & Colin Henshaw who also imaged the variable and its wider field (Figure 2).

Figure 2: Image of the field of AB Aur & iota Aur taken at 02:07GMT on the 19 September 2024 by Colin Henshaw from Bowden near Altrincham. The lettered comparison stars are labelled and AB Aur appears significantly fainter than star E (magnitude 7.6). It is worth mentioning that Colin witnessed the 1975 fade event and he remarked that the morning of 19th September 2024 was the faintest he had seen AB Aur in nearly fifty years.

The 2024 fade was 0.9 magnitude deep but unlike the three previous events it was not a rapid fade and recovery; it was more extended and there were several ups and downs with flickering reported on more than one occasion. Overall AB Aur was recorded as equal or fainter than comparison star E (HD31305 at magnitude 7.6) on multiple occasions between 15th September and 10th October. By the end of October AB Aur was still 0.1 magnitude fainter following the fade event compared to what it was beforehand. The light curve of the 2024 fade event is provided in Figure 3.

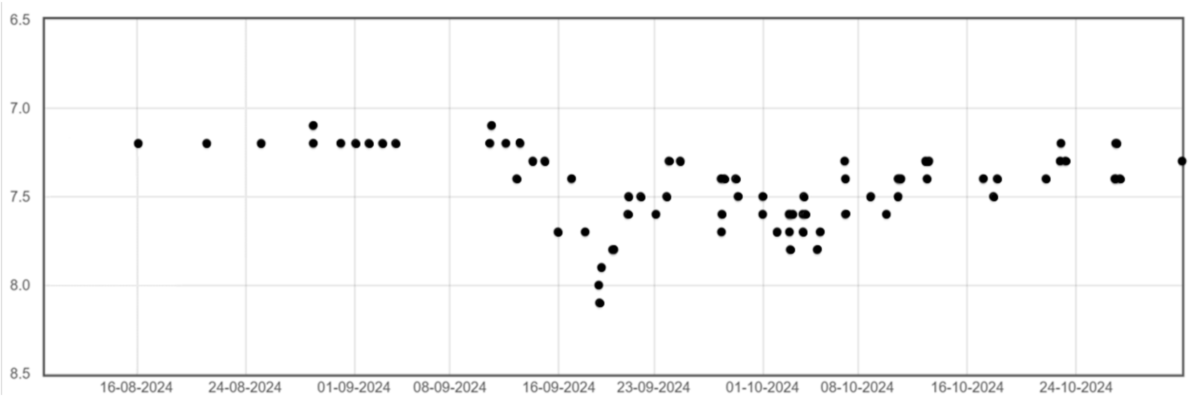

Figure 3: Light curve of AB Aur derived from BAA VSS visual observations during the months of August, September & October 2024. Note the multiple ups & downs with the faintest point reached on the evening of 18th September. Contributing observers are: Shaun Albrighton, Robert Fidrich, Rhona Fraser, Ray Pearce, Gary Poyner & John Toone.

So where does the 2024 fade sit in comparison with previous fades? Well, Table 1 provides a list of all recorded fades based on the work of Yamamoto covering the period 1898-1923 and the BAA VSS covering 1971-2024. Fades appear to have been more frequent during the early 20th Century in comparison with the last fifty years. Also, there is a gap in coverage between 1923 and 1971. Therefore, it would be a useful exercise to search the Harvard and Sonneberg plate archives for evidence of further fades taking place since 1923. Indeed, if anyone has old photographs of the constellation of Auriga, I would urge them to check out the field in the vicinity of AB Aur. If any image does not show AB Aur brighter than the nearby comparison E, then it would constitute a fade. Based on Table 1 data the 2024 fade event has only been exceeded in length by that of March/April 1916.

Min Mag	Start	Finish	Duration
8.05p	5 Nov 1899	7 Nov 1899	2 days
7.75p	7 Oct 1902	11 Oct 1902	4 days
8.1p	23 Jan 1903	23 Jan 1903	1 day
8.15p	6 April 1905	9 April 1905	3 days
8.4p	28 Feb 1906	6 March 1906	6 days
7.9p	3 Sep 1906	3 Sep 1906	1 day
8.0p	10 April 1909	10 April 1909	1 day
8.05p	7 Feb 1916	14 Feb 1916	7 days
8.4p	4 March 1916	8 April 1916	35 days
8.1p	14 Sep 1917	19 Sep 1917	5 days
8.0p	27 Aug 1918	27 Aug 1918	1 day
8.0p	7 Nov 1918	7 Nov 1918	1 day
7.86p	10 March 1919	10 March 1919	1 day
8.0p	12 Feb 1921	12 Feb 1921	1 day
7.78p	25 Oct 1921	25 Oct 1921	1 day
8.4mv	29 Nov 1975	1 Dec 1975	3 days
8.2mv	30 Nov 1997	2 Dec 1997	3 days
7.6mv	18 Sep 2019	18 Sep 2019	1 day
8.1mv	15 Sep 2024	10 Oct 2024	24 days

Table 1: List of fades of AB Aur detected by photographic or visual means. The photographic detections between 1898 & 1923 were determined by Yamamoto [4] and the visual detections since 1975 were determined from BAA VSS data.

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It will be interesting to see if the 2024 fade has any long-lasting effect on the overall brightness trend of AB Aur as had happened previously following the fades of 1997 and 2019.

AB Aur is clearly a worthy object for photometric study but the present data covering the short-term fades and the long-term variation still relies upon the systematic efforts of the amateur visual observers. In the future it would be good to have electronic photometry and spectra augmenting the ongoing dedicated work of the visual observers.

References:

1: 2019 VSS Circular, 180, 10
2: 1998 VSS Circular, 95, 13
3: 2019 VSS Circular, 182, 9
4: 1924 BHarO, 798, 7

The nature of the recent transient AT 2024aawt = ATLAS24qcz

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The outburst of the recent transient AT 2024aawt is shown to have a large amplitude, over 7 magnitudes in the red, but there are no clearly identified outbursts in the ATLAS data since 2017. The shape of the peak of the current outburst, the amplitude, and lack of previous activity suggests a UGSU or UGWZ superoutburst.

The recent outburst of the transient AT 2024aawt (= ATLAS24qcz) was discovered at o = 17.54 on 2024 November 11.07 (JD = 2460625.57) by the Asteroid Terrestrial-impact Last Alert System (ATLAS) group) (Tonry et al., 2024). Spectral classification was provided after one day by the (ePESSTO+ group) (Tsalapatas et al., 2024) as a CV with a blue continuum, and weak Balmer and HeI lines. The transient also falls within the 90% confidence limit of the gravitational wave detection and possible NSBH merger event S241109bn, but is unlikely to be related (see Gillanders et al., 2024). The transient is now listed as a UG variable in the AAVSO VSX under the ATLAS designation. The position of the transient is coincident with the star DES J205751.50-413839.1 in the Dark Energy Survey DR2 data (Abbott et al., 2021) with g =24.6±0.1 and r =24.5±0.2, so as o ∼ r, this implies an outburst amplitude of 7.2 magnitudes in the red. Gaia has not observed this star so there is no further information. The galactic coordinates are l =0.0, b =−40.7, so the distance from the plane could be unusually high.

The ATLAS project has observed AT 2024aawt since 2017 in the 'cyan' c band (420–650nm), and the 'orange' o band (560–820nm), and the data were downloaded from the ATLAS Forced Photometry web service (Tonry et al., 2018, Shingles et al., 2021). The bulk of the observations are relatively evenly distributed with a median cadence of 2.2 d in the orange band and 4.0 d in the cyan (c) band, but there are seasonal gaps of 100–150 days. Most of the ATLAS data are upper limits and prior to the current outburst there are no convincing observations brighter than magnitude c or o ∼18.

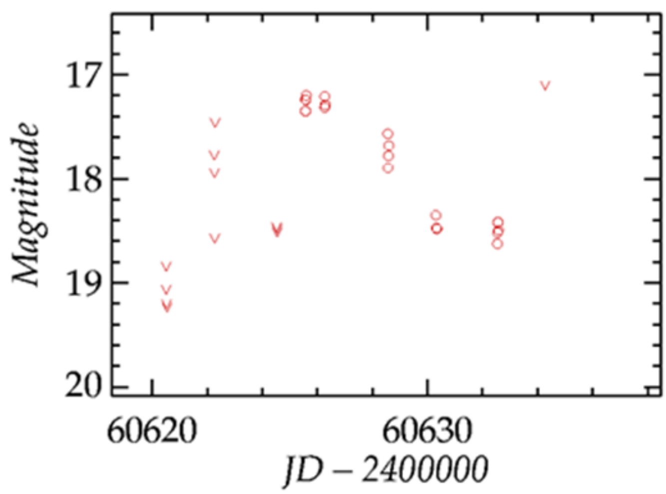

Figure 1: The recent ATLAS light curve of AT 2024aawt showing the individual positive orange (o) band observations and upper limits.

Given the coverage it seems unlikely that previous outbursts were missed, but it is possible that they fell between seasons, so the lack of activity could point to bad luck, or a long outburst cycle. The object is too far south to be covered by the Zwicky Transient Facility.

The light curve of the current outburst from the ATLAS data shown in Fig. 1. The individual observations and upper limits identify the run up to the outburst, the maximum, and initial steep decline at $\simeq 0.3$ mag d^{-1}, followed by a slower fade, more consistent with superoutbursts. The classification spectrum was taken at maximum and shows effectively constant flux across Hα with weak, but progressively deeper lines from Hβ to probably Hϵ. If the star is a CV, then an emission line spectrum would be expected, however, as it was observed close to maximum it may have been caught before the full development of the emission lines. In that case Hα would be completely filled in and the subordinate lines less so. For comparison see the spectral development of the WZ Sge star V455 And (see e.g., Tovmassian et al., 2022).

From such minimal information it is impossible to provide a definitive classification of the object, but there are some key indicators. The primary, and indeed only, facts are the large amplitude of the outburst, the spectral classification, and the shape or time scale of the peak of the outburst. On the other side of the coin is the curious galactic latitude, and the uncertainty about any previous activity. The galactic latitude could indicate an extragalactic origin, but the outburst has evolved very quickly, fading by over a magnitude in 4–5 days, which is not seen in supernovae. If it is a large-amplitude CV then the most likely candidates are SU Ursae Majoris (UGSU) or WZ Sagittae (UGWZ) systems, which can reach outburst amplitudes of 8 magnitudes, and have long, or very long outburst intervals. Some SS Cygni (UGSS) systems also have long outburst intervals, but all of the large-amplitude UGSS stars have frequent outbursts on time scales of tens of days, and in the red do not reach amplitudes of 7 magnitudes.

Assuming it is a system with a short orbital period then from the calibration of Patterson (2011) at maximum light $M_V \simeq 5.5$. At maximum the colour is assumed to be close to zero, so $o \simeq V$ and extinction is likely to be minimal, which leads to a distance d = 2.5 kpc. Using that distance, it is possible to calculate the absolute magnitude at quiescence, and from the DES colours of about zero, $V \simeq r$ is assumed, which leads to $M_V \simeq 12.5$. The DES colours are consistent with short-period CVs at quiescence so the system could accommodate a white dwarf and an early-mid M-type dwarf, which is typical of cool components in CVs, and match this luminosity. From the Rochester calibration (see Pecaut & Mamajek, 2013) the luminosity of M dwarfs falls rapidly, so there is some flexibility. Assuming d = 2.5 kpc then the high galactic latitude leads to a distance of 1.7 kpc from the plane (see e.g., Canbay et al., 2023).

The author is pleased to acknowledge use of NASA's Astrophysics Data System Bibliographic Services. This research has made use of the SIMBAD database and the VizieR catalogue access tool operated at CDS, Strasbourg, France. The author gratefully acknowledges use of the AAVSO Variable Star Index (VSX). This work has made use of data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. The ATLAS project is primarily funded to search for near earth asteroids through NASA, Kepler/K2 and STFC grants.

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VSS Data Sheds Light on an Old Quasar Mystery

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The blazar OJ287 is one of the most fascinating quasars that are known. This is a consequence of it being the system in which we see deepest into the relativistic jet. The fact that it may have a binary supermassive black hole in its core only adds to its interest. OJ287 seems to be unusual in many aspects of its behaviour. In particular, it does not follow the standard pattern of colour variability associated with blazars that their colour gets bluer as the blazar gets brighter. A long series of colour observations made in collaboration between BAA-VSS members and Spanish observers have started to shed light on this issue and have suggested that OJ287 does show significant colour variations and that these are more complex than previously thought, but masked due to multiple sources of emission overlapping.

Blazars are a sub-class of quasars in which the relativistic jet expelled from the poles of the central black hole points roughly towards the Earth. This allows us to look down the jet as if we were staring down a lighthouse beam. What makes OJ287 special in this respect is that it has the best-aligned relativistic jet of all known blazars, hence, in many senses, its behaviour is particularly extreme. Although there are blazars that have the jet pointing at an even smaller angle to our line of sight, these are at a larger redshift (the current record-holder for the smallest angle of jet, 0º.2, is QSR 0804+499, with a redshift of Z=1.436) and, thus, we do not see as far into the throat of the relativistic jet. In the case of OJ287, with a redshift of 0.306 and a jet at an angle of 1°.9, we have the object that has the relativistic jet best-aligned with our line of sight (Savolainen et al., 2010). [1]

Many highly variable quasars – such as BL Lac, AO 0235+164, AP Librae, Mark 501, etc. – have a bright host galaxy. For example, BL Lac appears to be an ordinary quasar when bright and a giant elliptical galaxy when faint, while the host galaxy of Mark 501 is so bright that it can be imaged easily with a CCD on a small telescope. In contrast, in OJ287, the beam of light from the jet is so intense that underlying giant elliptical galaxy is barely detectable save when the blazar is especially faint and, even then, can mainly be detected only indirectly. Indeed, the host galaxy has not even been detected directly with the HST.

One classic property of highly variable quasars is the way that that the colour gets bluer when the object is brighter. This is generally attributed to outbursts generating bursts of energetic, relativistic electrons that then decay radiatively (Brown et al., 1989).[2] In other words, there is a burst of strongly blue, synchrotron light that reddens as it loses energy by emitting light. In contrast, standard wisdom is that, normally, OJ287 does not show these, typical, variations and its colours remain constant over time (Kidger, 2024), [3] such that normally a fixed colour correction is applied between different photometric bands (e.g. Basta & Lehto, 2005). [4]

It is generally assumed that the only significant colour changes in OJ287 come at magnitudes fainter than V=16.5. At such faint magnitudes the colours of the quasar change, slowly, with increasing faintness, to those of a giant elliptical galaxy, as the fraction of the total light emitted by the host galaxy increases. At magnitudes fainter than V=17, the host galaxy can even start to dominate the total emission, however, such extremely faint episodes are very rare.

We normally measure the colour of an astronomical object by its colour index: B-V, V-R, etc. A larger value of B-V or V-R indicates a redder colour and a smaller value, a bluer colour. These colour indices are obtained my subtracting the magnitude in V from the magnitude in B, or the magnitude in

R from that in V, etc. The main problem with studying the colour variations is the quasar's rapid variability. Data in different bands are rarely simultaneous and, at faint magnitudes, the photometric errors can also be large. As the error on the colour sums in quadrature and adds to the error caused by any rapid variation between the two observations that are being compared, the uncertainty of the colour index can be very large. This has made previous studies of the colour behaviour of OJ287 highly uncertain.

The method applied here is to take the largest possible dataset and filter it carefully to eliminate data that may be affected by variability. Two large databases are available:

- The Basta and Lehto database of historic OJ287 observations. This comprises of 16678 observations covering 1891-2005. 61% of this data was obtained as part of the OJ-94 Project to monitor the predicted 1994 outburst of this object, with much of the OJ-94 data being obtained by Canadian amateur, Paul Boltwood.
- The BAA-VSS/Spanish database, which is an extension of the OJ-94 Project. This consists of almost 20000 observations covering 1996-2024.

These two databases were combed for simultaneous and pseudo-simultaneous multiband data in combinations of UBVR&I. Observations were eliminated manually if:

- Insufficiently simultaneous (typically, if two bands were separated by >30 minutes – however, see below for additional information).
- Affected by obvious rapid variations or the data quality was suspect (i.e., inconsistent observations).
- Photometric errors were large (typically >0.1 magnitudes) such that the error on the calculated colour index would be too large for the value to be useful.

Observations in multiple filters, close together in time were extracted. On many occasions, Paul Boltwood's data has long series of measures in BV&R, covering as much as eight hours. This allowed data to be grouped, bracketing the B and R data with photometry in V. The average time for the observations was calculated and the average V for the bracketed data

On nights when OJ287 was inactive, as indicated by the constancy of the V or R magnitude, observations could be averaged over an hour or, even, occasionally, two hours. This allowed averages of the magnitude in several bands to be calculated with a subsequent reduction in the errors and, hence, the uncertainty of the colour index.

The result was the extraction 2635 sets of pseudo-simultaneous photometry in multiple bands. This included:

- 70 sets of UBVRI
- 1062 sets of BV
- 883 sets of BVR
- 284 sets of BVRI

Particularly useful pseudo-simultaneous photometry datasets were obtained by David Boyd (VR), Gary Poyner (BVR) and Esteban Reina (BVRI).

Traditionally, the most used colour indices have been U-B, B-V, V-R and R-I. The advent of the CCD, with low blue sensitivity, has led to the U band falling into disuse and, until blue-sensitive chips became available, even B photometry became a rarity for some years. This has led to a disconnect in data between old, photoelectric sets, which were mainly UBV and, modern, CCD, which mostly VRI and, more recently, increasingly reported as sG, sR & sI, adding a further layer of complication in the extraction of colour information. The transformation of Sloan to Broadband has been mainly empirically determined and can be large. For example, Basta and Lehto use R=sR-0.34, I=sI-0.5.

The questions that are the main interest and motivation for this study are:

- What colour – brightness relation (if any) exists in OJ287?
- Is there are colour – time relation, possibly provoked by the large outbursts that occur every ≈11.8 years (e.g., Valtonen et al., 2023)? [5]
- Can we detect the host galaxy in data from backyard telescopes?

Here, we will mainly confine ourselves to the first two questions. The third will be the subject of a paper in the Journal.

An example of a raw colour-magnitude plot is shown in Figure 1. This is the V-R colour index taken from observations by David Boyd and Gary Poyner. Nominally, it is a scatter diagram, with no relationship between the V-R colour index and the magnitude in V. My attention was drawn to these data by two things. First, Gary Poyner noted that his colour data seemed to show different results to David Boyd's (Poyner, 2023). [6]. And second, there is a suspicion in Figure 1 that the data may split into two, or even three groups following roughly parallel lines of trend.

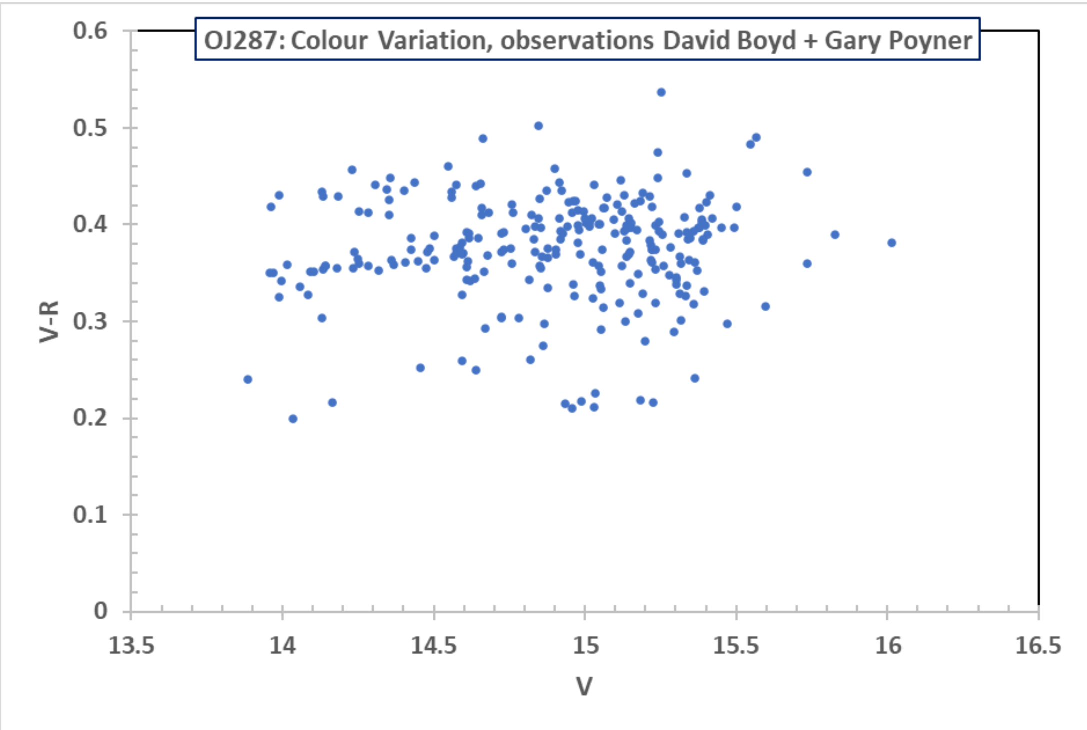

Figure 1: The V-R colour index for OJ287 from observations by David Boyd and Gary Poyner between December 2015 and January 2021. Most blazars are bluer when brighter but, within the dispersion caused by rapid variability, the colour of OJ287 shows no obvious correlation with brightness. The average colour index over the period covered is V-R=0.37.

This leads to the question: could there be a second correlation, perhaps between colour and time, which is masking the colour - magnitude correlation?

If we take all 1062 time-averaged B-V values and plot them against the measured V magnitude at each epoch, we see a cloud of points (Figure 2). The correlation coefficient, r^2=0.0032 indicates that there is no correlation.

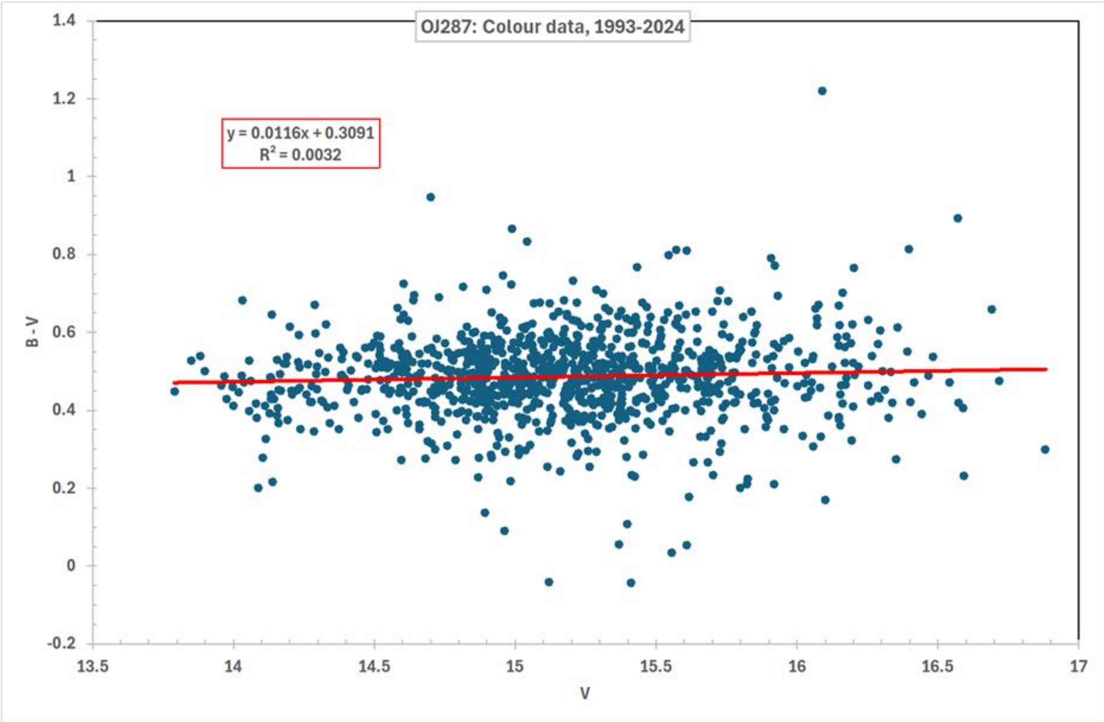

Figure 2. Time averaged B-V colour index values plotted against the V magnitude at the epoch of the observation.

However, if we take the same data and, instead, plot the B-V colour index against time, we see a quite different picture (Figure 3).

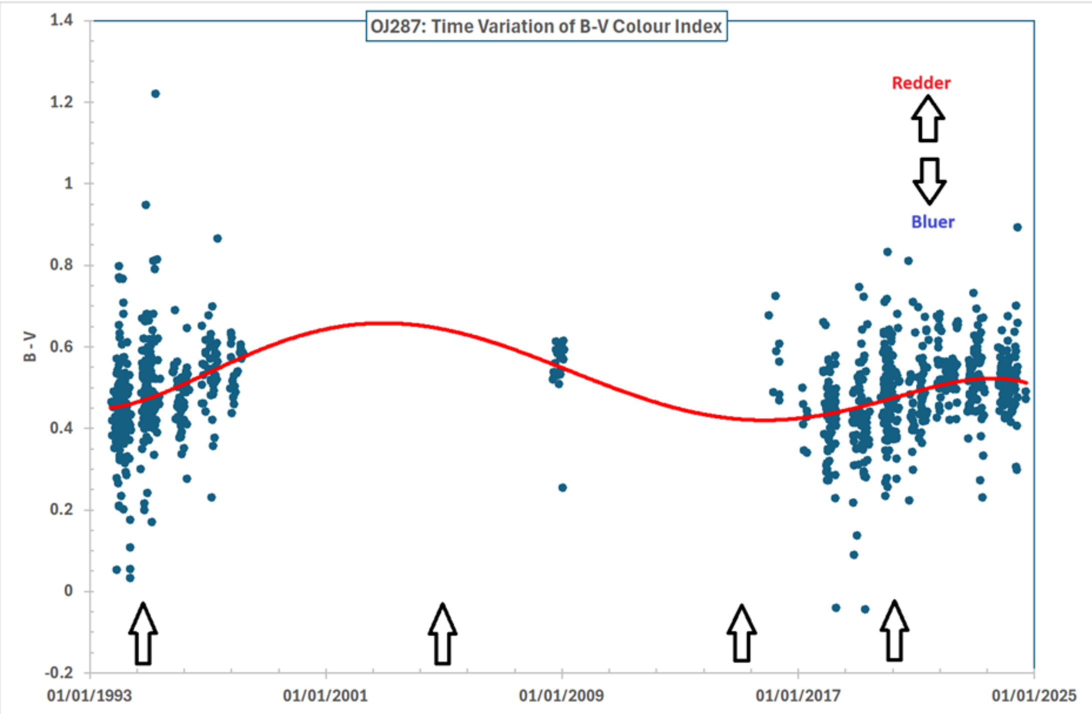

Figure 3. Time variation of the B-V colour index derived from all the data presented in the text. A fifth order polynomial fit has been added: this is to guide the eye rather than being a proposed fit to the data. The epochs of major outbursts are shown by arrows.

We see that the availability of B-V colour index data is mainly limited to 1993-1998 (principally data from Paul Boltwood) and 2016-present (BAA-VSS/Spanish data). A fifth order polynomial has been fitted to guide the eye to the slow variations. We see that the B-V colour index clearly got significantly larger (i.e., the quasar became redder) both between 1993 and 1998 and between 2017 and 2023. We also see that, despite the care taken in the data selection, there is a small fraction of points that are outliers. If we look at the V light curve for the same period (Figure 4), we see that there is no obvious correlation between these slow colour changes and events in the light curve.

In the cannon of light curve behaviour for a 'normal' blazar, we would expect the colour to become bluer during an outburst and redder when fainter. Instead, Figure 3 shows us that, judged by the B-V colour index, OJ287 actually became significantly redder during the 1995/95 and 2020 outbursts.

Astrophysically, what we are detecting is a change in the slope of the spectrum of the quasar. Most quasars show what is known as a power law spectrum. In other words, if we plot the logarithm of the flux received from the quasar against the logarithm of the frequency (or wavelength) we get a straight line, generally with a slope close to -1. When the light gets bluer, this slope gets flatter and, of course, when it gets redder, the spectrum is steeper. Of course, the longer the section of spectrum that you have, the easier it is to measure how the slope is changing. So, if you have the range from B to I or, even better, U to I, it should be far easier to detect changes in the colour and, thus, the slope of the spectrum. So, although plotting the B-V colour index against V is the standard way of looking for colour changes, plotting B-I or U-I against V is more efficient.

Unfortunately, we have little more than a quarter of the B-I data than B-V and it is even more poorly distributed in time, limited almost exclusively to 1993-1997, 2008-2009 and 2023-2024.

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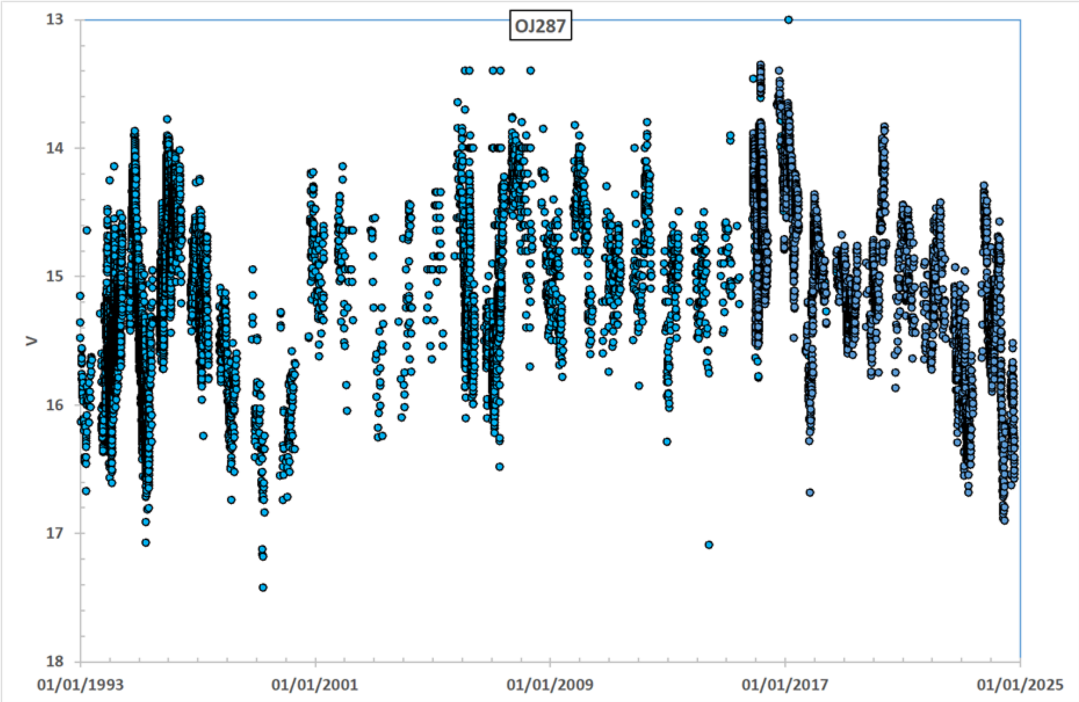

Figure 4. The light curve of OJ287 in V from 1993 to 2024. There are double-peaked outbursts in 1994-95, 2006-07, 2015-17 and, most recently, a single-peaked outburst in 2020.

At first sight, the B-I data seems even more unexpected (Figure 5). There is a slight correlation, but in the sense of the colour getting bluer at fainter magnitudes. This is just the opposite of what we would expect and would be very hard to understand under standard models of quasar emission involving synchrotron emission from black holes and relativistic jets. The spectral slope of v^{-1} is just what we expect from synchrotron emission and stronger emission from more energetic electrons spiralling in magnetic fields should be bluer: it is what we see in all other blazars. So, why not in OJ287?

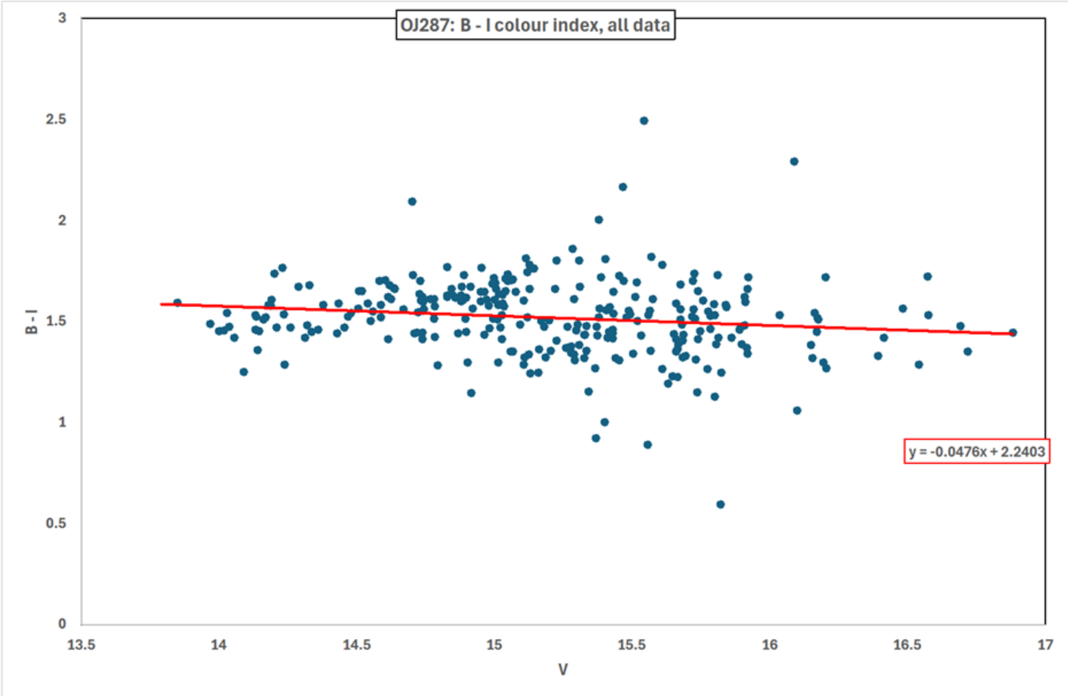

Figure 5. The B – I colour index against the V magnitude of OJ287 for the full data set. There is a weak correlation, but in the sense of the colour getting bluer, not redder, at fainter magnitudes.

The answer seems to be that the data is playing us false. A second effect is hiding the colour change. If we look at how the B-I colour of OJ287 has varied with time, even bearing in mind the limitations of very poor time-distribution of the data, we see that there are quite large variations (Figure 6).

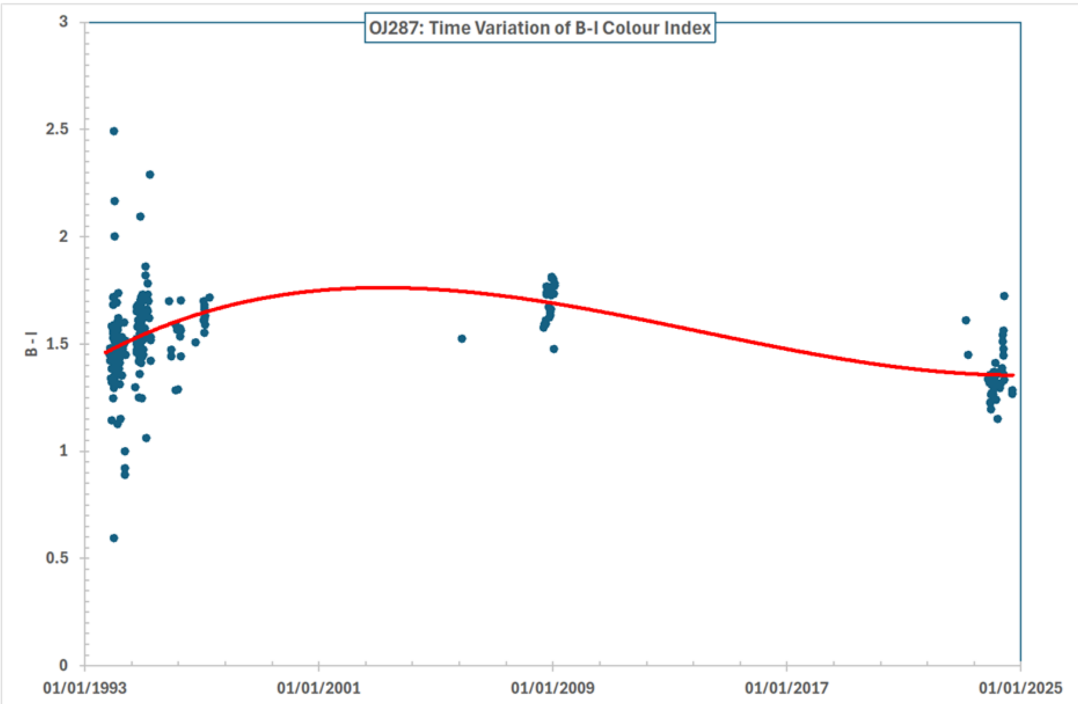

Figure 6. The time variation of the B-I colour index of OJ287. The B-I colour index gets significantly larger (redder) between 1993 and 1997. A 3rd order polynomial has been drawn through the data to guide the eye.

In particular, the B-I colour index increased quite sharply between 1993 and 1997 (redder colour) and decreased quite significantly between 2009 and 2023/24 (bluer colour). If we split the B-I data into three segments and plot the B-I colour against the V magnitude for each, we get the results shown in Figure 7, Figure 8 and Figure 9. We see that, the 1993-1997 data shows no correlation between colour and magnitude but, in contrast, the 2005-2009 and 2023-2024 segments show a similar, strong correlation in the expected sense of redder colour at fainter magnitude: the average slope is 0.09±0.01 magnitudes change of B-I colour for each magnitude brighter or fainter in V.

The key to this colour behaviour of OJ287 may be in the particularly complex, multi-component emission. Apart from the slowly-varying jet emission, we have emission from shocks in the jet (that it is suggested, by Brown et al., 2010, is emitted from regions between 0.001 and 0.1 parsecs in diameter, in magnetic fields ≈1 Gauss),[2] plus the massive injections of electrons caused by the outbursts every 11.8 years. Where we see no colour correlation, it may be because there are multiple components of emission rising and falling on short time-scales such that the colour-magnitude relationship is masked when we examine the data over a longer period of time. If this is the case, we would expect to see a colour-magnitude correlation only in short segments of data.

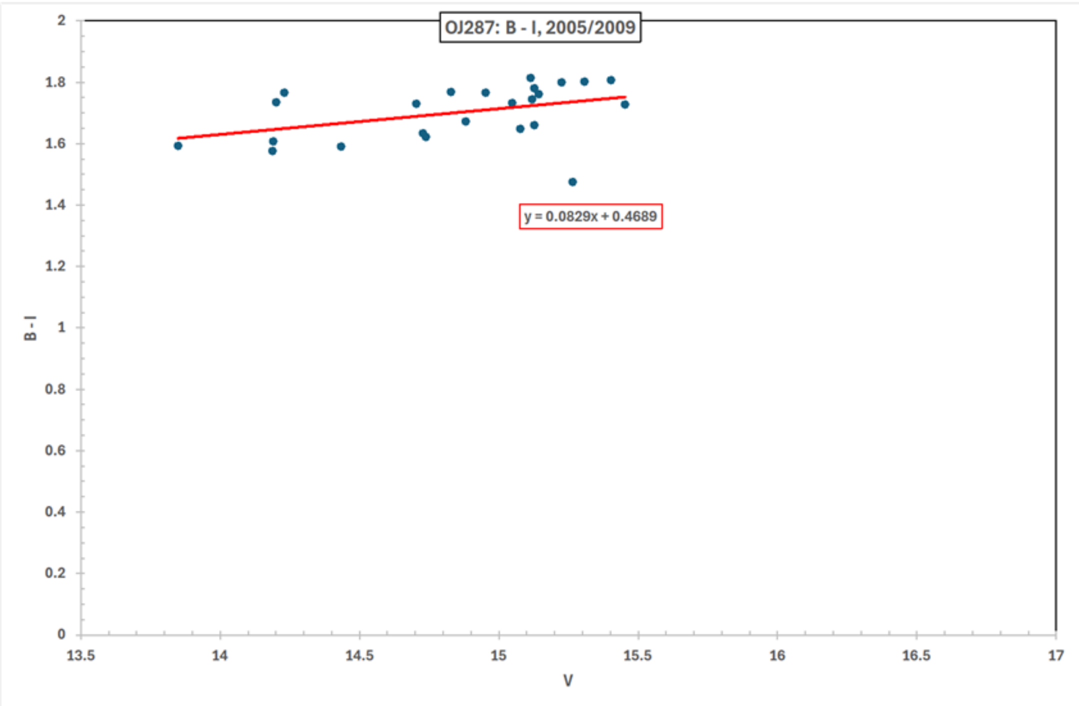

Figure 7. The variation of the B-I colour index with V magnitude for data obtained between 1993 and 1997. There is essentially no colour change with magnitude.

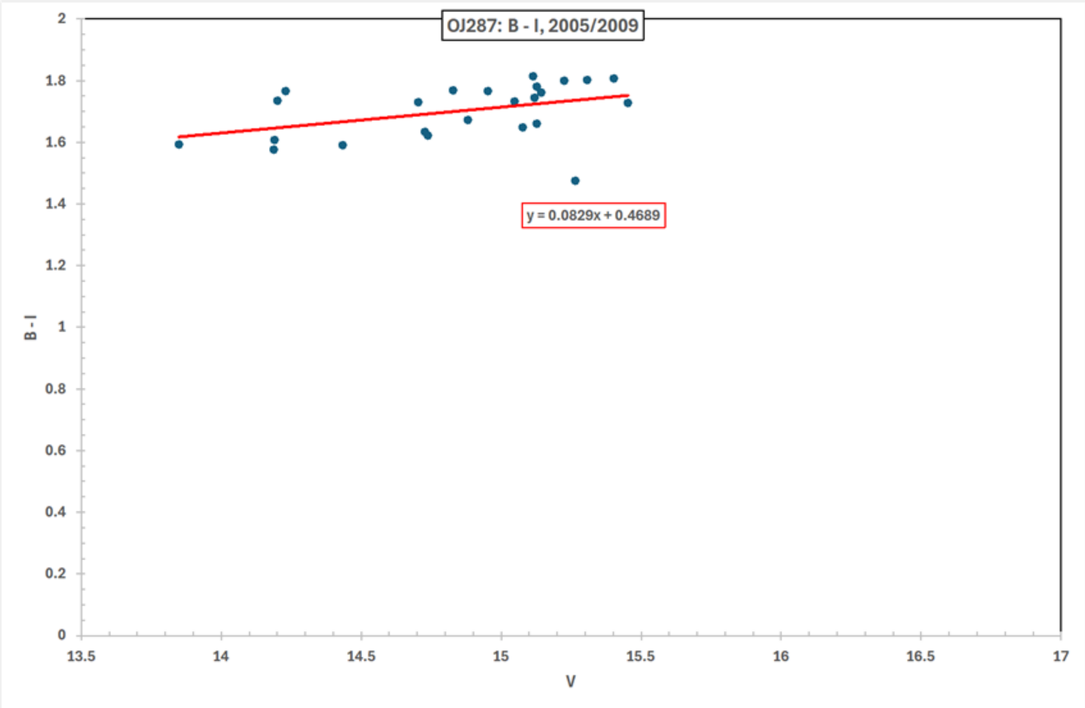

Figure 8. The variation of the B-I colour index with V magnitude for data obtained between 2005 and 2009. There is strong correlation in the expected sense that OJ287 gets redder at fainter magnitudes.

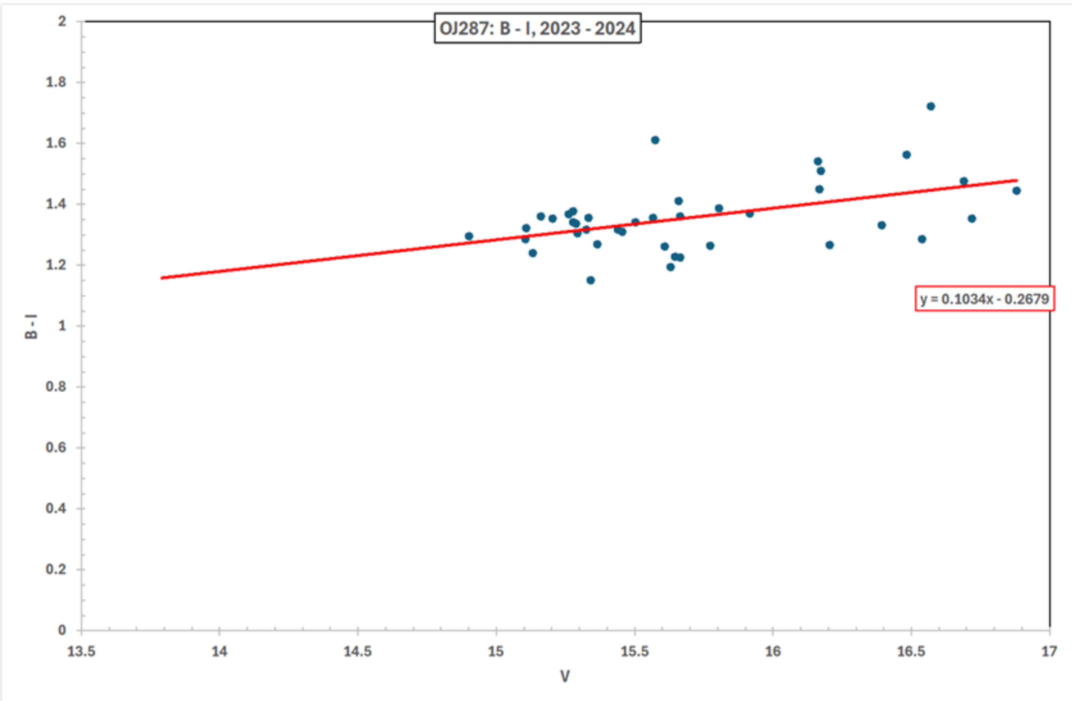

Figure 9. The variation of the B-I colour index with V magnitude for data obtained in 2023 and 2024. A correlation is seen with a similar slope to Figure 8.

If we take a segment of data around the peak of the 1994 maximum (Figure 10), from 1994 October 15th to December 31st, we do see a correlation between colour and magnitude with the same slope of approximately 0.1 magnitudes increase in B-I for each magnitude fainter (Figure 11). When we extend the data included in the plot to earlier or to later dates, the correction starts to disappear. This suggests that the colour-magnitude relationship exists at all epochs but is masked by the multiple components of emission. Each component gives a similar correlation, but with a different offset so that, when combined, they produce a scatter diagram. This effect is similar to what would happen if you tried to listen to multiple people reciting the famous soliloquy from Hamlet out of synchronisation: each person is saying the same words but, in concert, it is extremely difficult to isolate what any individual is saying.

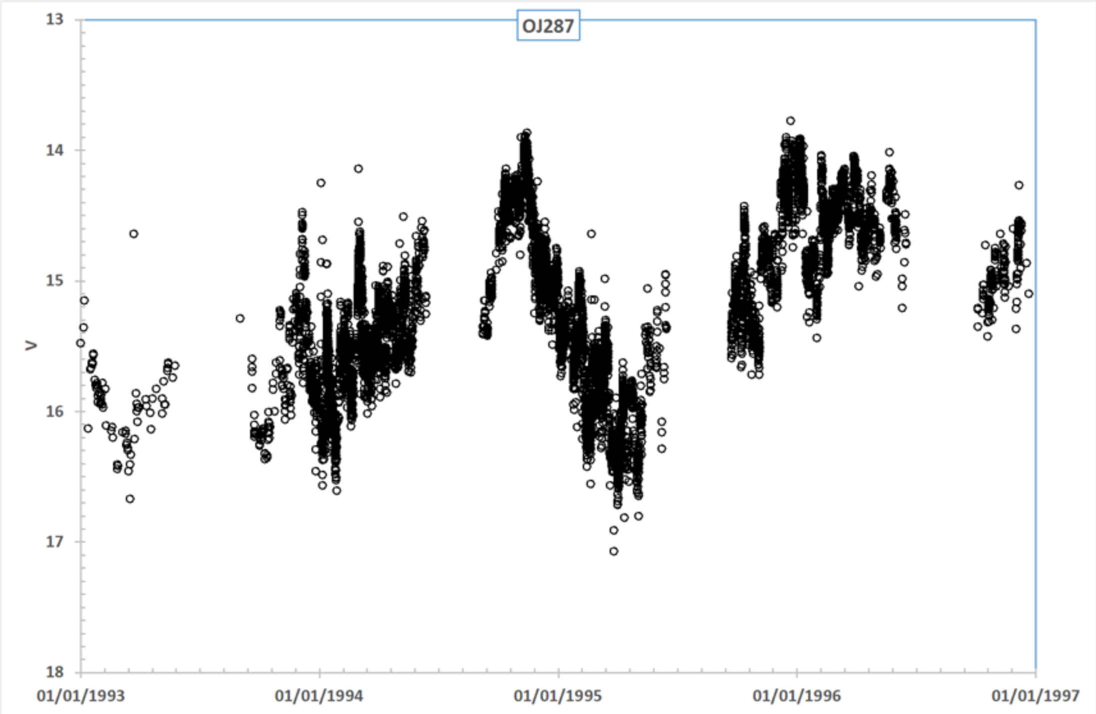

Figure 10. The light curve in V from 1993 to 1997 showing the multiple maxima associated with the 1994/95 outburst, each presumably associated with a massive injection of relativistic electrons.

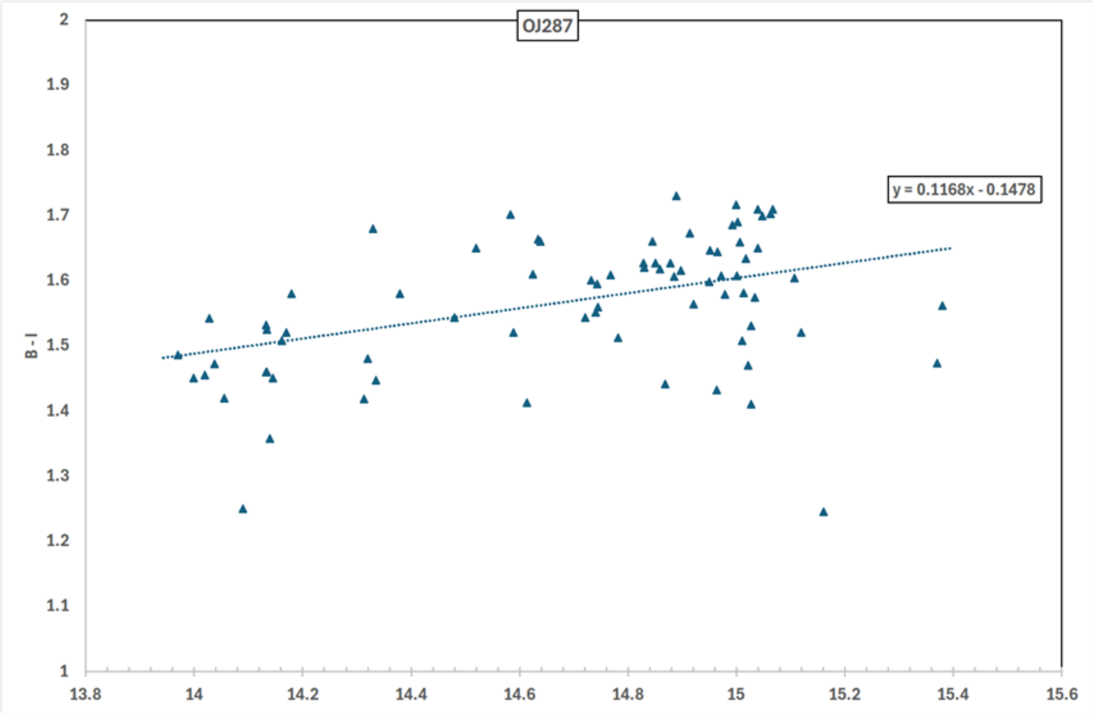

Figure 11. The B-I against V colour relationship for OJ287 between 1994 October 15th and December 31st. We see a correlation with the same slope as at other epochs in which the colour-magnitude relationship is clear.

Conclusions

This is probably the largest study of colour variability in OJ287 that has ever been carried out. The results suggest that OJ287 does, after all, behave in a similar way to other blazars in its colour variability and that there is a correlation between colour and magnitude in the sense of bluer colour at brighter magnitude, but that this correlation is masked by the presence of multiple sources of emission. The conclusion is that OJ287 is not an anomaly, save in the sense that we see the complex interaction of various sources of emission that combine to mask the trends that are seen in other blazars.

We see that there are long-term, slow variations in the colours of OJ287. While, due to the gaps in the record, the data presented here is insufficient to demonstrate it, the hypothesis is that these slow variations are caused by the large outbursts, although there may be a time delay between the massive injection of relativistic electrons in the core of OJ287 that leads to the outbursts and the appearance of the slow colour variations themselves.

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APT and SAO 28567: Never throw anything away – just in case

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Some issues around data handling from the Ells Automatic Photometric Telescope are described.

In 2024, it's not unreasonable to think that there's little need for data from observations made back in 1998, especially if they were made on "amateur" equipment, and stored via a BBC Model B computer. With almost 30 years of development in technology having taken place, why indeed would this data even be useful, and could the data even be located or extracted?

Readers of the VSS Circular No 201 in September 2024 might have read the paper from Christopher Lloyd (SAO 28567: One that got away) and noted that the object was observed over a number of nights back in 1997 by Malcolm Gough and Roger Pickard, using the Automatic Photometric Telescope of Jack Ells design.

The data were obtained by Malcolm and Roger using the APT at Trottiscliffe, Kent over a period of 10 nights between February and April 1998. There had been a suggestion that SAO 28567 (V352 UMa) had varied by 0.6 magnitude in just 12hrs, so the APT was used to check this. However, no sign of any short periods (i.e. a few hours) could be seen in the data set (VSSC 95, p15. 1998) so the data were essentially mothballed. The reported variation was likely a glitch. However there remained a suspicious disagreement between the brightness given in the various catalogues; and Hipparcos and other satellite-based telescopes subsequently suggested that SAO 28567 was an elliptical binary star with a rotation period of 1.4135 days so Chris was interested to find archived data that might support this.

The APT ran on a BBC microcomputer so a transcription process was needed to convert a BBC model B DOS disc to MS-DOS (which can then be processed and emailed using a more modern PC). John Howarth still had the original 800 or so transcribed observations on his PC (the filing system worked for once!) so following the request to find the data, we then sent them to Chris. When folded at a period of 1.4135 days, the data showed a strong indication of the twin-peaked light curve, which Chris compared to observations from Hipparcos. The peak-to-peak amplitude (about 0.02 mag) is less than the scatter in the data (0.03 mag), but still correlates when the right period is used. The result is a tribute to the accuracy of the APT in its heyday, Malcolm's efforts with its operation and, of course, Jack and Peter's novel and successful design.

As for the Automatic Photometric Telescope (and the BBC Model B controller) – these remain at Trottiscliffe for the time being, with efforts underway by Peter Ells to find a permanent home, or museum for display purposes, which will preserve this unique instrument for future generations. You never know, there might be further requests for data from VSS members, so we won't delete those files just yet!

V Pyxidis

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The little known southern semi-regular variable star V Pyxidis was observed from Saudi Arabia between 2013 and 2019. Images were taken with two Canon cameras and these were measured using AIP4Win software. The star was found to have an amplitude of a little more than two magnitudes, in good agreement with catalogue data. The star has been neglected since discovery in 1921, and internet searches revealed nothing about it.

Introduction

V Pyxidis (Position (2000) RA 08h 53m 25.6s Dec -34° 49' 09") is a little known southern variable not accessible from the U.K ., rising only three degrees at culmination from Manchester. It was discovered by Mary Applegate in 1921, who worked at Harvard College Observatory between 1918 and 1921. She engaged in measuring variable stars on photographic plates under Henrietta Leavitt, and later she worked on the asteroid (433) Eros. She died in 1954 at the age of 57. The AAVSO quotes an amplitude for V Pyxidis of 7m.7 – 10m.4, with a period of 79.9 days, Spectrum G8IIp - M1Ib/II, and Variability Type SRd. Internet searches on this star so far have revealed nothing, suggesting that few people have observed it in the intervening decades.

Figure 1. Chart derived from Chris Marriott's SkyMap Pro 10

Observation

Three comparison stars were used, (Fig 1) plus an additional star when it was very faint, and the results averaged. These were SAO 199763 (b) 7m.39, SAO 199736 (d) 8m.35, SAO 199762 (g) 9m.04, and TYC 7146-1592-1 (k) 10m.45.

The star was monitored between 2014 and 2019 from Briga Township, outside Tabuk in the Kingdom of Saudi Arabia. From Saudi Arabia the star showed pronounced seasonal gaps in the light-curve, but a sufficient number of observations were secured to reveal general trends in variability. Images were obtained with Canon 30D and Canon 6D cameras, using a Carl Zeiss 135mm telephoto lens set at f5.6. Five second exposures were given at 800ASA. Each data point was derived from eleven successive images of five seconds each, and these were processed after dark frame subtraction using AIP4WIN software. Monitoring of the star ceased after my departure from Saudi Arabia in 2019.

Results

Deep minima were recorded in February 2015, and in December 2017 when it reached 9m.9 and 10m.3 respectively (Fig 2). The December 2017 minimum was confirmed by Patrick Schmeer. Maximum brightness was at 7m.9. Between 2018 and 2019 the star seemed to be more quiescent.

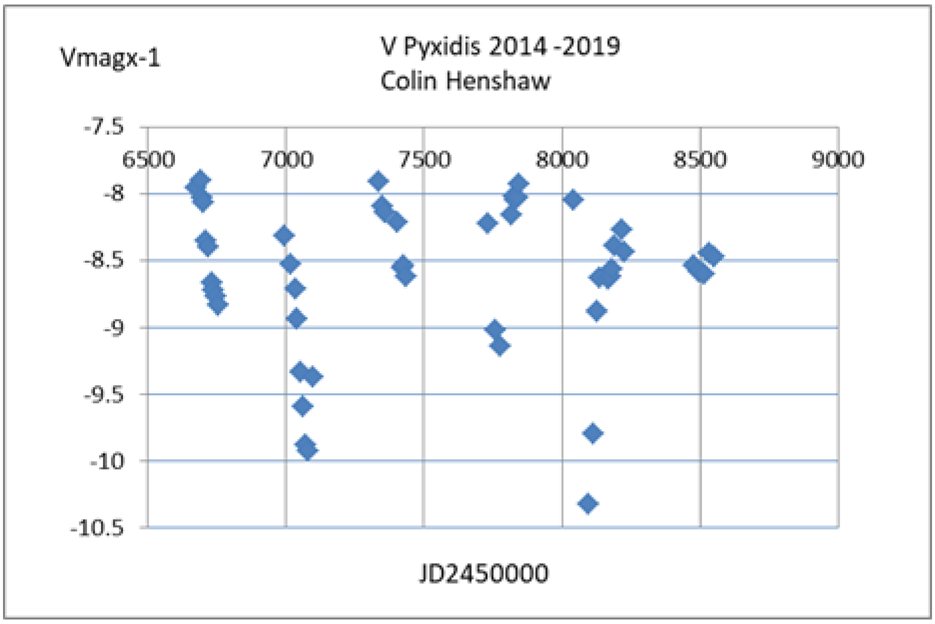

Figure 2. Light curve of V Pyxidis 2013-2019

The APT and micro-variability of the alleged delta Scuti variable V1116 Tauri = NSV 1663

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V1116 Tauri is a variable star with no convincing evidence of variability, and the previous work has only provided upper limits of perhaps a few mmag on any variation. Data from TESS and Kepler both show micro-variability with a full amplitude of 127 ± 7 μmag on a period of 0.645 d, probably due to rotation.

V1116 Tauri (NSV 1663, HR 1459) is a bright F5IV star with V = 6.02 and ($B - V$) = 0.38 and is a long-standing member of the open cluster Melotte 25 (No. 100), which in turn is part of the wider Hyades moving group. As such it has extensive historic photometry, including measurements by Johnson et al. (1962), Crawford et al. (1966) and Landolt (1967), but the published collections also include some disparate values (see Mermilliod, 1987). V1116 Tau appears to have been first listed as a suspected variable in the in the NSV (see the full entry from the GCVS under NSV 1663) with a full range of V = 6.01 − 6.34, but with no variability type, period, nor a reference to any previous study. Possibly on the basis of the 1982 NSV listing, the star was suggested as a target for the Ells Automatic Photometric Telescope (APT) and was observed during 1996, but exactly what drove this is lost in the mists of time. The star was considered to be a potential δ Scuti variable, possibly on the basis of a paper published the previous year reporting a search for γ Doradus stars in the Hyades by Krisciunas et al. (1995) (listed under HR 1459). However, they found the star to be an unconvincing variable with ΔV in the ±2mmag range, of indeterminate period. Nevertheless, these suspicions led to its later listing as a possible low-amplitude ($\Delta V \sim 0^m.01$) δ Sct variable (DSCTC:) in the GCVS, and ultimately in the AAVSO VSX. Also note their apposite comments on the DSCTC classification. The star is also given as a δ Sct variable in Simbad.

The APT was designed and constructed by Jack and Peter Ells in the mid-to-late 1980s (see Ells & Ells, 1989, 1990a,b), and was based on an earlier manually operated system, where the basics of data logging onto a computer were developed. It may seem ridiculous that this was even an issue, but it needs to be remembered that this was the dark ages of computing. The computers available to be public included the Commodore 64 and PET, Sinclair ZX Spectrum, BBC Micro, Apple II, and early IBM PCs running MS-DOS and the first version of Windows. The detector technology at the time was on the cusp of transition from photoelectric detectors to charge-coupled devices (CCDs), which became more generally available to the amateur community during the 1990s. Apart from the increase in sensitivity the other advantage of the CCD was that it was an imaging detector so the whole field was observed simultaneously. However, the early detectors were small with relatively poor resolution, and not well suited to most variable-star fields. Photoelectric photometry relies on measuring the flux within a physical aperture centred on each star individually, and the background sky, and measurements typically cycle around the variable and two comparison stars, and the sky, to generate differential magnitudes. These are not made simultaneously and can be subject to additional uncertainties if the extinction changes unexpectedly. Nevertheless, in a country like the UK with a poor photometric skies, differential photometry provided the best chance of getting usable data. The APT used an innovative fibre-optic fed photoelectric detector that reduced the weight on the telescope and was designed to take long runs on short-period variable stars and eclipsing binaries, and in its time generated many times of minima.

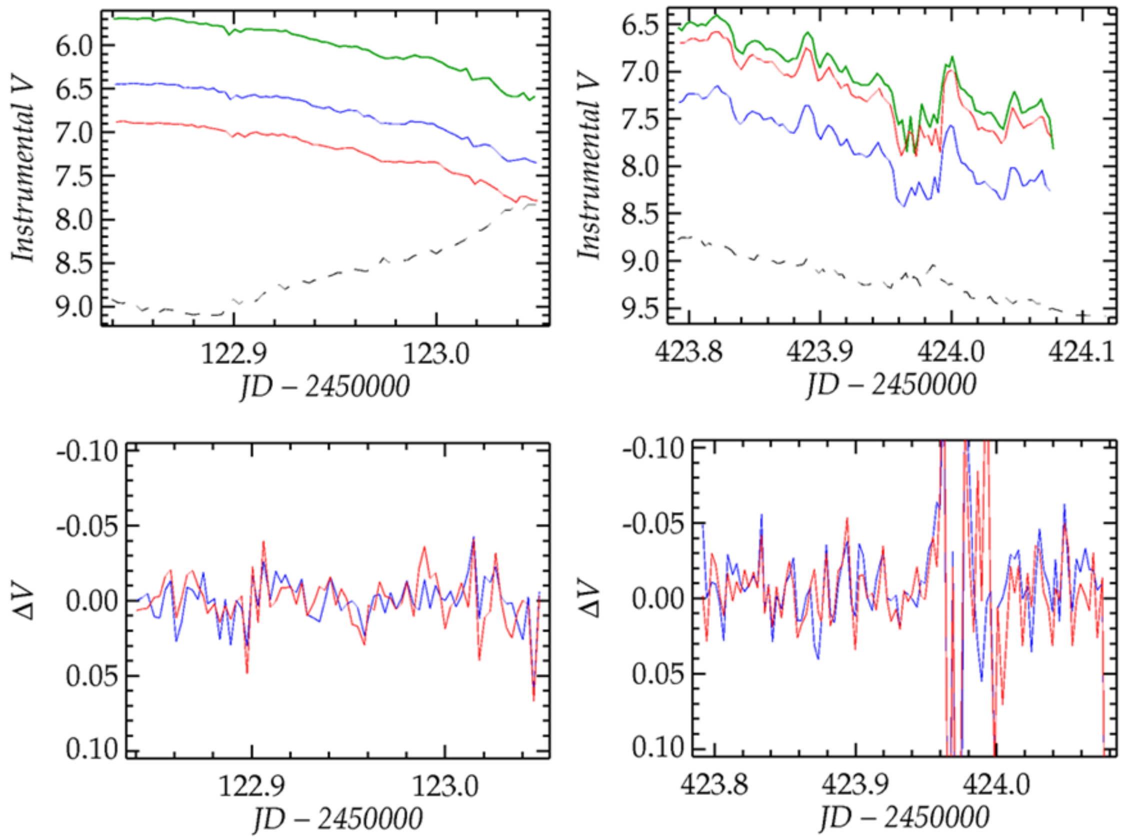

Figure 1: The raw and differential magnitudes for two sample nights. The top panels show the sky-subtracted magnitudes for the variable (green), and comparison stars, and the sky magnitude within the aperture (dotted line). The first run was curtailed by cloud and the deteriorating conditions are indicated by the rising sky background. The second run was long but interrupted by poor conditions. The lower panels show the corresponding differential magnitudes between the variable and each comparison star.

The APT observed V1116 Tau on three nights in February 1996 and another four in November and December, however, much of the data were taken under poor or compromised conditions. One night provided no useful data and all the others were either curtailed or interrupted by cloud. The data from two nights are shown for illustration in Fig. 1. These show the sky-subtracted instrumental *V* magnitudes, and the differential magnitudes obtained through interpolation. The change in flux of the variable and comparison stars, and background sky brightness can be seen through the nights, but despite these changes the differential magnitudes remain relatively stable. However, the irregular variation in extinction limits what is possible, and unfortunately highlights the problems of working in a compromised photoelectric environment. The best sections of data typically have rms errors $\leq 0^{m}.015$ and usable data slightly greater than this. So generally, despite the unfavourable circumstances, the APT is able to provide accurate timing data for bright eclipsing binaries, and through repeated observations, provide useful data on short-period low-amplitude variables $> 0^{m}.05$. Specifically in the case of NSV 1663 the upper limit on any periodic signal is $\sim 0^{m}.01$, and a preliminary review of the data, reported by Pickard & Gough (1997) also found no significant variation.

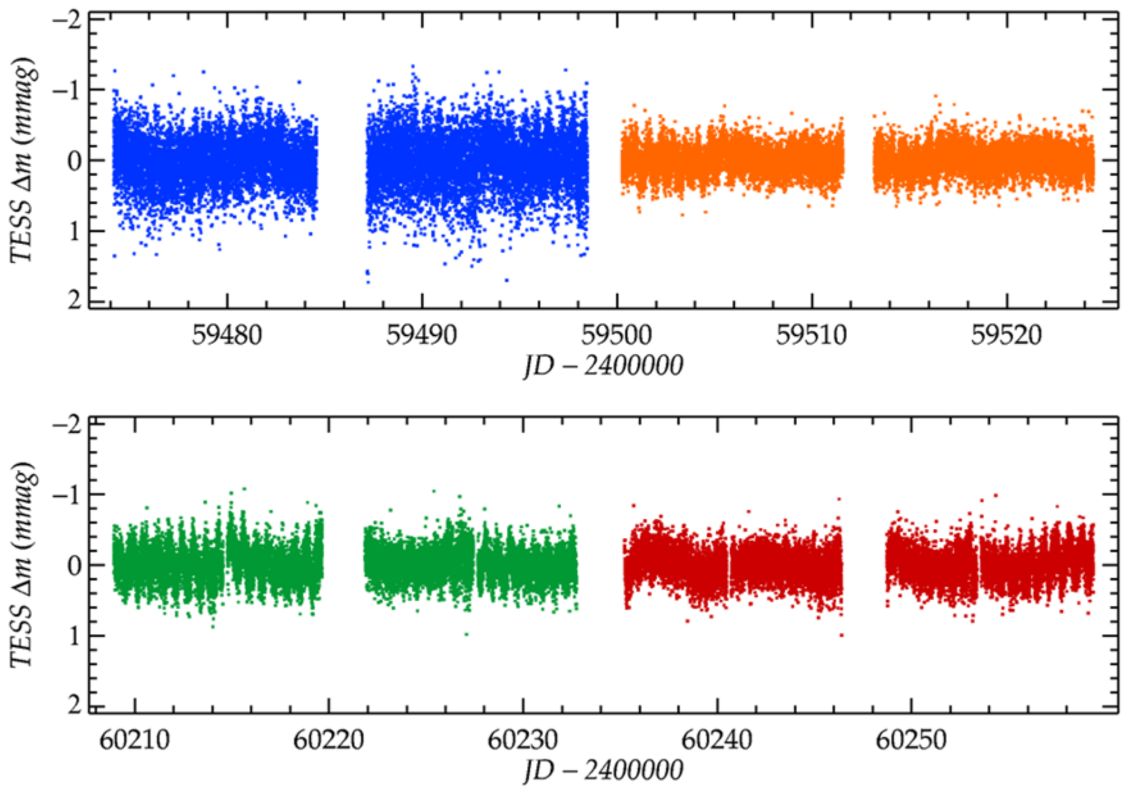

Figure 2: Epoch plots of the TESS data for Sectors 43 and 44 (top), and Sectors 70 and 71 (bottom). High frequency structure can be seen in parts of the light curve but is not always present. Longer-term trends can also be seen through most of the orbits and these can usually be traced to periods of high or rapidly changing background levels. Missing data and discontinuities near the mid-orbit point can be seen, most obviously in the lower panel.

Around this time the star was also observed by the Hipparcos mission, and although there was no evidence of variability, equally it could not be determined that the star was constant at better than $\simeq$ 5mmag. More recently V1116 Tau has been observed by both the Transiting Exoplanet Survey Satellite (TESS) (Ricker et al., 2015) and *Kepler* mission (Borucki et al., 2010). The star was observed by TESS in Sectors 43 and 44 between September and November 2021 and in Sectors 70 and 71 between September and November 2023, all at the 2-minute cadence. The data were downloaded from the MAST archive at the STScI. The SPOC pipeline PDCSAP photometry was used as this is better background corrected than the SAP variant, and provided over 60000 data points. Each sector is observed over two 13.7-day orbits, but with a day lost each orbit for data download, so the observations consist of two, nearly continuous runs of about 50 days, as shown in Fig. 2. Even at this scale, high-frequency structure can be seen in the light curve, but there are also small, longer-term trends through most of the orbits. These tend to be largest at the ends of the orbits and can usually be traced to periods of high or rapidly changing background levels due to scattered light. Similar issues also occur near the mid-orbit point, and in some cases missing data and discontinuities can be seen, particularly in the second set of observations. It is also possible to identify sections of the light curve where the high-frequency variation is not present.

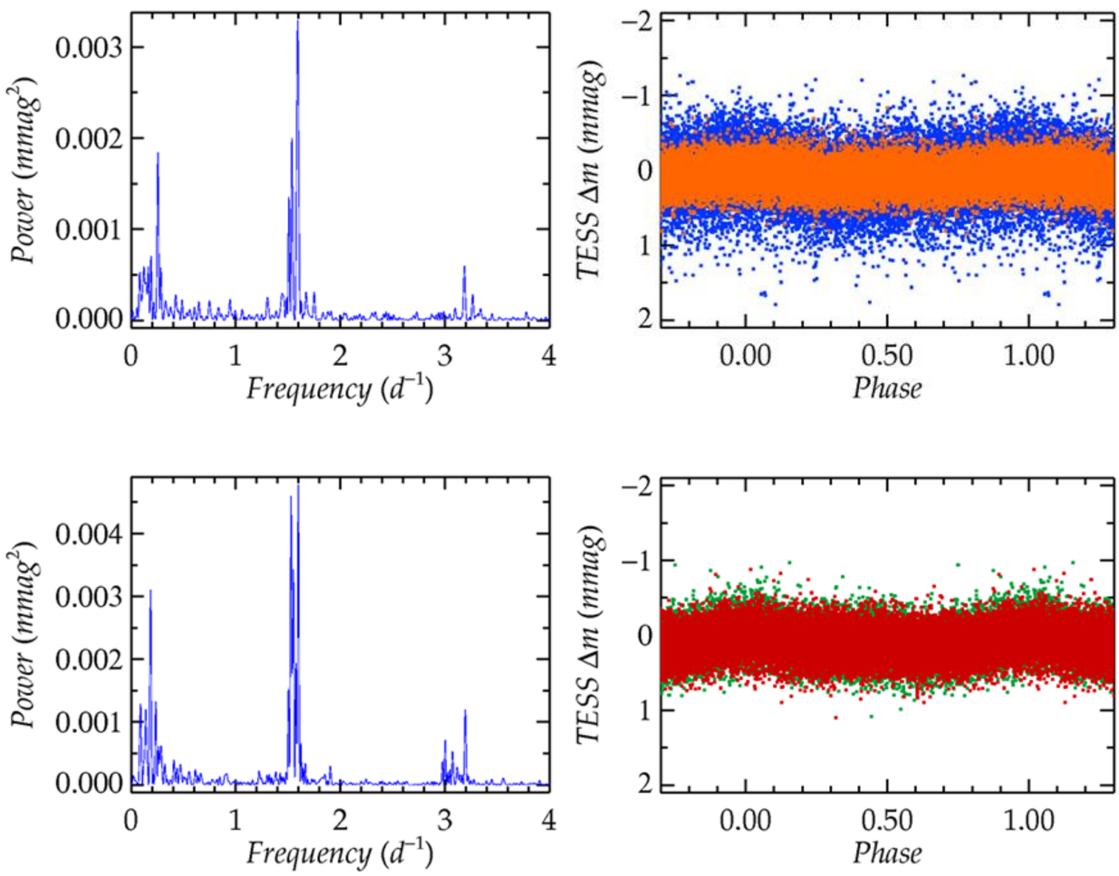

Figure 3: The left-hand panels show the DFTs of TESS Sectors 43 and 44 (top) and 70 and 71 (bottom). The signals at low frequencies are probably spurious and due to the incomplete removal of the complex background variations. The main features at $f \simeq 1.55$ d^{-1}, are not stable and the weak features at twice this frequency near $f = 3.2$ d^{-1} are likely associated. The right-hand panels show the phase diagrams of the corresponding data folded on $f = 1.593$ and 1.599 d^{-1}. The same symbols are used as in Fig. 2

Potential periodicity has been investigated through the Discrete Fourier Transform (DFT) periodogram, and these are shown in the left-hand panels Fig. 3 for the two contiguous runs of Sectors 43 and 44, and Sectors 70 and 71. Significant features appear at low frequencies, with $f < 0.3$ d^{-1}, also in a small range near $f = 1.55$ d^{-1}, with some weak features near $f = 3.2$ d^{-1}. No other significant features appear out to 50d^{-1}. The low-frequency features are probably spurious and are due to the limitations in removing the background signal, but of course these could also mask any real variations in this range. The features at $f \simeq 1.55$ d^{-1} are very significant, and appear in independent data sets, plus features near twice this frequency also appear. The dominant features range between $f = 1.51 - 1.59$ d^{-1} and a component at $2f$ is likely. The structure seen in the periodogram could be due to either multiple frequencies or a single frequency moving with time. Periodograms of the individual orbits obviously restrict the time range, but also limit the frequency resolution, so these tend to show a single frequency, of varying position and width, and in two cases with a weak side lobe.

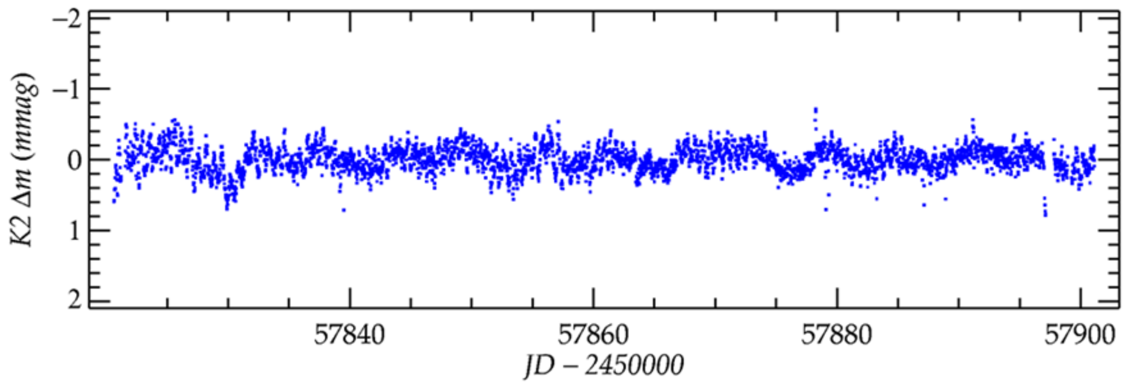

Figure 4: Epoch plot of the K2 long-cadence data. The light curve is dominated by coherent trends on a time scale of 2–5 days that are most likely remnants of the incomplete removal of the sharply varying background.

Also, the individual periodograms show a wide range of power, from 2–3 times that seen in Fig. 3, down to nearly zero, and this mirrors what can be seen in the light curves. The nature of the variation near 1.55 d^{-1} is not clear, but is does present in different data sets, and is clearly not stable.

The *Kepler* data were taken during the K2 mission extension (Howell et al., 2014) in SOP-13 from March to May 2017, covering 80 days almost continuously at the long cadence of 30 minutes. The data were downloaded from the MAST archive at the STScI. The short-cadence data are also available, but as provided they retain significant background contamination so were not used. The K2 long-cadence epoch data are shown in Fig. 4, and although the general scatter is less than the TESS data, the light curve is dominated by coherent trends on a time scale of 1–2 days. As with the TESS data, these are most likely remnants of the incomplete removal of the sharply varying background. In fact, the DFT of the K2 data is completely dominated by the low-frequency variations, so to suppress these it was necessary to filter the data by removing a 4-day boxcar moving average. The DFT of the filtered data is shown in Fig.5 together with the phase diagram folded at the best frequency. The same features that are present in the TESS data also appear in the K2 DFT, and the feature at $f \simeq 1.55$ d^{-1} is also shown some instability.

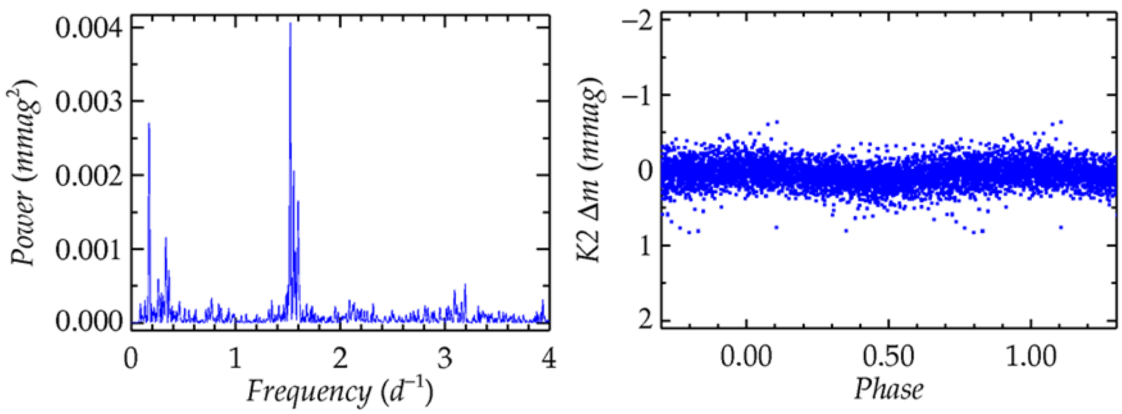

Figure 5: (Left) The DFT of filtered K2 data, and as with the TESS data the features at low frequencies are probably spurious and due to the incomplete removal of the complex background variations. The main features at $f \simeq 1.55$d^{-1}, are not consistent and the weak features around 2*f* are likely associated. (Right) The K2 data folded on the best frequency, $f = 1.52144(38)$ d^{-1}, and not the same as the TESS data.

In general, the features at $\sim 2f$ are weaker than in the TESS data. The K2 data have been fitted with a 2-harmonic Fourier series and gives the best frequency of f = 1.52144(38) d^{-1} and is shown in the right-hand panel of Fig. 5. The full amplitude is 0.127(7) mmag with an rms residual of 0.15mmag, so the variation is barely visible. The scatter is inflated by the unresolved low-frequency noise, which is the second most significant feature in the filtered data, and the variable frequency. The first overtone was included in the fit in an attempt to include some component of the signal $\sim 2f$, but this is very weak and only significant at the 2-sigma level.

Although V1116 Tau has been listed as a possible δ Sct star there is no sound historic evidence of any variability, and the limits are at least an order of magnitude larger than the variation found here. Krisciunas et al. (1995) considered it an unlikely candidate δ Sct star as it lies outside the extension of the Cepheid instability strip on to the main sequence, as defined in the Stromgren photometric system. Also, from the TESS and K2 data there is no significant variation in the δ Sct range of $f \sim 10$ – 40 d^{-1}. More precise stellar parameters are now available from *Gaia*, which give the distance d = 44.0 ± 0.2pc and essentially zero extinction. Slightly different calibrations of the Apsis processing chain provide $T_{\rm eff}$ = 6639 and 6672 K, M_G = 2.716 and 2.686, R = 1.85 − 1.86 $R_\odot$, and the Final Luminosity Age Mass Estimator (FLAME) processing gives the luminosity as $L = 6.037 L_\odot$. The temperature and luminosity place the star just on the cool edge of the empirical δ Sct distribution defined by Murphy et al. (2019) (see their Fig. 9 & 12), and just beyond the red edge of the theoretical limits (see e.g., Dupret et al., 2005) (see their Fig. 15). A very small fraction of δ Sct stars lie outside the boundaries, but V1116 Tau is unlikely to be one of them.

The other likely origin of the variations is rotation, possibly due to chromospheric activity, and although this is not common in early-type stars, 'solar-like' activity cycles are observed in a small number of A-type (Balona, 2013) and F-type stars (Mittag et al., 2019). The rotational velocities of main-sequence stars peak at about 200 kms^{-1} for the A-type stars and then through the F-type stars the distribution splits into the fast and slow rotators. The projected rotational velocity of V1116 Tau is measured as $v_e \sin i$ = 69 – 81 kms^{-1}, which places it among the fast rotators. Using the Apsis radius, a rotation period of $0^d.645$ would imply an equatorial velocity v_e = 144 kms^{-1}, and this compares with typical velocities for mid F-type stars of $v_e \sim 120$ kms^{-1}.

V1116 Tau is clearly variable, but at a very low level, and all the previous estimates of the upper limit provided no real constraint. The mean amplitude is 0.127(7) mmag, but this is not constant, and the variation is not exactly sinusoidal. The frequency is also unstable, but is restricted to $f \simeq 1.55 \pm 0.004$, although it is not clear if the frequency evolves in a continuous manner or if different frequencies in this range emerge then decay. The star is unlikely to be a δ Sct star as the frequency range is inappropriate and the form of the variability is also not consistent. Its location in the HR diagram also argues against it and excludes the γ Dor classification as well. Rotation seems to be the most likely origin of the variation as v_e is consistent with the period of $0^d.645$, but this requires some, probably chromospheric features on the surface. However, these will need to change on a time scale of tens of days to produce the frequency variations. Although there is no direct evidence to suggest that the star is a binary, Douglas et al. (2014) consider it as a possibility.

The author is pleased to acknowledge use of NASA's Astrophysics Data System Bibliographic Services. This research has made use of the SIMBAD database and the VizieR catalogue access tool operated at CDS, Strasbourg, France. The authors gratefully acknowledge use of the AAVSO Variable Star Index (VSX). This paper includes data collected by the TESS and *Kepler* K2 mission, which are publicly available from the MAST data archive at the Space Telescope Science Institute (STScI). Funding for the TESS and K2 missions are provided by NASA's Science Mission directorate. STScI is operated by the Association of Universities for Research in Astronomy, Inc., for NASA.

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Eclipsing Binary News

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Zeta Aurigae - 2025 Eclipse

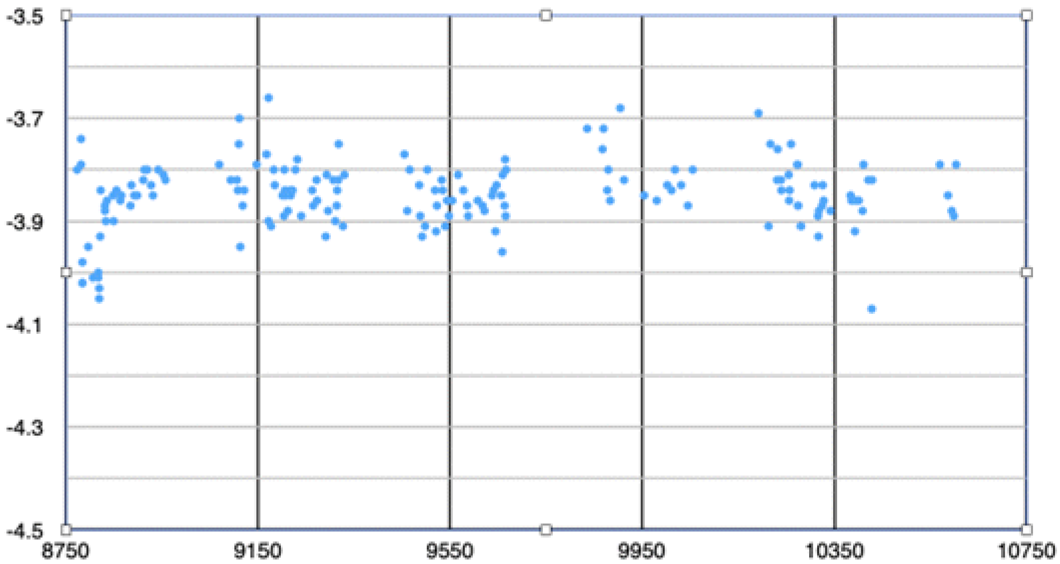
Conditions in 2025 will be favorable for observing this eclipse.

Zeta Aurigae is a well-known eclipsing binary which has a period of 972 days. The eclipse lasts about 37 days and is somewhat unusual because a small very hot blue star passes behind a red supergiant star. Ingress and egress last about 1.5 days. There are no sharp boundaries to the eclipse as the smaller star continues to shine, during ingress and egress, through the tenuous outer atmosphere of the larger star.

The midpoint of the 2025 eclipse is scheduled for 11th March 2025 which means that ingress will be around 21 February and egress around 29th March. Out of eclipse magnitude has been found to be 3.75V. The eclipse magnitude is 3.99V.

There are differing views of the depth of the eclipse. GCVS states it to be 0.27V and Krakow 0.6V. In the 2009 eclipse the depth was found to be 0.15V. In 2017 the depth was found to be 0.22V.

The eclipse is a good target for DSLR photometry. V magnitude measurements are the most useful as it allows international measurements of the eclipse to be combined. I use Eta Aurigae as a comparison with the Hipparcos value of 3.18 as the V magnitude. As I use a Canon 550D DSLR the magnitude I measure needs to be corrected to arrive at a V magnitude for Zeta Aurigae. The transformation coefficient for this Canon model is 0.08. This is multiplied by the difference in (B-V) between the two stars. The difference is 1.302 which multiplied by 0.08 comes to 0.104. This is the correction that needs to be applied to each measurement. On the 19/10/24 I measured zeta Aurigae at 3.892 magnitude. The correction was added to give a V magnitude of 3.788.

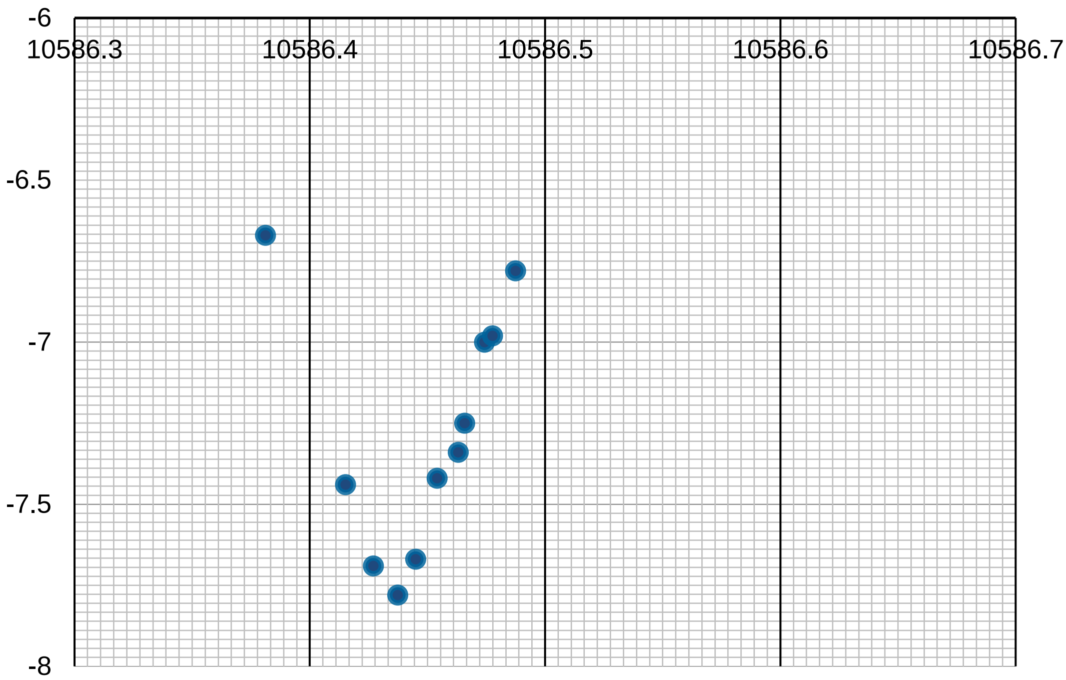


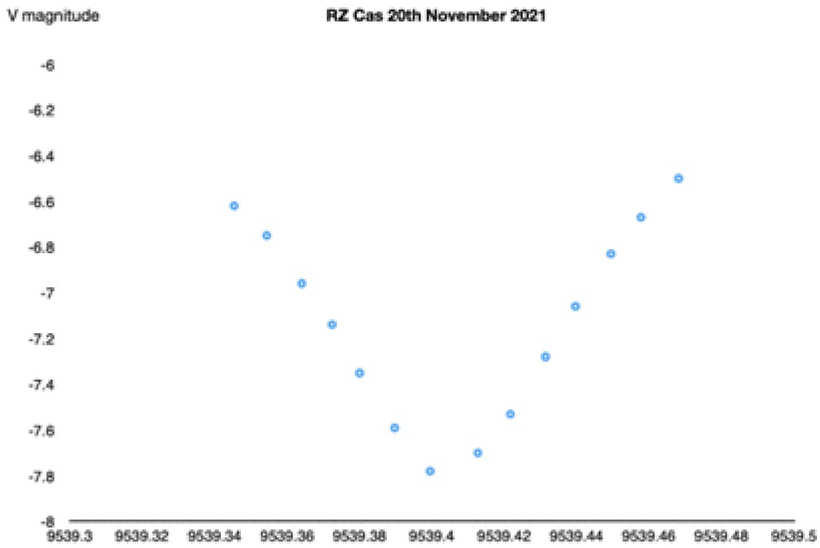
One of the challenges in observing this eclipse is that the primary star of the zeta Aurigae system seems itself to be a variable star. This is, perhaps, not surprising as it is a red supergiant. Here are my measurements of zeta Aurigae (above) over a 900-day period. It can be seen that zeta Aurigae seems to vary between magnitude 3.7 and 4. The variation may account for the different official findings of the depth of the eclipse. The bottom axis is Julian Date between 2458750 and 2460750.

An eclipse of RZ Cas on 2nd October 2024

Measurements of the eclipse were obtained by DSLR photometry. The measurements are reproduced in the diagram below where V magnitude is the vertical axis and Heliocentric Julian Date is the horizontal axis. The HJD date is 2460586. The measurements can be compared with those obtained on 20th November 2021. Both eclipses have V shaped profiles which indicates a partial eclipse. The timing of mid-eclipse in 2021 showed that the difference between the observed time and the predicted time was 18.9 minutes early. On the 2/10/24 the predicted time was HJD 2460586.457 The actual time was 2460586.435. The eclipse was 31.7 minutes early. This seems to confirm the trend that the period is shortening. We do seem to be getting to the point where the elements of RZ Cas need to be revised so that accurate predictions can be made.

RZ Cas is a system that continues to be of interest to professional astronomers. This abstract indicates the reasons for this interest.





HJD 2459539.

Predicted Mid primary eclipse = 2459539.4171

Observed Mid Primary Eclipse = 2459539.404

Measurements by DSLR Photometry. Each point on the graph represents the analysis of a stacked image derived from 20 images.

The O'Connell effect

Well known amongst Eclipsing Binary observers, the O'Connell effect is an apparent asymmetry in the maximum brightness of the binary system between eclipses. The phenomenon is visible in short period, close binary systems. The effect is named after Daniel Joseph Kelly O'Connell, of Riverview College in New South Wales, who made studies of the phenomenon during the early 1950s.

The AAVSO have produced a target list of 256 stars for observers to monitor, and a web page giving further information on the phenomenon. The web page can be found here, and the target list, in .CSV format, can be downloaded here or from the web page mentioned above.

Recent minima of various Eclipsing Binary stars. 9

Tony Vale

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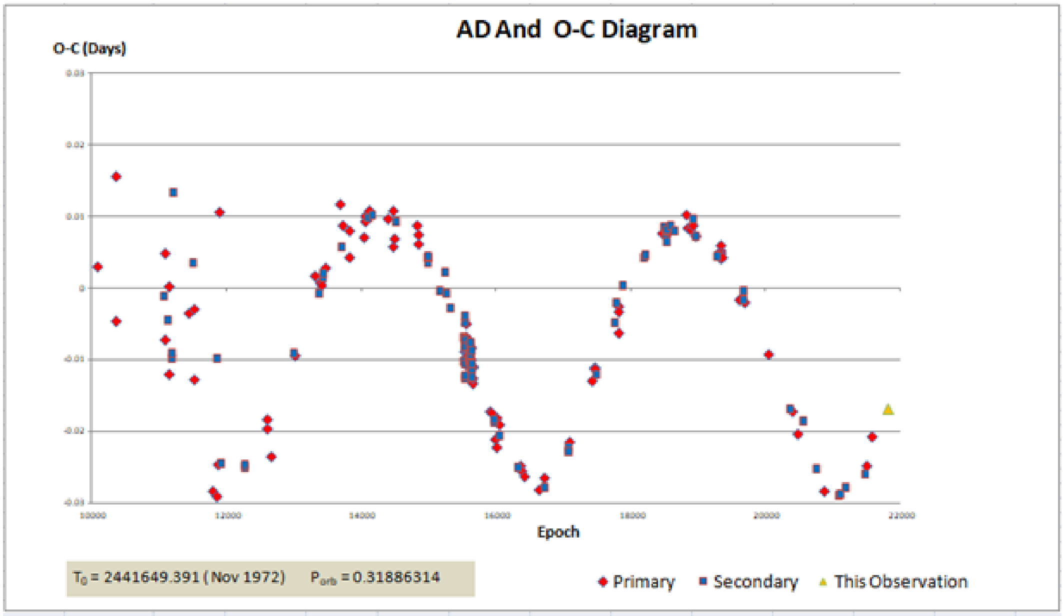
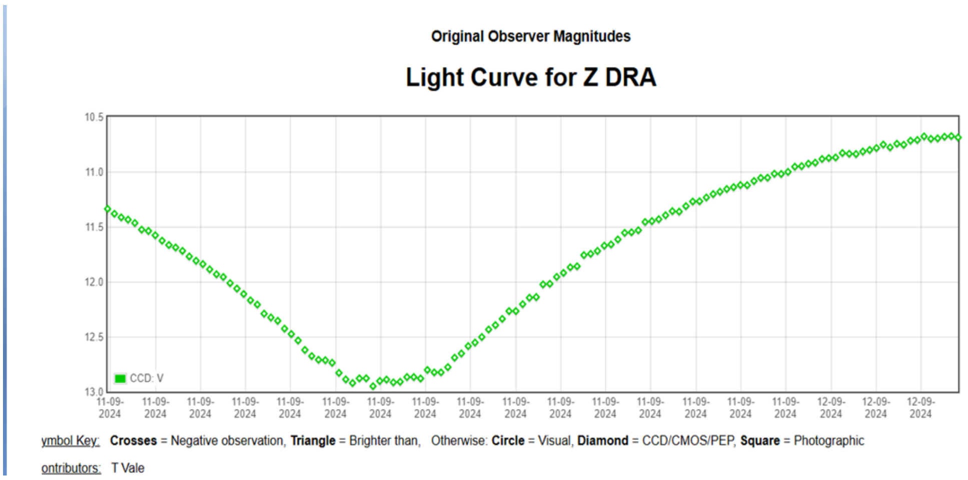
This report lists recent timings of minima of various eclipsing binaries. The observations from which the timings were obtained have all been posted to the BAAVSS and the AAVSO photometric databases.

Star	HJD of Min	Filter	Error	Type of Minimum
NU Uma	2460450.47662	V	0.0005	Secondary
ZZ Cyg	2460482.46266	V	0.0002	Primary
DK Cyg	2460502.51467	V	0.003	Primary
V704 Cyg	2460524.49297	V	0.00105	Primary
AD And	2460534.49234	V	0.0006	Primary
SW Lac	2460539.47454	V	0.0001	Secondary
SV Cam	2460547.50240	V	0.0005	Primary
V608 Cas	2460552.45790	V	0.00119	Secondary
Z Dra	2460565.42958	V	0.0003	Primary
V608 Cas	2460570.52575	V	0.0002	Primary
CW Cas	2460601.56219	V	0.0004	Primary
V765 Cas	2460603.65336	V	0.002	Secondary
PV Cas	2460604.59527	V	0.0005	Primary
AM Her	2460605.40022	V	0.0006	Primary

The observations were obtained from May to October 2024 using a 102mm refractor and an ASI 183MM-Pro cooled mono CMOS camera. The timings were extracted using Bob Nelson Minima software. In past reports, I have used the O-C Gateway of the Czech Astronomical Society to plot my observations both as a sense check and to illustrate the various O-C diagrams. However recently, following an update of the database this facility no longer seems to be available. Instead, I have decided to rely on the data from the Nelson Database of Eclipsing Binary O-C Files (https://www.aavso.org/bob-nelsons-o-c-files) and draw charts using Excel. The database is maintained by the AAVSO and updated a couple of times a year. It is the only database I can find that includes the Times of Minima which have been published in the Circular.



As well as the eclipsing pair, the AD And system has a third, unseen component resulting in the sinusoidal curve in the O-C diagram caused by the light time travel effect as the eclipsing pair approaches and recedes from us every 12 years or so. The time of minimum listed above is shown as the yellow triangle on the O-C diagram.



Z Draconis is an Algol type eclipsing binary. Its O-C diagram is highly irregular with many changes of gradient as the system spins up or down. Mass transfer between the components or mass loss from the system might explain spinning up or spinning down but period reversals would require sudden changes from one mechanism to another and are more difficult to explain.

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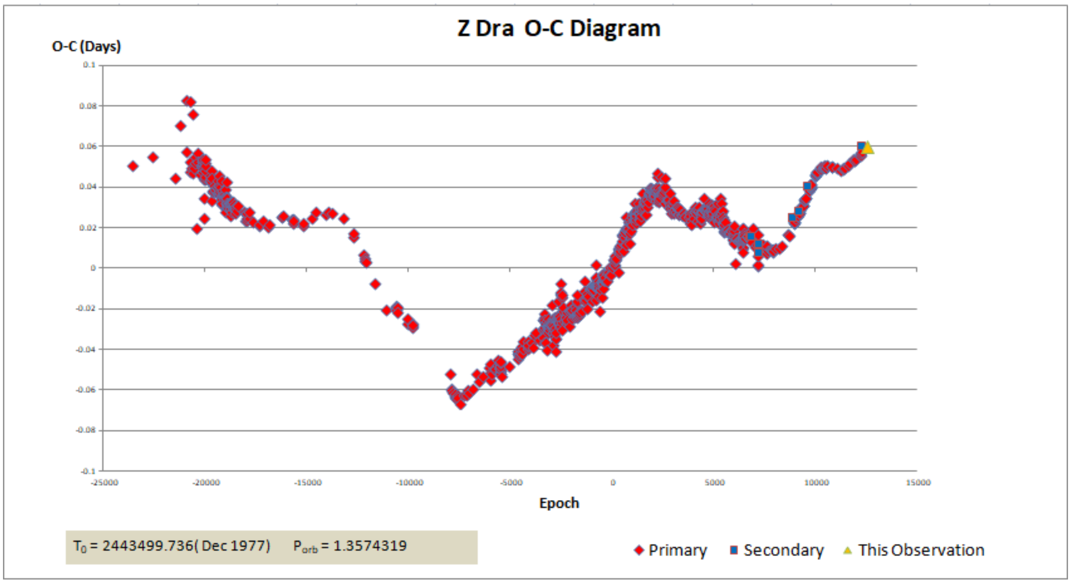
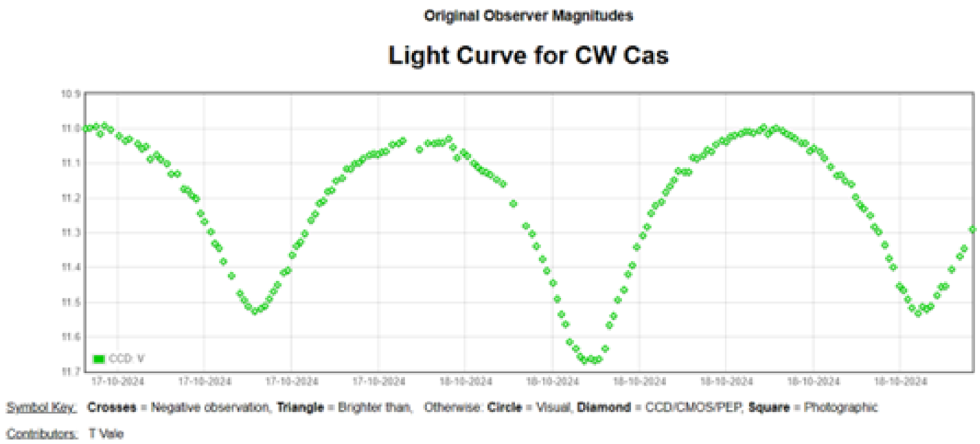
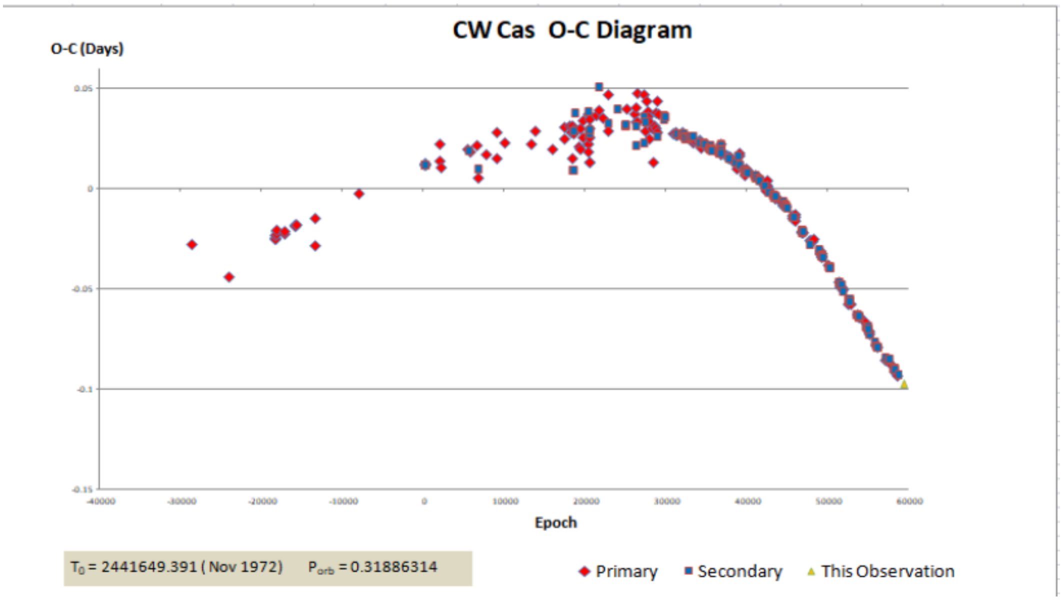


The observation of CW Cas was made on the night of 17th to the 18th October from Andalucia in Spain. It required over 10 hours of clear sky, something which has rarely happened recently in the UK. It shows a primary and two secondary eclipses. The first and third maxima reached magnitude 11.0, the second, a little less. This might be the because of chromoshperic activity or starspots. At maximum the stars are side by side (see the representation of the system below). If there are more starspots visible on one side than the other then when that side is earth facing, the associated maximum could be dimmer than the other. CW Cas is an EW Uma type eclipsing binary and chromoshperic activity is a characteristic of these systems. The Primary minimum is shown as the yellow triangle on the O-C diagram.

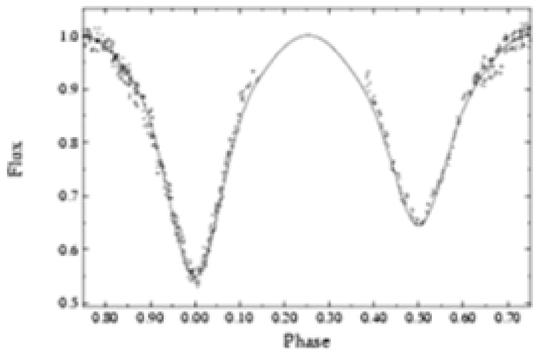


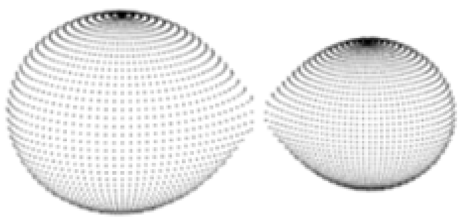


The Catalogue and Atlas of Eclipsing Binaries (CALEB, https://caleb.eastern.edu/) includes the following phase diagram and a representation of the CW Cas system.

CW Cas

Pribulla2001 - Pribulla2001V (Johnson V)





New observations of three eclipsing binaries in Coma Berenices.

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Three EW/KW contact eclipsing binaries (RW Com, SS Com and CC Com) were observed with the Open University COAST telescope in order to determine the shapes of their light curves, with a view to determining their times of minima at later dates from my home observatory.

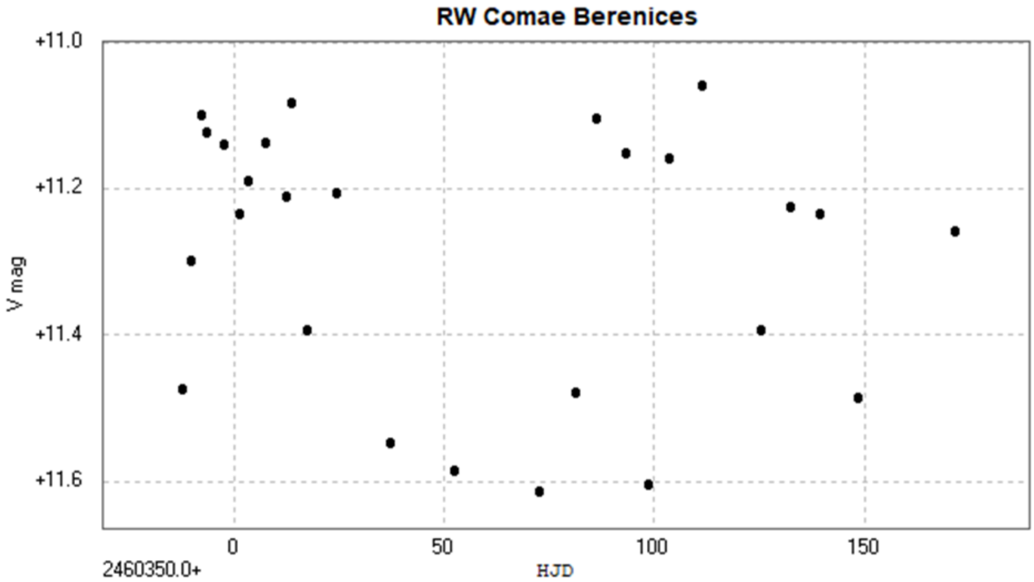
Observations of three eclipsing binaries in Coma Berenices – RW Com, SS Com and CC Com – which I have not previously observed. All observations were made with the Open University COAST telescope in Tenerife, a 17”/42cm corrected Dall-Kirkham, using a V filter.

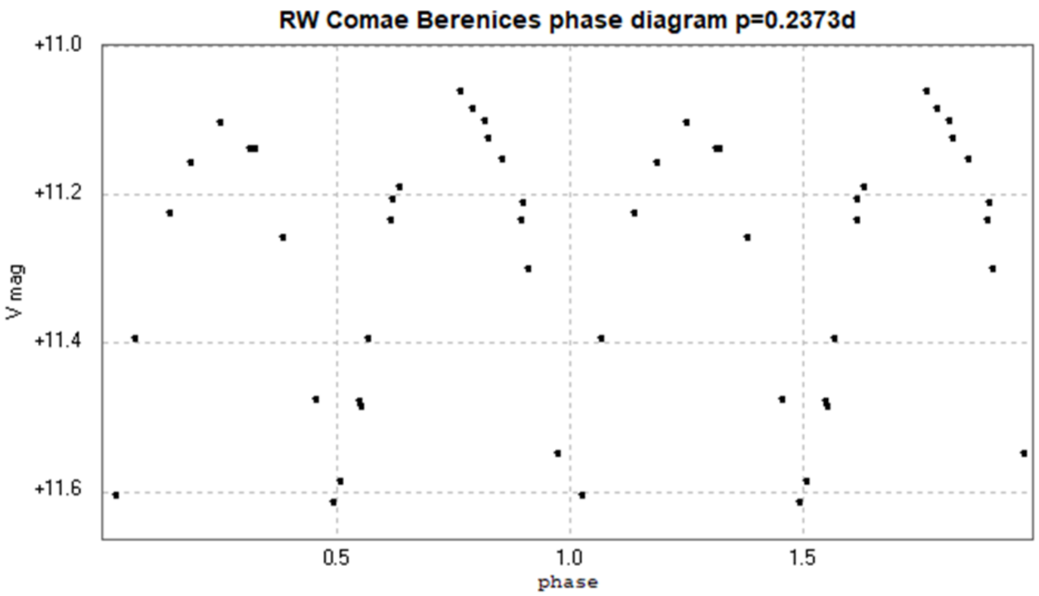
Each of the three systems is listed in the GCVS as an EW/KW type eclipsing binary, where the KW designation applies to EW type eclipsing binaries which are in contact with each other (see GCVS reference). There is also considerable O-C activity with each system, as described in the related *Kreiner* links, and discussed below.

Although Mount Teide is a world class observing site the weather is often windy, cloudy or foggy and not always conducive to observations, hence the relatively low number of observations made during this period.

RW Comae Berenices

Light curve and phase diagram of RW Comae Berenices / RW Com constructed from photometry of 26 images taken between 2024 January 28 and 2024 July 29.



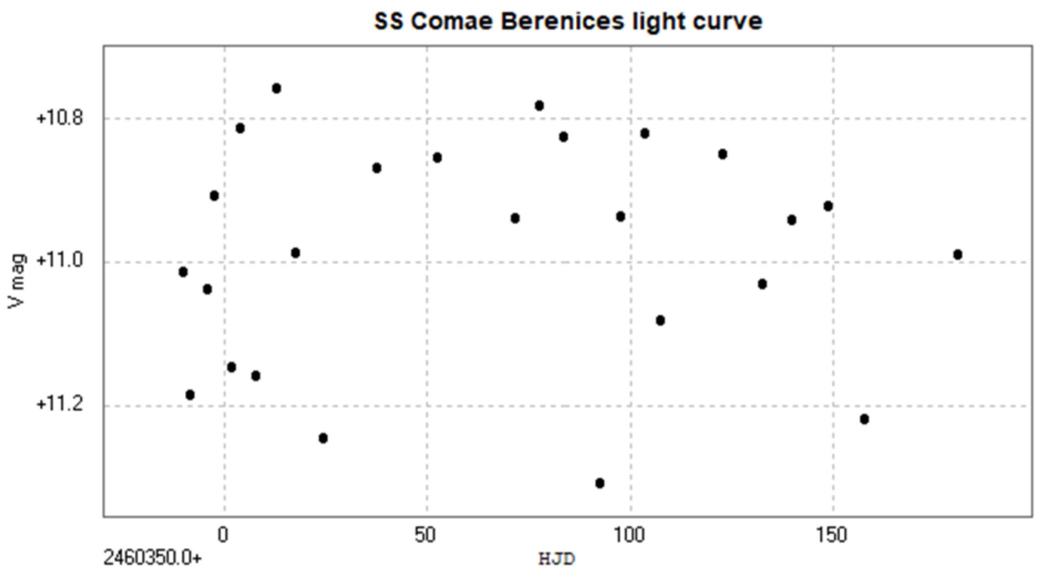


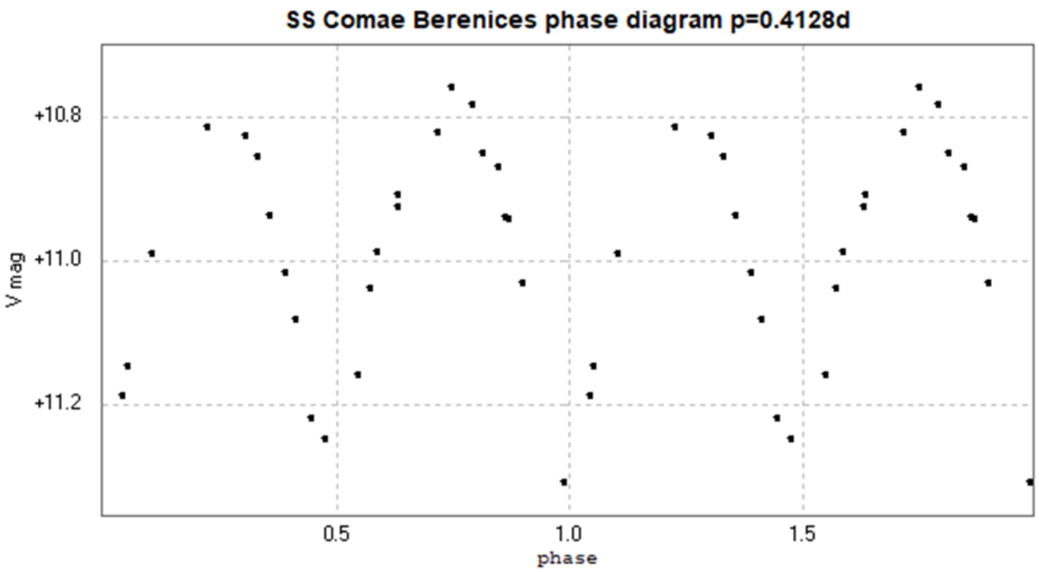
The catalogue value for the period of this system is 0.2373459d (GCVS) and 0.23734706d (AAVSO VSX), accessed 2024 November 12. There is considerable O-C activity with this system (Kreiner).

SS Comae Berenices

Light curve and phase diagram SS Comae Berenices / SS Com.

The plot is made from 25 observations made between 2024 January 30 and 2024 August 7.



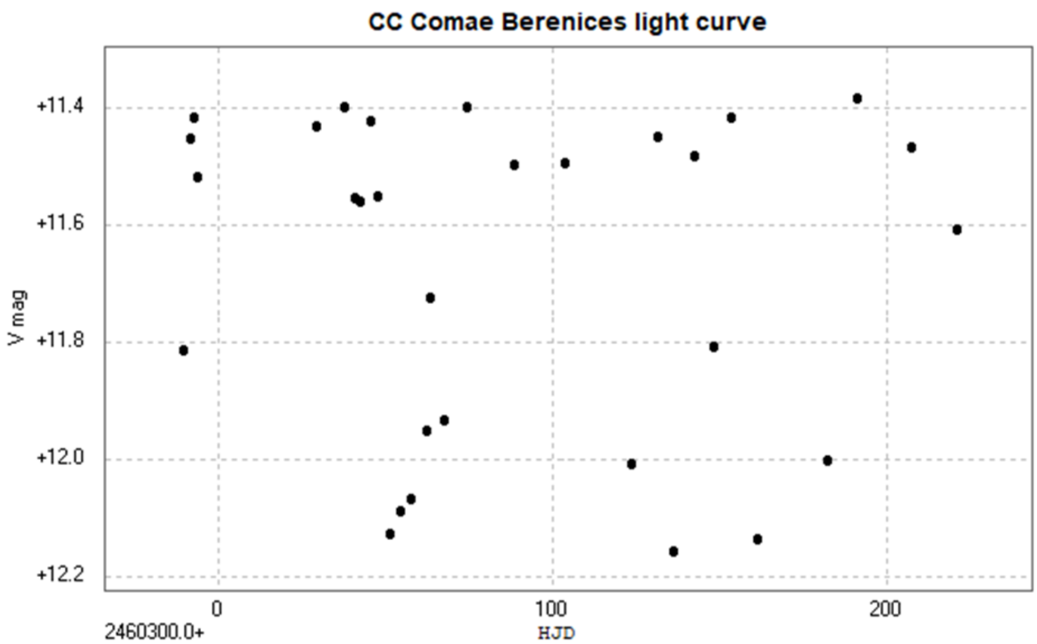


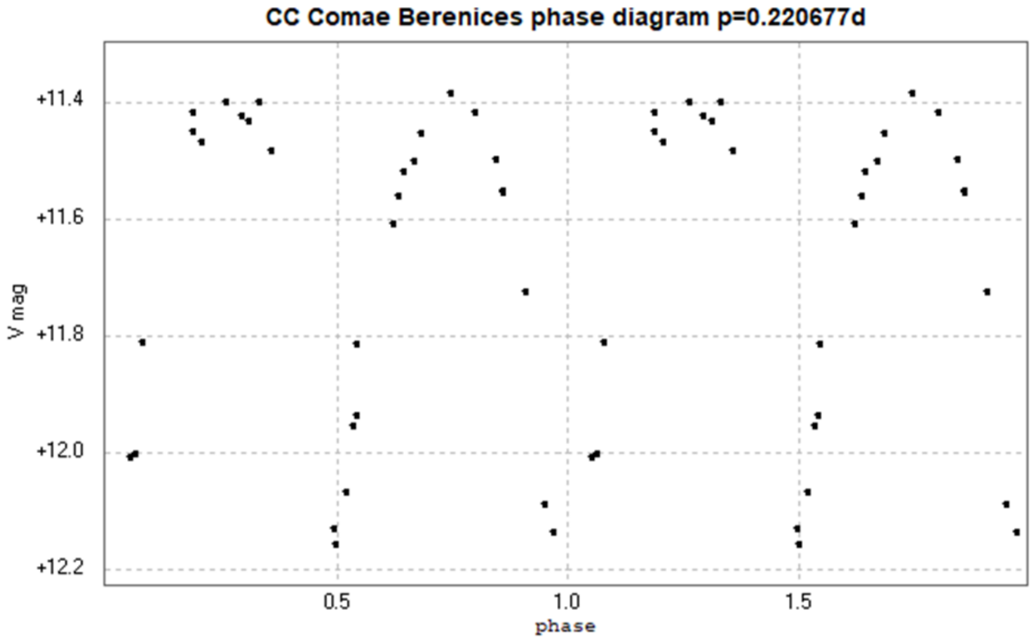
The catalogue period for this star is 0.4127919 days (GCVS) and 0.412822 Days (AAVSO VSX), accessed 2024 November 12. There is considerable O-C activity with this system (Kreiner).

CC Comae Berenices

Light curve and phase diagram of CC Comae Berenices / CC Com.

The plot is made from 30 observations made between 2024 January 21 and 2024 July 29.



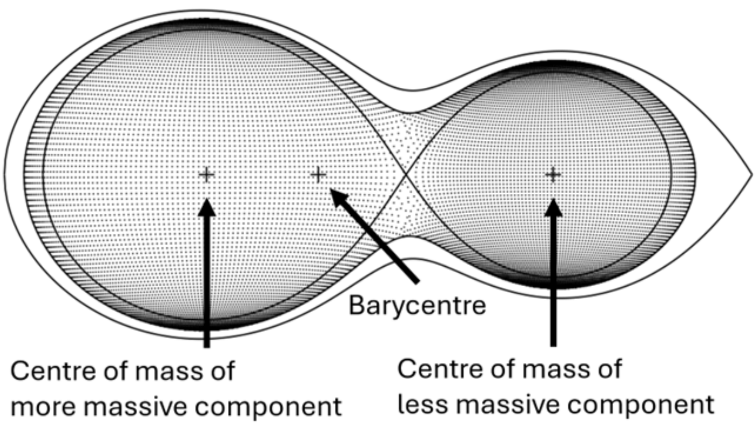


The catalogue period for this star is 0.22068628 days (GCVS) and 0.2206864 days (AAVSO VSX), accessed 2024 November 12. There is considerable O-C activity with this system (Kreiner).

Discussion

The references discuss observations made of these three systems and model the changes to their periods over time. They are all 'over-contact' systems, where both the components of the system expand beyond their inner Roche lobes and the two stars share a common atmosphere bounded by a dumbbell-shaped equipotential surface. The changes to the periods are due to mass transfer from the less massive component to the more massive component.

The following figure is a Binary Maker 3 model of CC Com (using data from *Bradstreet, D. & Steelman,D. 2002*) illustrating the general structure of these systems, including the inner and outer Roche lobes.



Observations will continue to be made of these systems; from Mt Teide to generate more accurate light curves, and with the 2" Titan from my home observatory to determine times of minima.

References

1 Yang, Y., & Liu, Q., Period Changes of Two W UMa–Type Contact Binaries: RW Comae Berenices and CC Comae Berenices. Publications of the Astronomical Society of the Pacific, 115:748–754, 2003 June.

2 Qian, S.-B., Zhu, L.-Y., BO CANUM VENATICORUM AND SS COMAE BERENICES: A PHOTOMETRIC STUDY OF AW UMa–TYPE BINARIES. The Astronomical Journal, 131:1032–1043, 2006 February.

3 Bradstreet, Binary Maker 3.

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