



Dr Tom Richards with his 16" RC scope and Astro-Physics AP-1200 GEM mount which is now for sale. Tom is not giving up variable star work, just observing, and will now concentrate on analysis. See Tom's note on page 29 of this issue for more details.

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From the Director – *Mark Blackford*

From the director.... *Mark Blackford*

Welcome to the first edition of the Newsletter for 2024, a bumper issue with excellent articles by Mati Morel, Tom Richards, Rod Stubblings and Simon Sikora, as well as my own contribution. Also, Dan Homer introduces his upcoming photobook highlighting amateurs who make major contributions to pro-am collaborations. Dan stayed at my place in October 2022 during the Australian leg of his photo-shoot tour. He visited several VSS members and other prominent amateur researchers in Victoria, NSW, ACT and Queensland. I am looking forward to seeing the finished product.



In the previous Newsletter I announced that VSS would be holding a symposium on Good Friday, prior to the NACAA XXXI meeting. Unfortunately, I have had to cancel the symposium for a couple of reasons. Firstly, I will not be able to be in Parkes over the Easter weekend due to family visiting from overseas. But the more disappointing reason is the low number of speakers offering to give presentations. I thank those people very much and will explore the possibility of holding a Zoom meeting later in the year like the one held in 2022.

The NACAA meeting itself is definitely going ahead with an exciting program of talks and panel sessions. The programme can be found at <https://nacaa.org.au/2024/programme>, with several VSS members

giving presentations. There will also be a panel session on Getting Started in Observing Variable Stars on the Saturday. I will co-chair the session (via Zoom) with Roy Axelsen and Peter Williams. Questions will be fielded from the live audience, but it would be good to have requests in advance so we can prepare appropriate responses. Please contact me directly or through the VSS email group.



In another development our editor, Phil Evans last year advised me privately that this year will be his last producing the newsletter. I would like to encourage one of our members to offer to continue the newsletter in 2025. Phil assures me he will provide any assistance a new editor might need.

Summer observing conditions have been terrible at Congarinni Observatory, with only 4 clear nights in December. At least my water tanks are full.

In this column in the previous Newsletter, I mention buying a new telescope for my bright star photometry rig. Well, my wife relented with surprisingly little resistance, so I order a Williams Optics RedCat51 F4.9 Petzval APO refractor. This is a beautiful little scope with excellent imaging capabilities and field of view of 5.4 deg by 3.6 deg with the ZWO ASI2600mm-pro CMOS camera. I'm looking forward to using these to monitoring bright variables, however, a thunderstorm and high winds on Christmas night caused significant damage to my observatory roof (again!). So, I will be out of action for a few months while a new roof is designed and installed.

Wishing you all clear skies and good health,

Mark Blackford

Abstract

An historical lightcurve for S Dor is presented, compatible with the modern B scale. A dataset of 93 mean magnitudes from Gaposchkin (1943) is used after adjustment from the old IPg system to B. A zero point error is corrected, while discussing other general aspects of S Dor.

Basic data: S Dor and companion

S Dor : (J2000) 05 18 14.357 -69 15 01.15 G=9.401, BP=9.511, BP-G= 0.110, Sp = B8eq-F0 lae
Comp. 05 18 16.678 -69 15 05.65 G=12.40, BP=12.285, BP-G= -0.118, Sp. = B0 I

Sourced from Gaia EDR3.

VSS,RASNZ ref: Chart 906, with visual sequence, date 11.06.88. [SL360 is actually OC SL371].

Observational history

First noted as having an unusual spectrum by Pickering (1897). Spectral lines H β , H γ and H δ bright. Also variable. Named S Dor in 1904, and appears in the 2nd **Catalogue of Variable Stars** (Cannon 1907) as an irregular variable.

A photographic sequence of eight comparison stars was published by Fleming (1907). Star “b” in her sequence was actually a compact star cluster SL 371. Because of the small-scale plates used in those days an unresolved star cluster could emulate a bright star and could justifiably be used for comparison purposes. However the magnitude scale in Fleming’s sequence was, by later standards, poorly calibrated, being far too bright by one magnitude. For at least 50 years there was no regular monitoring of S Dor using a reliable magnitude scale, although photographic plates continued to be taken regularly of the LMC and archived at Harvard Observatory.

It was always assumed that S Dor was a member of the LMC, but actual proof was problematic. The broad emission spectrum (P Cyg-like profile) meant that the old objective prime spectra were not suited to measurement of radial velocity. Any lingering doubts were dispelled by Wesselink (1956) who used a spectrograph attached to the 74-in Radcliffe reflector in South Africa. He determined that the RV is +295km/s, consistent with LMC membership. After 1950 the standardized photometry that started to appear in professional papers was tied to a modern system, such as the Cape “S” whose SPg and SPv magnitudes could be converted to Johnson-Morgan BV magnitudes. However, a check of the AAVO’s Light Curve Generator reveals **no** data in the database, and only a few scattered observations appear after about 1987.

Gaposchkin’s lightcurve

Sergei Gaposchkin (1943) made a study of S Dor, based on 1120 archival plates in the Harvard collection. A complete set of photographic magnitudes, plate by plate, was published in the *International System (IPg)* then in use. He found four deep minima - 1891, 1900, 1930 and 1940 - which he associated with eclipses of a 40-year period. This model has since been refuted. Nevertheless Gaposchkin’s work has provided a detailed set of data over a 50-year interval which was previously neglected. He also lists four main comparison stars, in the IPg system. Unfortunately his sequence has a significant zero-point error. This was first pointed out by Lourens (1964), noting that the IPg values differed from the Cape SPg system by as much as 0.79mag. Gaposchkin’s magnitudes were far too bright, as shown in the following Table 1. The corresponding magnitudes in different systems, IPg, SPg and B, are easily compared.

My work corroborates the zero-point error already noted by Lourens.

Table 1. *Gaposchkin Comparison Stars for S Dor.*

Star	RA	Dec (J2000)	HD	IPg	SPg	B	Remark
a	05 11 28.20	-69 32 45.7	34437	8.31	9.10	9.16	K5 III
b	05 18 11.30	-69 13 04.0	35342	8.80	---	9.75*	SL371, OC. Adopted B mag.
c	05 25 38.44	-69 35 43.9	36436	9.02	9.56	9.67	F8 V
d	05 17 56.07	-69 16 03.8	269321	9.98	10.7	10.78	LMC V1941, 10.37-10.87V

Conversion table

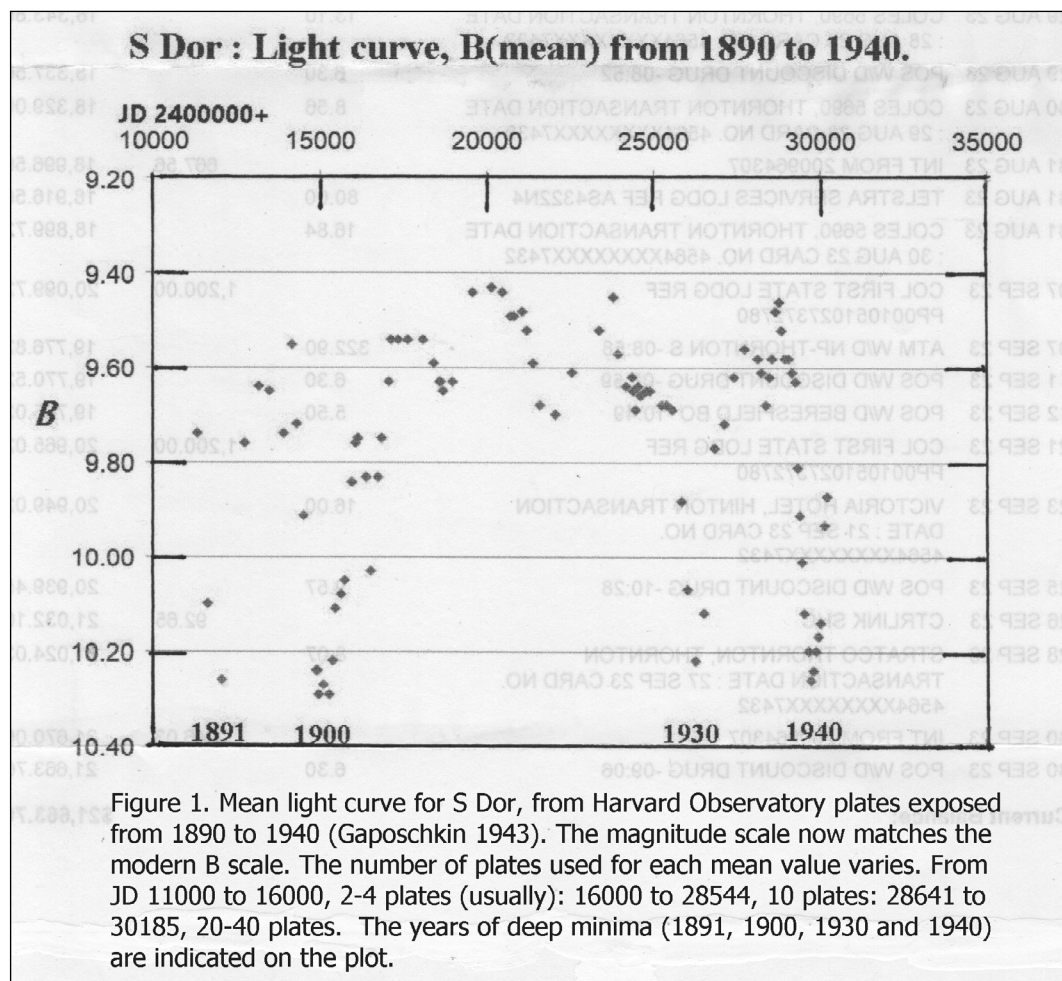
I plotted a graph (figure 1) using IPg means and modern B. Notwithstanding the slight variability of star “d” I adopted a mean value of 10.78B. In the modern era star “b” is of limited value for comparison purposes. It came down to assuming that the slope between “a” and “d” is a straight line. From the plot I read off each equivalent value of B, at intervals of 0.1mag. A condensed table is given here.

IPg	B	B-SPg
8.31	9.16	+0.85
8.50	9.35	+0.85
9.00	9.83	+0.83
9.50	10.31	+0.81
10.00	10.80	+0.80
0.50	11.29	+0.79

I expect that the application of a simple correction to IPg magnitudes will not introduce any additional errors. It will not negate the internal errors/variations which already arose in his methodology. A glance at his Table 1 observations shows that his repeat estimates of the same plate are usually in good agreement, but in other instances the variations can be up to 0.4 or 0.5mag.

Conversion to B

For the purpose of creating an adjusted light curve I have chosen Gaposchkin’s Table 4, a list of 93 means. S Dor is a variable whose type is not expected to show rapid variations from day to day or plate to plate. It made more sense to collect the results from a number of epochs and to determine the means. My adjusted results are listed in Table 2. Each IPg magnitude has been converted to B. The number of plates in each mean is included, as “N”. From this file a light curve has been created. See Figure 1.



From inspection of the data the extremes of mean magnitude are:

$$\text{Max}_{\text{mean}} = 9.43\text{B JD } 24020136$$

$$\text{Min}_{\text{mean}} = 10.29\text{B JD } 24015270$$

According to Gaposchkin the average of 1287 estimates, while near maximum brightness, was IPg = 8.78 (=9.62B). while his average value near deep minimum was IPg = 9.42 (=10.24B).

Lourens (1964), using the Cape “S” system. had also concluded that the brightest magnitude attained by S Dor was 9.26SPg, and that it had never exceeded 9.2SPg for the whole range of epochs studied, by Gaposchkin and also plates from Cape and Radcliffe.observatories.

Table 2. Corrected B mags. (mean) for S Dor. Adapted from Gaposchkin (1943). N = no. of plates.

JD	Mag.			JD	Mag.			JD	Mag.			JD	Mag.		
2400000+	B	N		2400000+	B	N		2400000+	B	N		2400000+	B	N	
11313	9.74	2		16744	9.83	10		23790	9.45	10		28453	9.62	10	
11624	10.10	3		16832	9.75	10		23944	9.57	10		28544	9.58	10	
12044	10.26	10		17050	9.63	10		24171	9.64	10		28641	9.48	30	
12713	9.76	2		17111	9.54	10		24338	9.62	10		28738	9.46	30	
13147	9.64	3		17320	9.54	10		24386	9.65	10		28834	9.52	30	
13487	9.65	2		17600	9.54	10		24448	9.69	20		28923	9.58	30	
13911	9.74	2		18074	9.54	10		24520	9.64	20		29043	9.58	30	
14161	9.55	1		18408	9.59	10		24610	9.66	20		29153	9.61	30	
14300	9.72	1		18580	9.63	10		24778	9.65	10		29232	9.63	30	
14516	9.91	3		18610	9.63	10		24900	9.65	10		29320	9.81	20	
14894	10.24	3		18675	9.65	10		25222	9.68	10		29373	9.91	20	
14922	10.24	10		18975	9.63	10		25372	9.68	10		29443	10.01	30	
14965	10.29	6		19578	9.44	10		25573	9.69	10		29540	10.12	40	
15089	10.27	1		20136	9.43	10		25835	9.88	10		29655	10.20	20	
15270	10.29	8		20457	9.44	10		26028	10.07	10		29750	10.26	30	
15372	10.22	1		20700	9.49	10		26283	10.22	10		29821	10.24	20	
15465	10.11	1		20798	9.49	10		26526	10.12	10		29870	10.20	20	
15646	10.08	4		21045	9.48	10		26848	9.77	10		29946	10.17	20	
15735	10.05	2		21192	9.52	10		27104	9.72	10		30037	10.14	20	
15956	9.84	1		21359	9.59	10		27407	9.62	10		30144	9.93	30	
16051	9.76	10		21596	9.68	10		27735	9.56	10		30185	9.87	20	
16122	9.75	7		22056	9.70	10		28102	9.58	10					
16378	9.83	10		22532	9.61	10		28224	9.61	10					
16514	10.03	10		23373	9.52	10		28346	9.68	10					

Conclusion

I hope that the corrected data, as presented, will fill a gap in the observational record. From the 1950s onwards, better standardized and more precise measurements were made, though the reported data often included the 12th mag companion. The required correction, at the 10.3 -10.4 mag level. is 0.17mag S Dor underwent deep minima in 1955 and 1964. The latter event was prolonged, and p.e. observations showed it still lingering at ~10.5V on 1970 Feb. 25 (Alexander and Thackeray 1971).

References

- Alexander, J.B. and Thackeray, A.D. 1971 Observatory 91,25
Cannon, A.J. 1907 HA 55,1 [2nd Catalogue of Variable Stars]
Fleming, W.P. 1907 HA 47.15
Gaposchkin, S. 1943 Astrophys.J. 97,166
Lourens, J.v.B. 1964 MNRAS 23,34
Pickering, E.C. 1897 Harv.Circ. No. 19
Wesselink, A.J. 1956 MNRAS 116,3

A documentary photobook about pro-am in astronomy

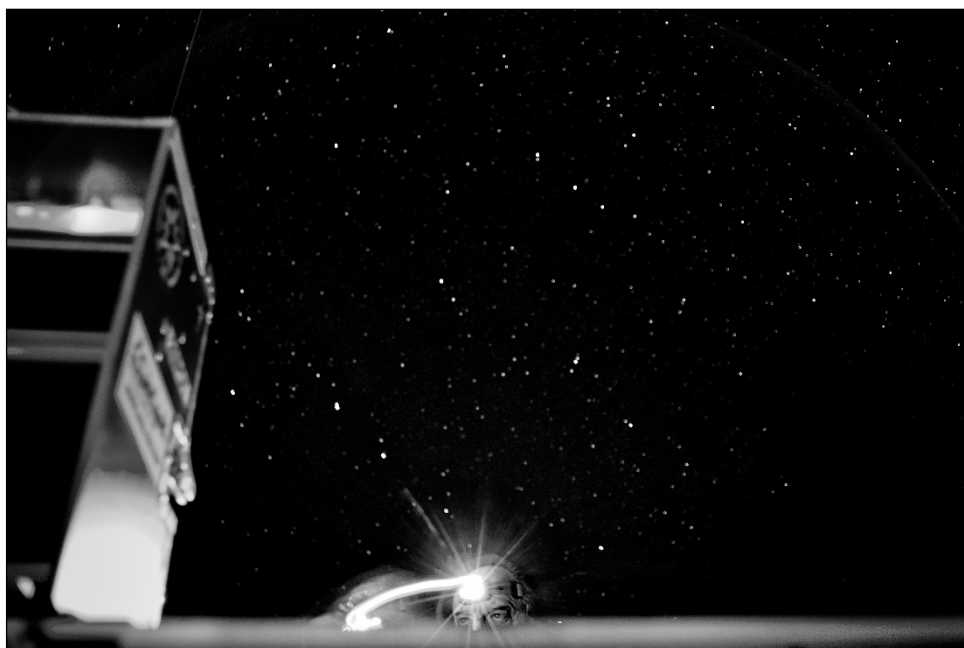
It was early 2019 when I chanced upon a news article, its detail now long forgotten. Still, the feature, championing the work of an amateur astronomer, left a lasting impression. What followed were four years of intense research punctuated by a pandemic, with many a self-funded journey to photograph amateur astronomers, who in some way contribute to professional research.

I am no astronomer, it must be said. But my interest runs deep – and has sustained since I was a boy, when my grandfather would hoist me atop his shoulders, point upwards and name the constellations. In my encounters with these amateur astronomers, I felt a degree of kinship, our lives intertwined by a zeal for the stars, not to mention the frequency with which Star Trek cropped up in conversation.

My forthcoming book *Route de la Belle Etoile - Route of the Beautiful Star* attempts to reflect the global gossamer thread of amateur scientists, and I did my utmost to reach them, photographing amateurs in the UK, France, Germany, Belgium, The Netherlands, India, Australia (where I photographed many Berenice and Arthur Page Medal winners), and Canada. If I had a bit more money that list would be longer. If I had a lot more money, this project may have never ended.

As the end of 2019 beckoned, (and before the pandemic made 2020-2021 ‘research’ years) the project was well underway, as I found myself driving solo for hours towards the Canadian border from Spokane in the USA. Later that evening, I was perched on Jack Newton’s rooftop home observatory overlooking Osoyoos, with a moon underlit by soft earthshine. We discussed the unlikely possibility of extra-terrestrial visits to Earth with other guests in tow in his eclectic astronomy-themed and wallpapered B&B. Jack’s supernova work is familiar to those in the know - of particular note his efforts in search of the Progenitor of the Type Ib Supernova 20100 in Arp 299, for which he was granted time as an investigator on the Hubble Space Telescope. The B&B sadly closed its doors for good in 2023.

Armed with his 20” Meade RCX400, Jack is a classic example of the lone amateur, remotely partnering with the professionals. From a photographer’s perspective, documenting this kind of intimate yet behind-the-scenes collaboration can be a challenge, so I was keen to find a visual opportunity that would illuminate it more emphatically.



Olivier Garde | *Spectro Star Party, L'Observatoire de Haute-Provence, France*

It came in 2021, strolling amongst the domes of L'Observatoire de Haute-Provence, France. I arrived in Provence to the warm embrace of a French summer evening. I was there for five nights to attend the Spec-

tro Star Party, organised annually by instruments manufacturer, Shelyak. I disembarked my taxi to a field littered with telescopes, ghoulishly covered against the harsh sun, sat squat in anticipation of the night. As the light dimmed, amateurs and professionals worked in unison. Common targets of interest were 10 Lac and Deneb, but observers freely pointed their instruments on targets that took their fancy.

Some collaborations hit sweeter notes; married couple Christian Buil and Valérie Desnoux, sat side by side, night after night, in quiet spectroscopic observation. On its website proclaiming the event, Shelyak promised participants much merriment: “*you may not have time to do everything, because there is also a swimming pool on the site, hiking trails in the scrubland around the site, singing cicadas, some opportunities to take a nap... It will give an excuse to return the following year.*”



Amateur astronomer | Spectro Star Party, L'Observatoire de Haute-Provence, France

When it comes to amateurs collaborating with each other, the so-called “Finnish Pro-am Network” is a self-organised standout. They operate a three-observatory mission spanning the girth of the country, mostly focused on variables. Amateur astronomer Arto Oksanen proved a generous guide for the course of my stay in the country in late 2019.

Trying to maximize the science output of observations, those from the network are, for example monitoring the recurrent nova M31N 2008-12a for nova outburst – taking a deep image every clear night to check if the nova is visible or not.

In tandem with other observers around the globe, they also make observations of other high interest targets like eclipsing cataclysmic variables – combining light curves that can be several days long – something a single professional telescope cannot do.

Two years later though, and roughly six thousand kilometres south-east of Finland - I was in a decidedly moister Pune, India. It was there I met another variable-observing group, members of Jyotirvidya Parishad which claims to be the oldest such astronomical society in the country. On a nondescript rooftop in Pune, their blue, domed observatory sits as a beacon to amateur science against the disorder of the cityscape.

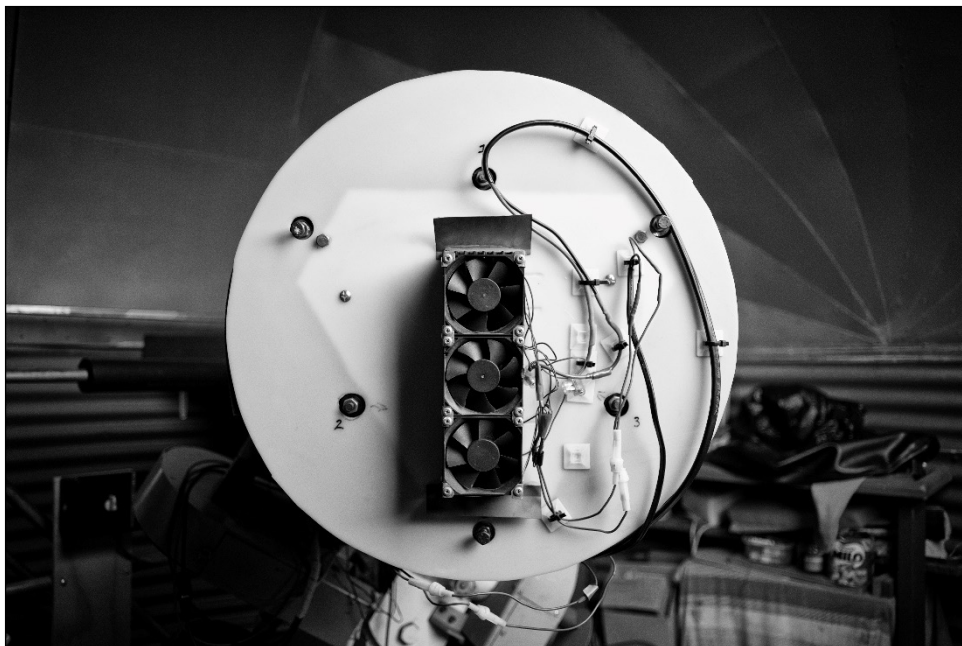
Using a 12” 1200mm scope, JVP members make variable star observations and submit them to the AAVSO (American Association of Variable Star Observers). They tend to use an 11” 3000mm for planetary imaging and also report asteroid occultation data to the IOTA (International Occultation Timing Association), and on top of that – they coordinate the IOTA-India.

Only a month or so earlier, I was on the other side of the world in Australia, having driven more than eight hours from Melbourne to the frontier home of Trevor Barry in Broken Hill. Trevor’s is a name etched in many a memory – forever associated with Saturn. His custom 408mm F4.5 Newtonian is



*Nyrölä Observatory,
Finnish PRO-AM
Network | Jyväskylä,
Finland*

imprinted with care, attention, and NASA stickers. We sat in his office as Trevor chronicled his recent collaborative efforts observing a cyclone at 50°N in the atmosphere of Saturn – the source of eight separate convective storms. Back in 2018, in a broadcast interview, he had articulated how many a space scientist invariably describe their work: “*what does it make me feel? Insignificant.*”



Trevor Barry's custom telescope | Broken Hill, Australia

This is a small excerpt of the stories of the people and places featured in this extensively researched book, understood to be the first photobook spotlighting the global patchwork of amateur astronomers who contribute to professional astronomical research. The Kickstarter: <https://www.kickstarter.com/projects/gblimitededitions/route-de-la-belle-etoile-route-of-the-beautiful-star> (live from Feb 6th) will support the printing of the work by renowned publisher GOST books and help make this book accessible to a wider audience.

Oh, and the title! *Route de la Belle Etoile* (the route of the beautiful star) is a road in Grenoble, France. Amateur spectroscopist Olivier Thizy lobbied his local authority successfully for the name change.

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This article originally appeared in the Journal of the British Astronomical Association (www.britastro.org).

Introduction

Up until March 2023 X Caeli was listed as an EC type eclipsing binary in the AAVSO Variable Star Index (<https://www.aavso.org/vsx/>). These are defined in the VSX as:

“Survey type. Contact binaries in ASAS-3. Both components filling or close to filling their Roche lobes. These are mostly EW variables.”

I observed it on four occasions between November 2020 and December 2022 as part of the VSS Southern Eclipsing Binaries Project with the aim of refining its period and epoch. The results were puzzling, and I had planned further observations. However, in March 2023 Roy Axelsen contacted me to say Brent Joyce of the AAQ had looked at the TESS light curve and realized it was peculiar. A quick search by Roy found a paper “*Simultaneous intensive photometry and high resolution spectroscopy of Scuti stars IV. An improved picture of the pulsational behaviour of X Caeli*” (Mantegazza, et al., 2000) which clearly identified the star as a DSCT type pulsating variable.

Roy contacted Sebastian Otereo at AAVSO and the misclassification in VSX was quickly corrected.

Digging a little deeper, I found that X Cae was first identified as a DSCT variable by D. H. P. Jones of the Radcliffe Observatory, Pretoria (Jones, 1966), and has been the subject of several published studies since. The initial VSX classification was probably a transcription error.

To salvage something from the time I’d spent observing X Cae I decided to carry out a frequency analysis of pulsations in the TESS light curves to see how they compared with results reported by Mantegazza, et al. (2000).

TESS observations

TESS recorded light curves of X Cae in Sector 5 (2018) and Sector 32 (2020) which exhibit complex beating patterns due to multiple pulsation frequencies. Figure 1 is the entire Sector 5 light curve, and Figure 2 shows just the first 3 days.

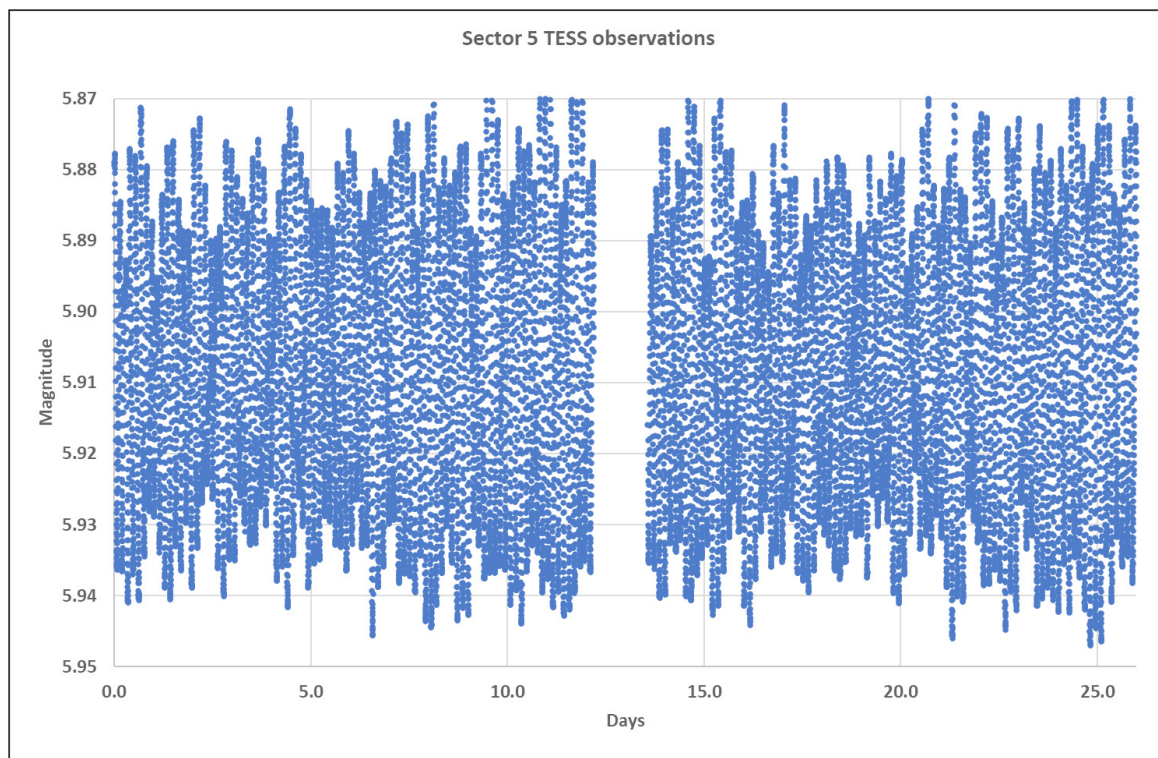


Figure 1. Sector 5 (2018) TESS light curve of X Cae.

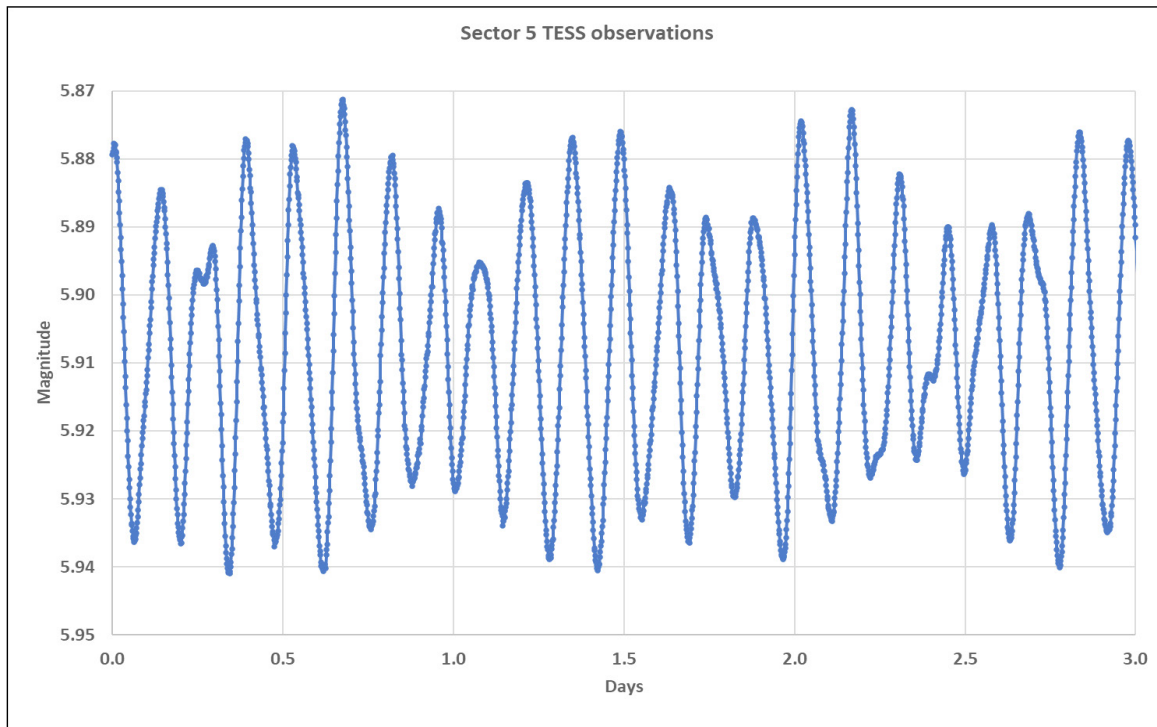


Figure 2. First 3 days of the Sector 5 (2018) TESS light curve of *X Cae*.

Frequency Analysis

Mantegazza, et al. (2000) listed 17 significant pulsation frequencies measured from ground-based photometric and spectroscopic observations. Analysis was conducted using Period98 software (Sperl 1998). Table 1 list their results from B and V band photometry.

Table 1. Frequencies, S/N and amplitudes reported by Mantegazza, et al. (2000) from B and V band photometry. Listed in order of decreasing S/N.

Freq c/d	S/N	B mmag	V mmag
7.394	128	50.83	7.2
6.036	25	9.5	7.6
13.988	24	9.2	7.1
7.453	19	7.5	5.6
6.656	13	5.1	3.9
13.517	13	5.1	4.0
12.917	11	3.9	3.3
13.434	8.8	3.2	2.8
11.771	7.0	2.9	1.9
14.779	7.0	2.9	2.0
5.882	5.8	2.1	1.8
12.092	5.5	1.9	1.8
10.622	4.5	1.9	1.2
8.848	4.3	1.6	1.4
6.221	4.0	1.4	1.4
9.003	3.5	2.0	0.6
11.264	3.4	1.2	0.9

The TESS light curves are much more precise, and each Sector covers 26 days at 2-minute cadence with a single break in the middle for data download from the satellite. I used the updated Period04 software (Lenz and Breger, 2004) to determine pulsation frequencies and amplitudes. Each TESS Sector was analysed separately, and the results are shown in Table 2.

2018			2020		
Freq [c/d]	S/N	Amp [mmag]	Freq [c/d]	S/N	Amp [mmag]
7.394	541	26.37	7.394	553	26.61
6.042	165	4.84	13.977	140	4.89
13.978	144	3.92	6.042	108	4.83
13.519	74	2.37	7.461	73	3.50
7.459	74	3.64	13.437	49	1.89
13.437	59	1.89	13.520	44	1.66
11.113	41	2.02	0.005	41	1.93
5.890	40	1.02	14.920	29	1.20
14.919	38	1.28	11.917	28	1.34
6.624	34	1.49	6.623	28	1.32
11.914	33	1.40	7.997	28	1.26
14.788	29	0.93	11.112	28	1.29
7.687	25	1.24	27.954	27	0.45
7.998	24	1.23	5.884	27	1.15
6.198	21	0.75	7.686	26	1.29
6.660	20	0.88	14.788	23	0.94
14.032	19	0.50	10.643	22	1.13
10.643	19	1.04	11.764	18	0.90
27.954	18	0.28	6.661	17	0.81
12.922	16	0.59	6.198	14	0.75
14.051	16	0.40	0.293	14	0.66
13.280	15	0.47	12.924	13	0.57
14.149	14	0.36	13.278	13	0.49
5.337	13	0.36	0.294	13	0.62
13.891	13	0.35	13.223	12	0.45
11.763	12	0.51	9.171	10	0.51
5.861	12	0.31	9.596	10	0.53
18.037	12	0.39	13.594	10	0.36
9.173	11	0.55	5.338	8.3	0.35
11.069	11	0.54	11.072	8.2	0.39
13.232	10	0.32	13.881	7.9	0.28
12.096	10	0.45	18.036	7.8	0.30
9.590	9.8	0.55	11.847	7.5	0.36
5.406	9.6	0.24	14.032	7.1	0.25
8.847	9.6	0.45	7.427	7.1	0.34
11.852	9.3	0.40	8.861	7.0	0.35
13.592	9.0	0.29	12.086	6.6	0.32
14.856	7.4	0.24	9.920	6.5	0.36
21.434	6.8	0.23	0.148	6.5	0.30
12.244	6.4	0.28	7.369	6.4	0.31
22.314	6.4	0.19	14.062	6.4	0.22
20.917	6.1	0.22	11.254	6.3	0.32
9.918	6.0	0.32	9.278	6.1	0.29
18.510	5.9	0.22	10.257	5.9	0.28
11.253	5.6	0.29	8.830	5.9	0.30
10.256	5.6	0.28	21.439	5.4	0.24
8.481	5.1	0.22	9.432	5.1	0.25
9.431	5.1	0.27	0.600	4.7	0.22
9.276	5.1	0.25	11.159	4.7	0.22
0.028	4.8	0.31	11.404	4.4	0.22

Table 2. Frequencies, S/N and amplitudes of pulsations in TESS light curves from Sector 5 (2018) and Sector 32 (2020). Listed in order of decreasing S/N ratio. Bold text indicates frequencies similar to those reported by Mantegazza, et al. (2000).

The Period04 results were used to create model light curves in Excel. These are shown in orange in Figure 3 superimposed on the first three days of each TESS data set (blue). The residual light curve is plotted in grey.

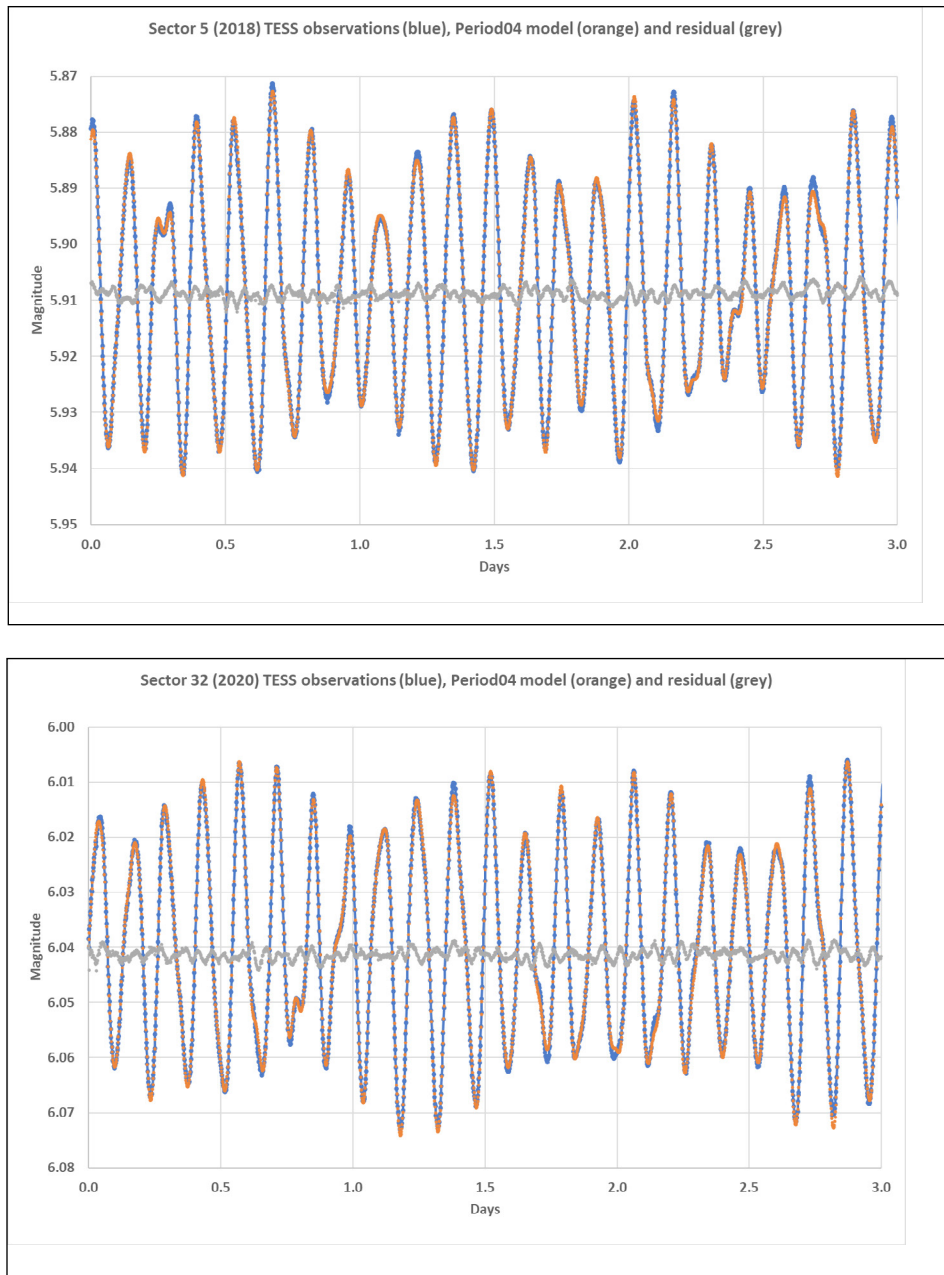


Figure 3. Observed, modelled and residual light curves for first 3 days of the 2018 and 2020 TESS data.

Discussion

Analysis of TESS light curves yield essentially the same pulsation frequencies as 16 of the 17 frequencies reported by Mantegazza, et al. (2000) from ground-based photometry. Their 9.003 c/d frequency was not present in the TESS light curves, however, it had very low S/N ratio indicating its detection was marginal.

The higher precision TESS data resulted in much higher S/N values and at least 50 significant pulsation frequencies with S/N values > 4 which, according to Breger et al. (1995), have a high probability of being intrinsic to the star.

Interestingly, many frequencies with relatively high S/N identified in the TESS data were not found by Mantegazza, et al. (2000). This is likely to be due to the lower cadence and non-continuous nature of the ground-based photometry.

The TESS photometer has a broad transmission curve approximating the Cousins I filter. Delta Scuti type pulsations are most prominent at shorter, i.e. bluer, wavelengths. This is evident in the B and V band amplitudes listed in Table 1 and I band amplitudes in Table 2.

The VSS Southern Eclipsing Binaries Project, through new observations and analysis of photometric survey databases, aims to refine our understanding of these relatively under observed southern variables. In the case of X Caeli, Brent and Roy's investigations led to the correct variable type being assigned in the AAVSO's VSX database.

Acknowledgements

I thank Roy Axelsen and Brent Joyce for pointing out the true nature of X Caeli.

This research made use of the AAVSO VSX database and the NASA Astrophysics Data System Bibliographic Services. This paper includes data collected by the TESS mission, which are publicly available from the Mikulski Archive for Space Telescopes (MAST). This research made use of AAVSO's VStar software and Period04 program (Lenz & Breger 2005).

References

- Breger M., Handler G., Nather R.E., et al., 1995, A&A 297, 483
Jones, D. H. P., 1966. Mon. Notes R. Astr. Soc. Sth Afr., 25,97.
Lenz P. and Breger M. 2004 IAU Symp. 224, The A-Star Puzzle ed J. Zverko et al. 786 doi: 10.1017/S1743921305009750
Mantegazza, L., Zerbi, F.M., and Sacchi, A., Astron. Astrophys. 354, 112–124 (2000)
Sperl M., 1998, Comm. in Asteroseismology (Vienna) 111, 1

X-Ray binary A0538-66 (= LMC V3434) – Rod Stubbings

stubbo@dcsi.net.au

Discovered in 1977, the Be/neutron star binary A0538-66 is a remarkably hard X-ray transient source in the Large Magellanic Cloud. A 16.64-day optical periodicity was derived from archival plate material (Skinner 1980). During observations with NASA's Einstein observatory (the first fully imaging X-ray telescope put into space) of this object, 69-millisecond X-ray pulsations were detected in M.P.C. data that confirmed the presence of a neutron star in the system (Skinner et al. 1982)

The X-ray binary A0538-66 has been on my observing list since 1996. In June 2022, I received an unexpected email from Gerald Skinner, an X-ray astronomer at the School of Physics and Astronomy, University of Birmingham, UK, regarding A0538-66.

"I just wanted to say how grateful I am that you are keeping an eye on A0538-66 (= LMC V3434). I am now retired, but during my professional life in X-ray astronomy, I worked quite a lot with this system and still keep an interest in it. The X-ray pulsations from it were always a bit anomalous. I am still awaiting news of renewed activity, prepared to use my contacts to get new X-ray observations if it shows signs of another outburst. For a while, a colleague and I were using remote telescope time to make measurements of it from here in the U.K., but that was tedious and expensive, so I am pleased to get your reports through the AAVSO.

Gerry Skinner."

Gerry explained that he discovered the variability of this object sitting on a train from Edinburgh to Birmingham. "I had gone to The Royal Observatory Edinburgh to measure this star on all the UK Schmidt plates they had using an Iris photometer (this was 40 years ago). I arrived to find the photometer was broken and took the first train home, but not before quickly taking Polaroids of some plates from critical times. On the train, I looked at the photos. It was so obvious I started writing the Nature letter".

A few months later, and to my surprise, some activity was detected on November 17, 2022, showing A0538-66 was noticeably brighter than average at magnitude 14.4. After years of monitoring this field, this was the first time I had seen any bright activity in this star. I emailed Gerry to let him know of the activity.

Dr Skinner contacted Keith Gendreau at NASA- Goddard Space Flight Center to see if he could schedule the Neutron Star Interior Composition Explorer (NICER) for observations ASAP. NICER is an International Space Station payload that studies neutron stars through soft X-ray. NICER observed A0538-66 on November 17 at 22.4h UT and has been scheduled for further monitoring over the next predicted outburst from the 16.64-day cycle.

The first NICER observation detected X-rays coming from A0538-66, though at a comparatively low level and with a relatively soft spectrum. An announcement (Figure 1) was sent on the renewed activity in A0538-66. Atel#15781.

A plot of observations of A0538-66 (=LMC V3434)

Figures 2, 3 and 4 show I-band OGLE-IV from the public online database at <http://ogle.astrouw.edu.pl/ogle4/xrom/1a0538-66.html> (Udalski, 2008, Acta Astron., 58, 187).

We thank Keith Gendreau and the NICER team at NASA-Goddard Space Flight Center for arranging the NICER observations.

Markers indicate the predicted times of outbursts based on the ephemerides of Rajoelimanana et al. (M.N.R.A.S. 464 p4133, 2017) and Ducci et al. (A&A 661, A22, 2022).

Renewed activity in recurrent transient A0535-66

ATel #15781; **Rod Stubbings (Tetoora Road Observatory, Victoria, Australia and AAVSO), Gerry Skinner (University of Birmingham, UK)**

on 29 Nov 2022; 14:32 UT

Credential Certification: G. Skinner (gerald.k.skinner@gmail.com)

Subjects: Optical, X-ray, Binary, Neutron Star, Transient, Variables

✕ Post

We report signs of a new period of activity in A0535-66 (=LMC V3434), a recurrent X-ray and optical transient with a period of 16.64 days. In the past, it has shown evidence of 69 ms X-ray pulsations and various super-orbital periods. On 2022 Nov 17 at 12.5-17.5 h UT visual observations from Tetoora Road Observatory found A0538-66 to have a magnitude of 14.6 compared with 15.3 in most recent data. The Nov 17 observations were close to phase 0, cycle $n=254$, on the extrapolated ephemeris of Rajoelimanana et al. (2016) and about 12h after phase zero on that of Ducci et al (2022). NICER x-ray observations were commenced at 22.4h UT and monitoring has continued. Examination of publicly available A0538-66 data from OGLE-IV shows relatively bright I-band magnitudes (15.0-15.2m) close to the times corresponding to cycles $n=249-252$, but the increases in brightness were smaller (0.2-0.45m). At the time of the $n=252$ brightening, Tetoora Road Observatory visual observations also indicated an optical brightening to (15.0m). A summary is of the times of observations and of the optical results is provided at the link below. The next phase zero is due to occur at 2022 Dec 03 at 22.0h +/- 2.0h UT according to the ephemeris of Ducci et al., or at 2022 Dec 04 at 09.8h +/- 2.0h UT according to that of Rajoelimanana et al. Multiband observations around these times are encouraged to elucidate the nature of this quixotic system. We acknowledge the use of OGLE data (Udalski, Acta Astron. 58 p187, 2008) available at <http://ogle.astrouw.edu.pl/ogle4/xrom/1a0538-66.html>. We wish to thank Keith Gendreau and the NICER team at NASA-GSFC for the rapid organisation of the NICER observations which will be continued with high cadence through the time of the next expected brightening. References : Ducci, L. et al. A&A 661, A22, 2022 Rajoelimanana, A.F., MNRAS 464, 4133, 2017

Figure 1. A facsimile of the announcement of renewed activity of A0538-66 in The Astronomer's #15781

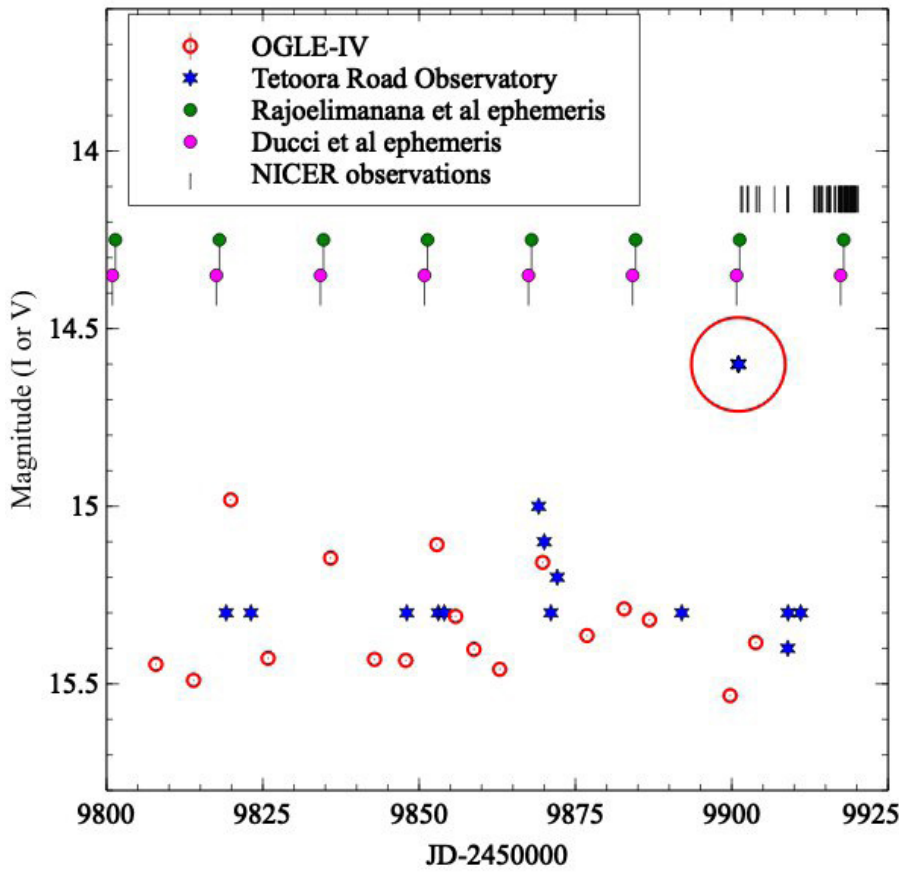


Figure 2. *Pb*servations of A0538-66 from August to December 2022

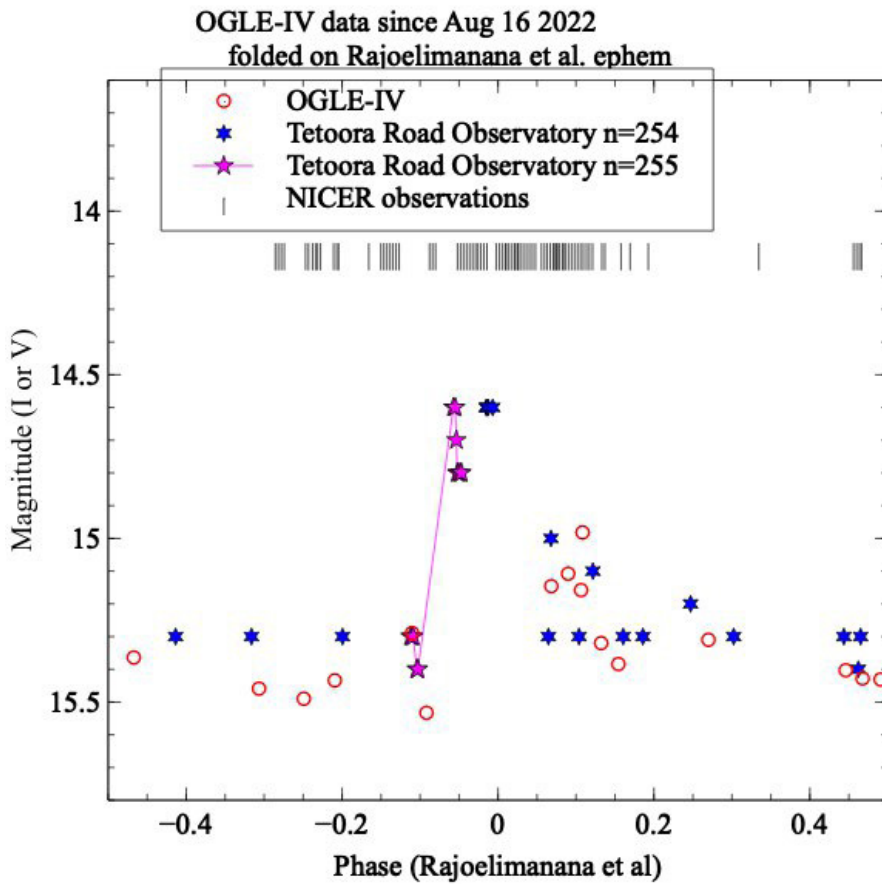


Figure 3. *OGLE-IV* and *Stubbings* phase folded data since August 2022

OGLE-IV data since March 2010 folded on Rajoelimanana et al. ephem

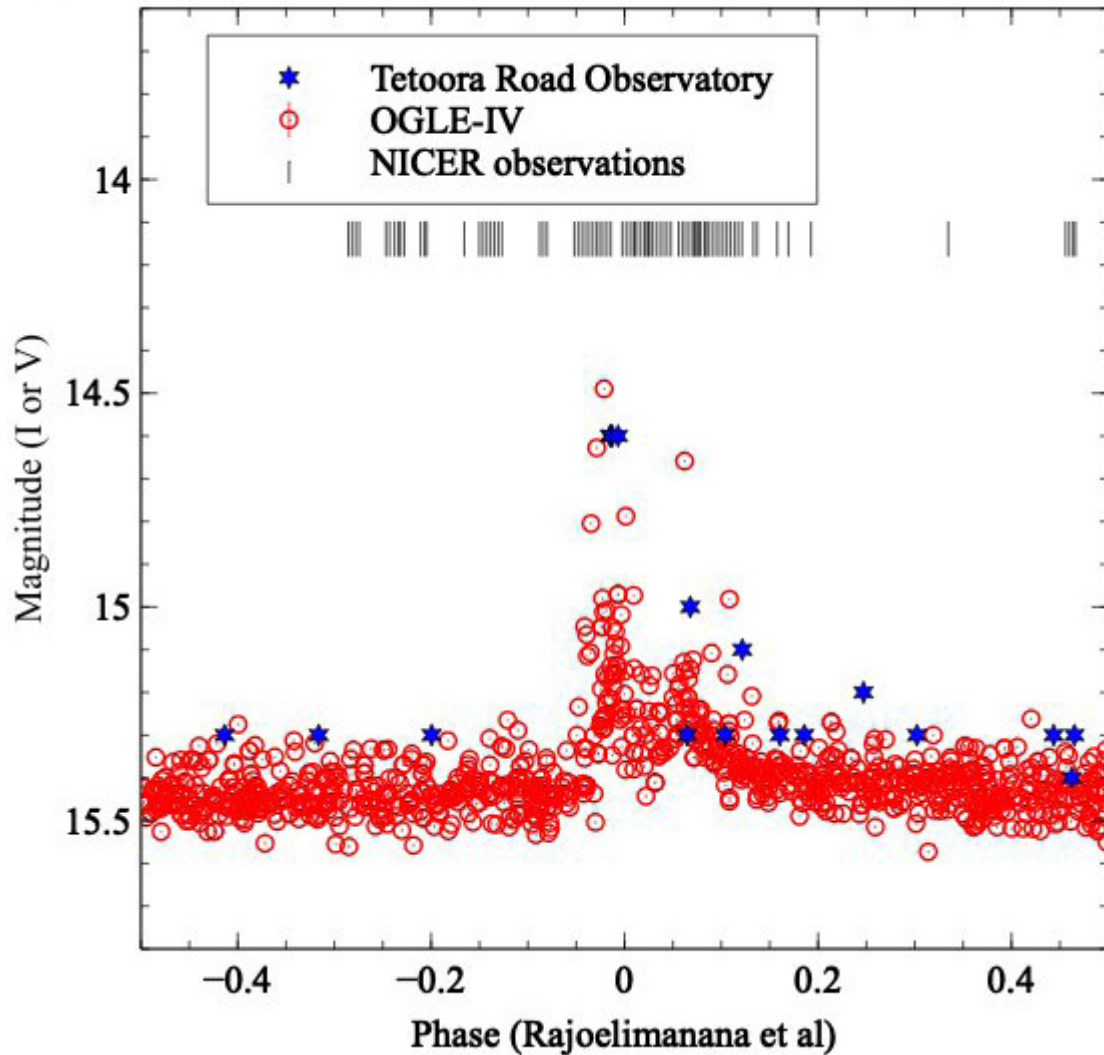


Figure 4. *Phase folded data since March 2010*

Monitoring of A0538–66 continued from November 2022 to February 2023. Six detections occurred around the 16.4-day period. Optical and X-ray observations from NICER were obtained for each 16.4-day orbital cycle.

A Swift TOO request was submitted by Gerald Skinner in December 2022 and approved. The Swift observation on January 6 showed some X-ray emission from A0538-66 but weak enough that NICER wouldn't see it.

After the Swift observations were taken, Gerry picked up a discrepancy in the visual comparison sequence compared to the Swift data. I contacted Sebastian Otero (AAVSO), who organised a new sequence for A0538-66. This reduced the discrepancy with the Swift data.

On January 22, 2023, I detected the system brightened again for the next cycle. A0538-66 was a lot brighter than the previous 16.4-day cycle. The Ducci et al. ephemeris put the phase zero = MJD 59966.835 = 2023-01-22 20:02 U.T. My detection was early, and the system could still be brightening. The peak visual brightness during this cycle was magnitude 14.0.

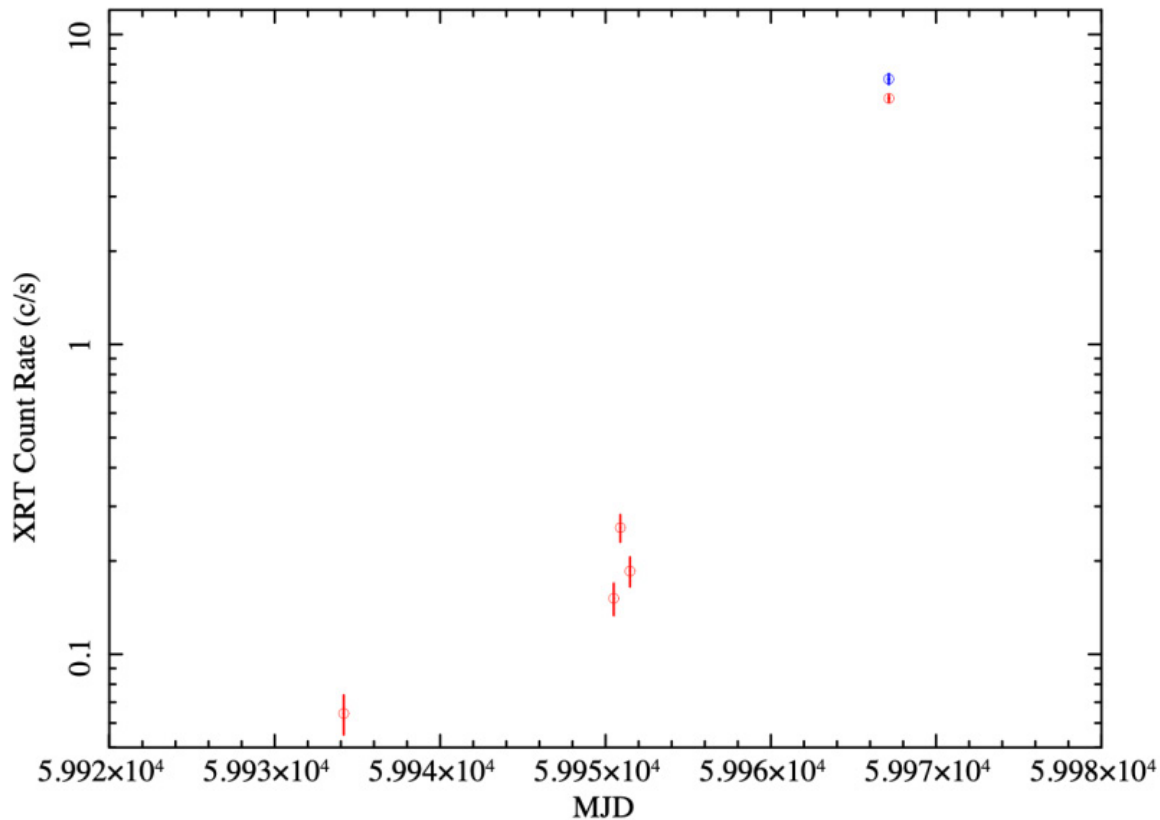
Gerry had not been pressing for more space observations on the basis that it looked like the trend had been weaker and weaker activity, and it looked like it wasn't going to do anything in this series of flares that would give a chance of catching pulsations. So, no NICER or SWIFT observations had been scheduled, and it was relatively late to do anything during this cycle.

Dr Jamie Kennea, Research Professor of Science Operations and X-ray Telescope Lead at NASA Neil

Gehrels Swift Observatory, who was involved in the first request, replied, “We could look at it with Swift today if you think it’s worthwhile”. So, another observation was set up that night on January 22. A0538-66 was significantly brighter in X-rays than the first Swift observations taken on January 6.

Swift X.R.T. observations January 22

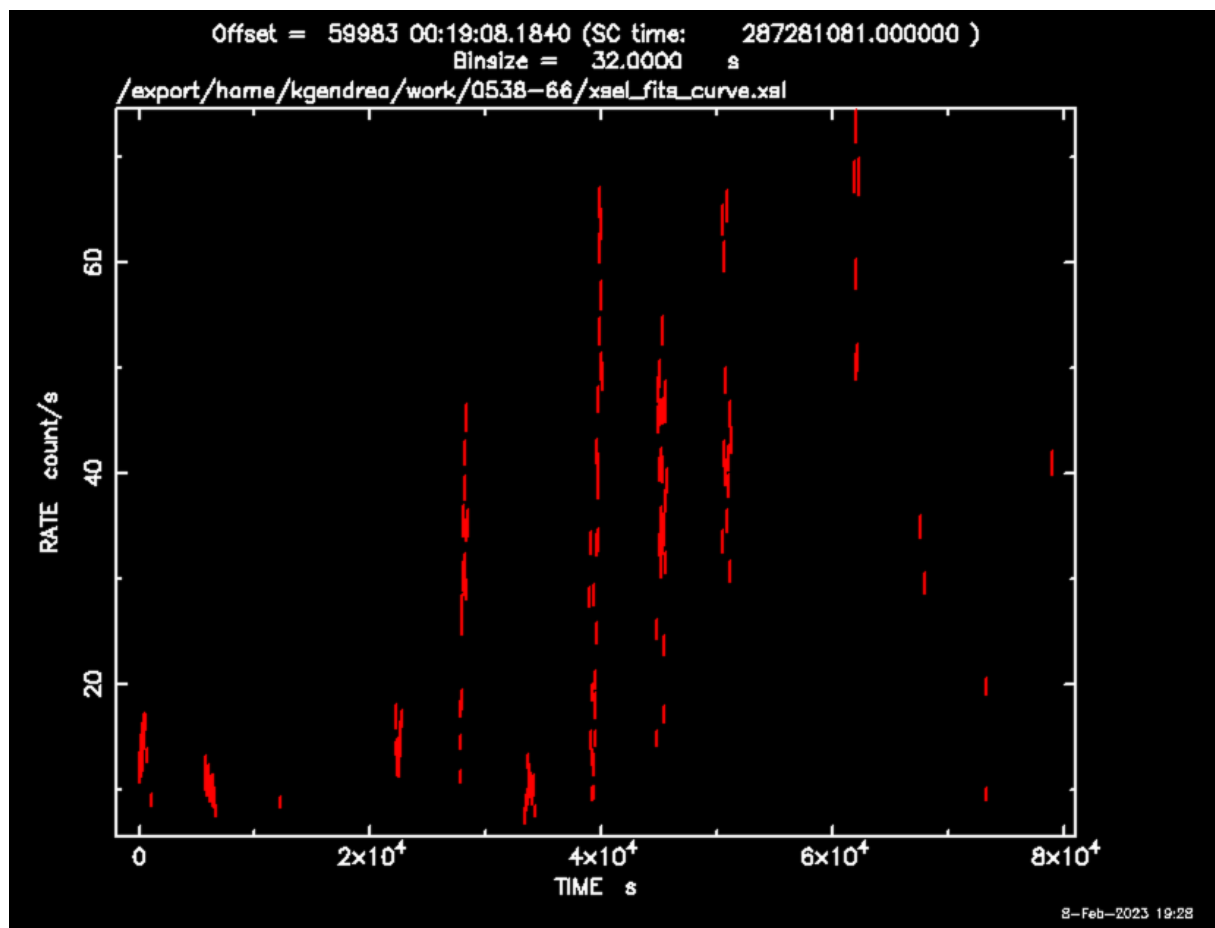
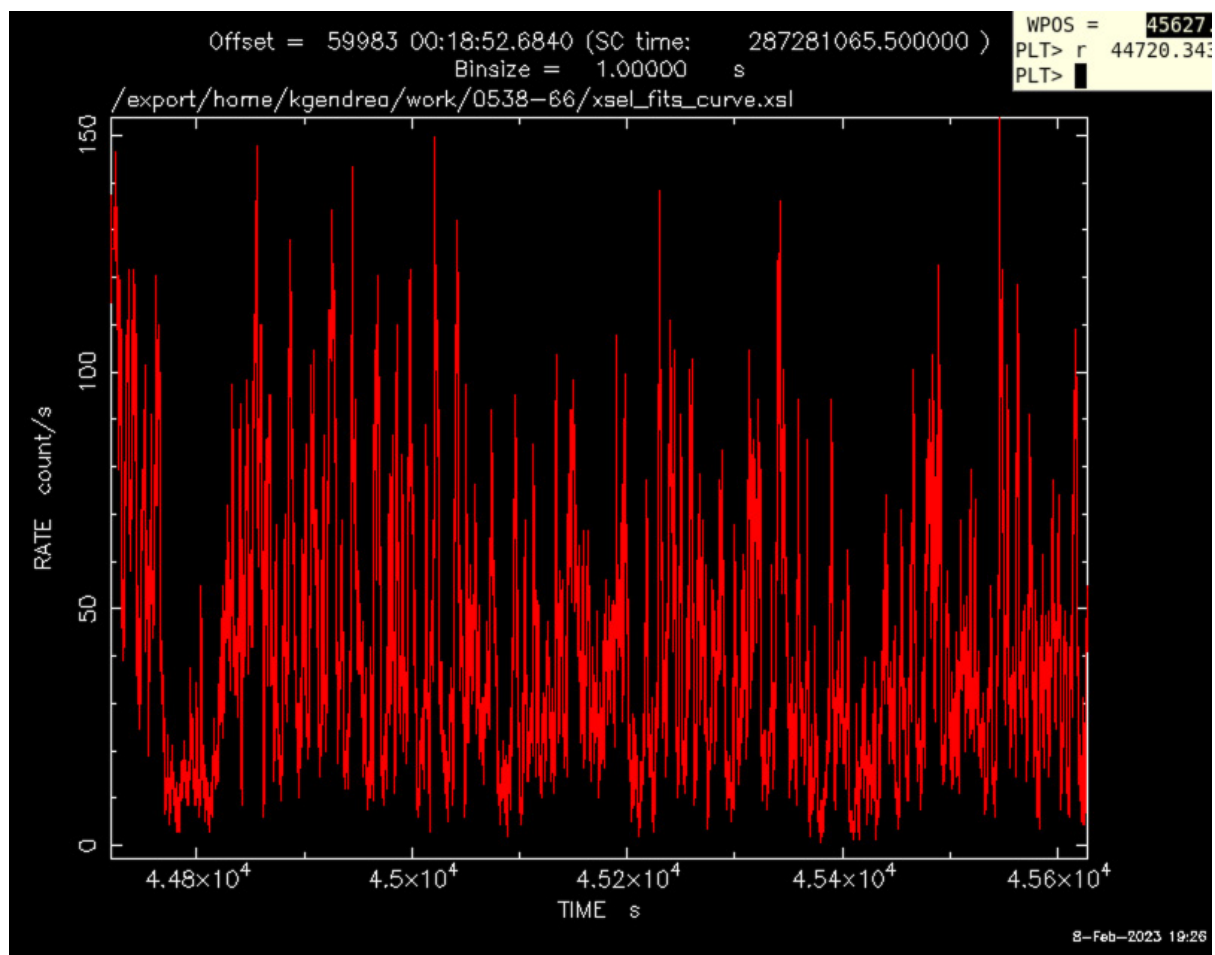
Analysis of the most recent dataset and light curve of Swift X.R.T. observations from Dr Jamie Kennea. “It’s around 7 c/s in X.R.T. (so the P.C. mode data we took is piled up; we also took W.T. data, which is not), and the observed flux is 1.7×10^{-10} erg/s/cm² (0.3-10 keV).”



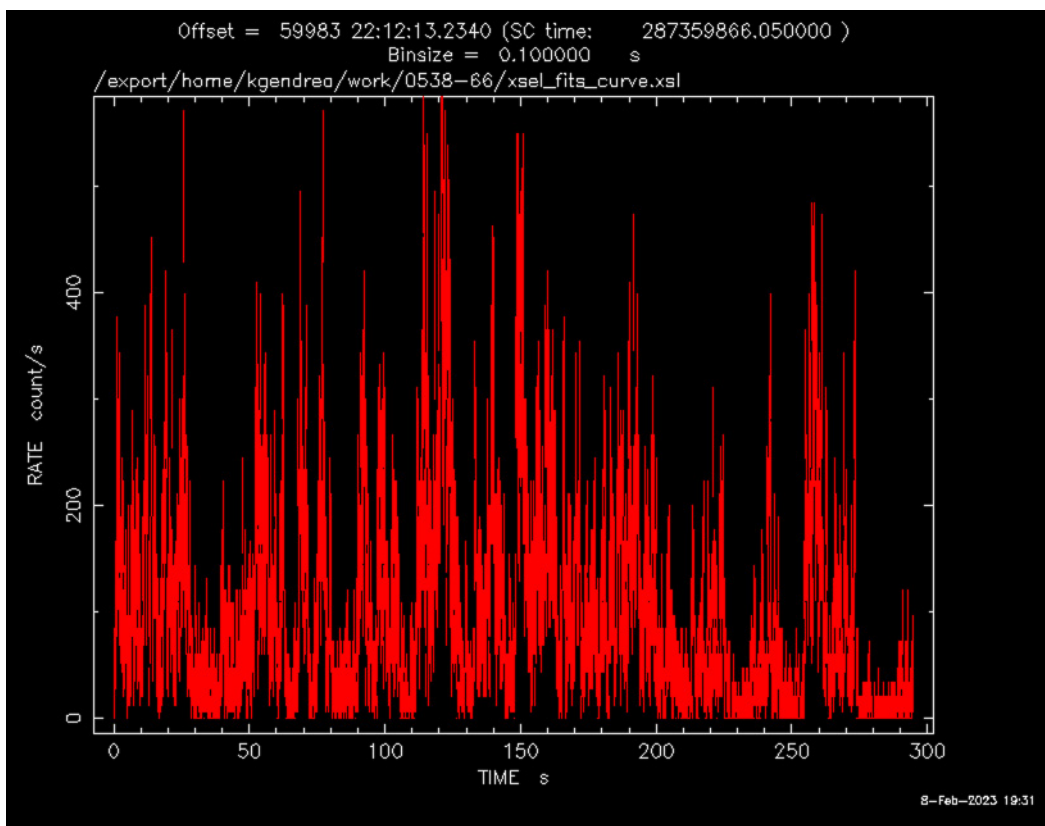
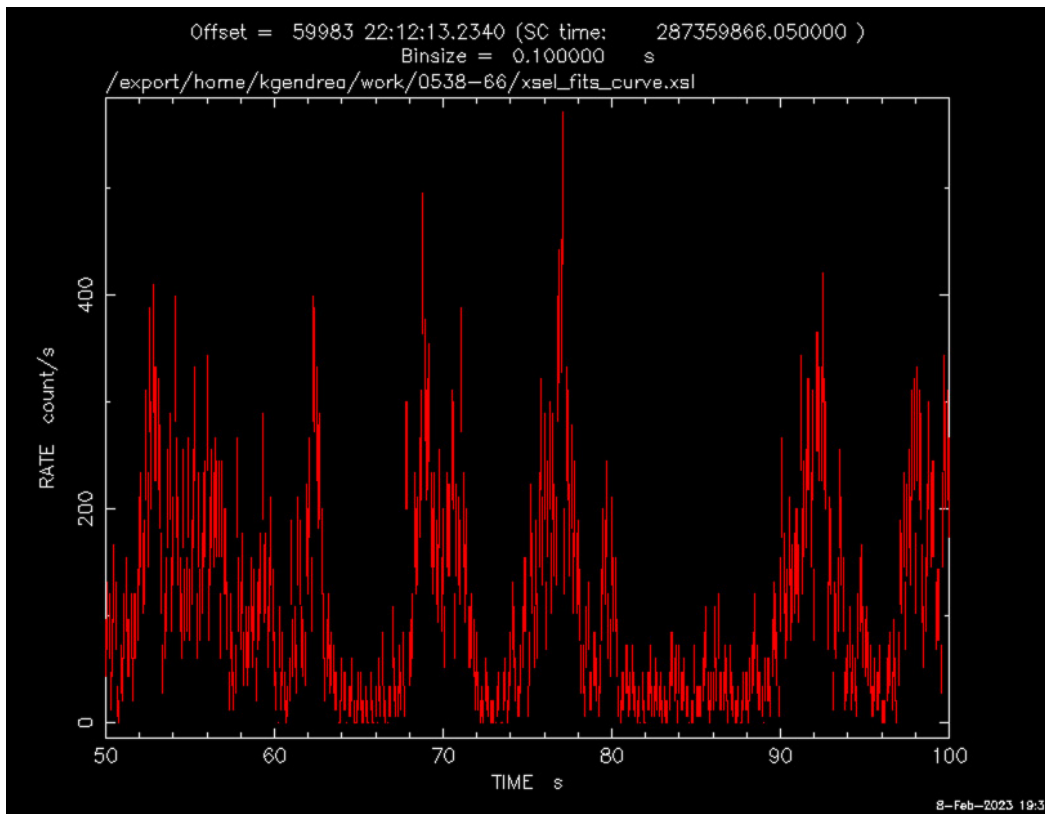
The next A0538-66 phase zero cycle was due around February 8, 2023. After the activity observed by Swift from the previous cycle Keith Gendreau had scheduled lots of NICER observations throughout this period. My early observation on February 8 showed that A0538-66 was bright once again.

NICER observations were taking place and suddenly saw lots of variability with a count rate consistent with what Swift saw the last cycle. Here are some comments and snaps of the overall light curve during the X-ray outburst from Keith Gendreau, NASA Goddard Space Flight Center.

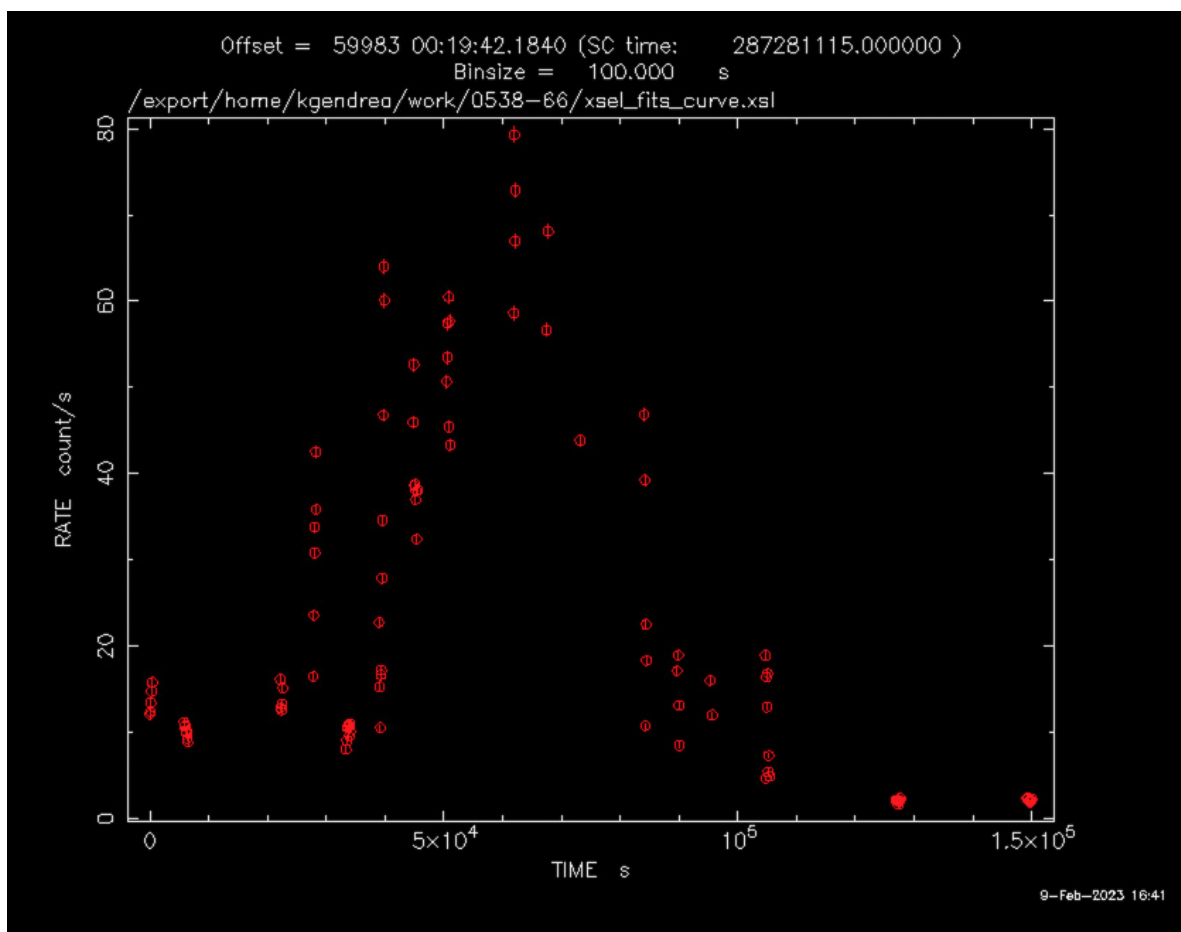
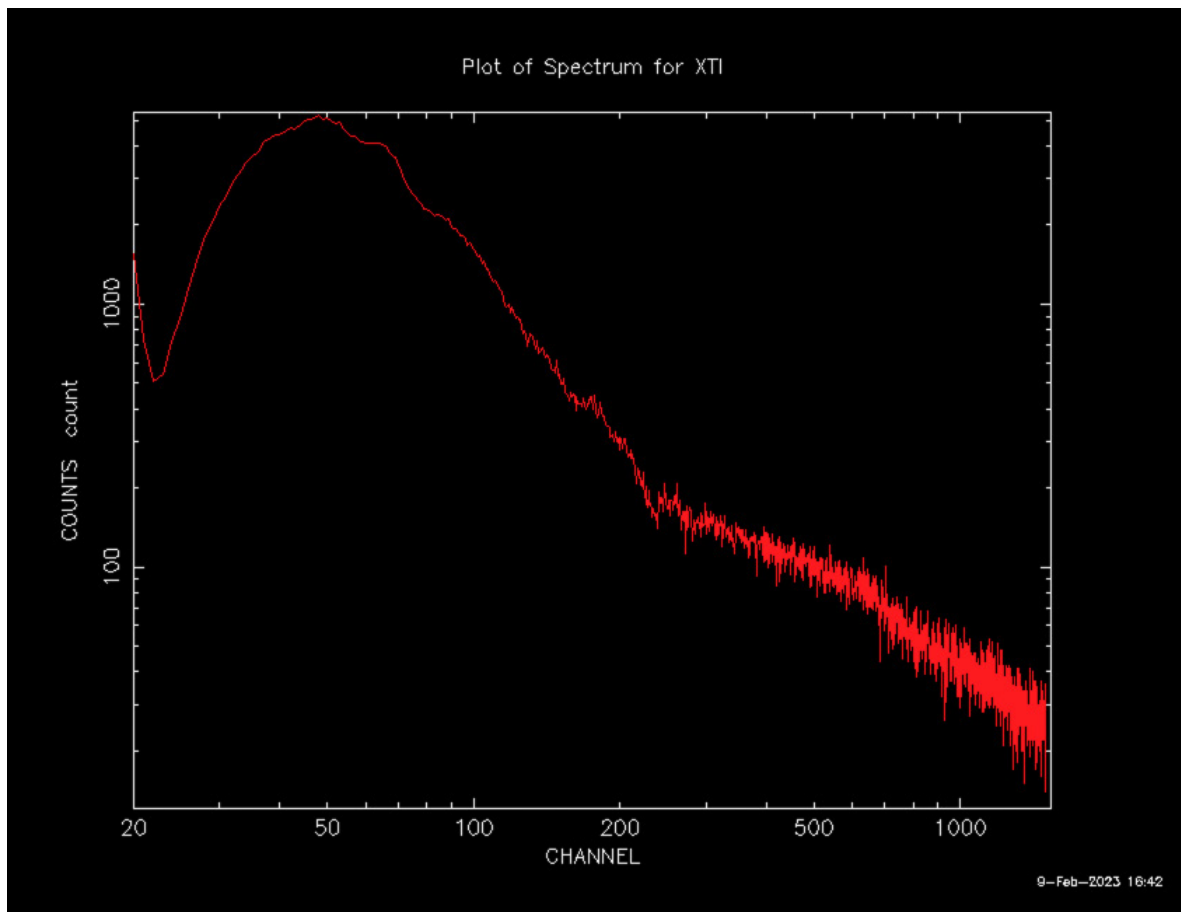
The source is quite variable- and maybe has not finished its outburst in X-ray. The following six graphics show various aspects of the outburst since early this morning (Ed. 6 Jan 2024). Some are in bins of 1 second, and one is in bins of 32 seconds (to show the overall change in flux over the day)

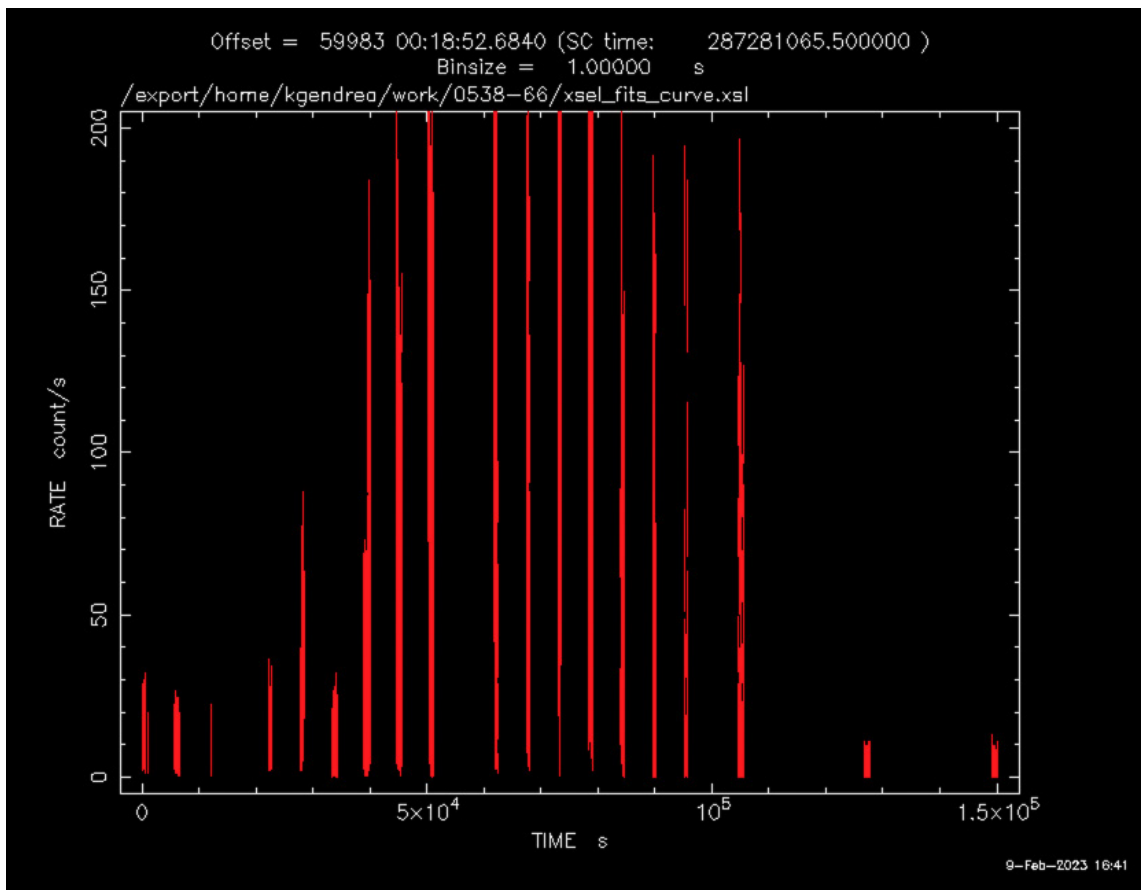


I have also included a few zoom-ins with 0.1-second bins where you can see a lot of “snap, crackle, and pop”.



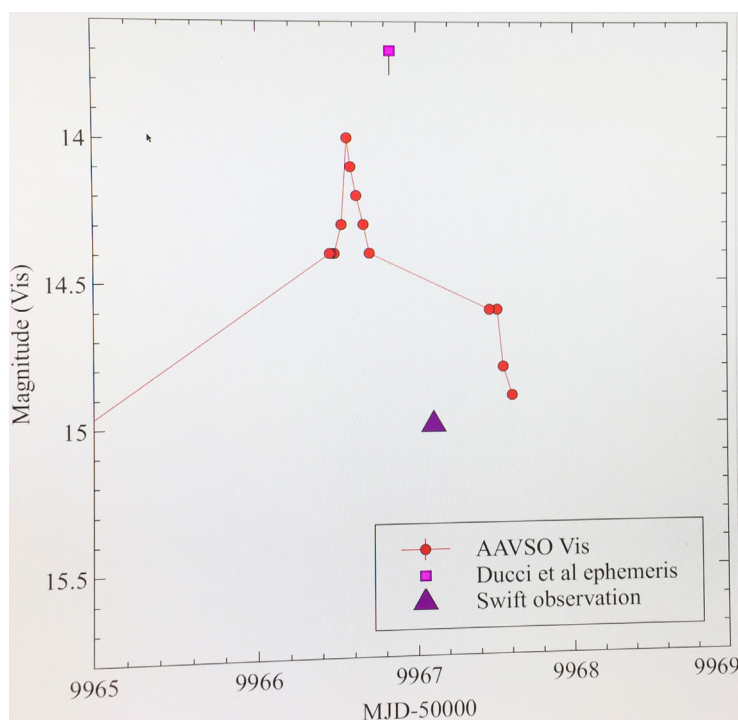
After the X-ray activity, Keith provided updated screenshots of the light curves where you can see when the peak activity was. Clear break at iron K... but the peak of flux is around 0.5 keV





The data results will require serious analysis, and some investigation by Gerry Skinner will be needed to see if any 69-millisecond X-ray pulsations were detected.

So Gerry's conclusion that a series of outbursts were fading away was proved that the system is still active. "Who knows, in another 16 days, it might get bright enough to do the NICER pulsation search that was the original objective. Or it may go back to sleep".



Dr Jamie Kennea explained that a good rule of thumb is that the "NICER rate is about 10x Swift XRT rate, and the NICER effective area is >10x Swift XRT's. The count rate I get from 100s of XRT data in WT mode, so not piled up, is 7.2 +/- 0.3 count/s. When I put that and the spectrum into WebPIMMs, it estimated 100 c/s in NICER".

So it is now bright enough now to do a NICER pulsation search.

Here is a plot of my recent data showing the relationship to the ephemeris and the Swift observation.

References

- Ducci, L. et al. A&A 661, A22, 2022
- Rajoelimanana, A.E. MINDRAS 464, 4133, 2017
- Skinner, G. K., 1980, Nature, 288, 144-143
- Skinner, G. K., Bedford, D. K., Elsner, R. F., et al. 1982, Nature, 297, 568
- Udalski, 2008, Acta Astron., 58, 187
- Email, G. Skinner to R. Stubbings, 2022 June 26
- Email, R. Stubbings to G. Skinner, 2022 June 27
- Email, R. Stubbings to G. Skinner, 2022 November 18
- Email, G. Skinner to R. Stubbings, 2022 November 18
- Email, G. Skinner to K. Grendreau, R. Stubbings, November 22
- E-mail, G. Skinner to A. Udalski, R. Stubbings, 2022 November 30
- Email, G. Skinner to R. Stubbings, K. Grendreau, 2022 November 30
- Email, G. Skinner to K. Grendreau, R. Stubbings, 2022 December 22
- Email, R. Stubbings to S. Otero, G. Skinner, 2023 January 09
- Email, R. Stubbings to G. Skinner, 2023 January 23
- Email, J. Kennea to G. Skinner, R. Stubbings, K. Grendreau, 2023 January 23
- Email, R. Subbings to G. Skinner. K. Grendreau, 2023 February 08
- Email, K. Grendreau to G. Skinner, R. Stubbings, Z. Arzonmamian, C. Markwardt, 2023 February 09
- Email, K. Grendreau to G. Skinner, R. Stubbings, Z. Arzonmamian, C. Markwardt, 2023 February 10

Abstract

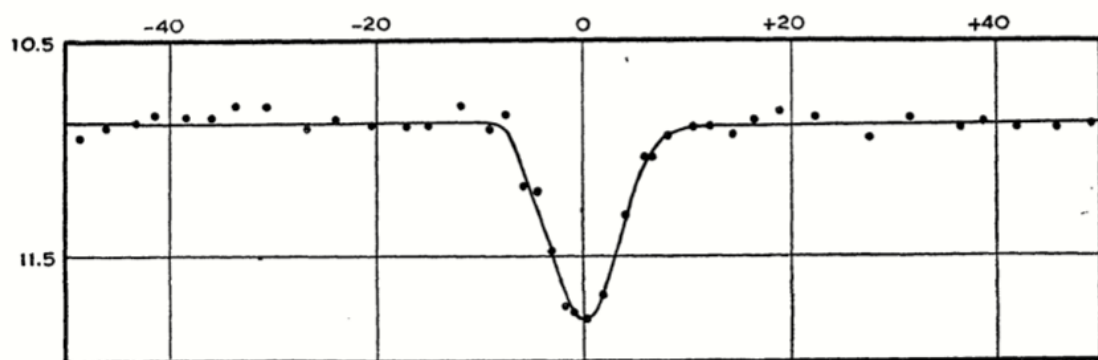
An analysis of times of minimum of the Algol-type eclipsing binary W Vol over the last 20 years (and one from a century ago) was executed. It revealed (a) residuals from the best linear fit greatly in excess of the reported (and likely) errors of the minima estimates, and (b) a mis-identification of the early minimum estimate as secondary. The residuals show no pattern, so not supporting simple non-linear fits. Recent research shows W Vol has a Delta Scuti primary, which can account qualitatively for the irregularities. But the available data are insufficient to draw any astrophysical explanation of them, or of the mis-identification of the minimum type of the early estimate.

Introduction

W Volans (RA 07 37 40.05, Dec. -69 32 32.4, J2000), is catalogued in the GCVS (Samus *et al* 2017) as an Algol-type (EA) eclipsing binary possibly of subtype AR: (wrongly as it turns out) – i.e. both components subgiants. The VSX (Watson. et al 2006) lists its period as 2.75815 d and V magnitude 10.6 to 11.8, following (Dvorak 2004). It was discovered by Annie Cannon at the beginning of last century. Later, Waterfield published a light curve and period analysis of the system, using plates mainly taken with a one-inch lens (Waterfield 1927). Of his 342 plates, just fourteen were in the primary eclipse curve which he used to derive his ephemeris (1).

$$T_0 = \text{JD } 2416846.411(8) \text{ d}, P = 2.758361(8) \text{ d} \quad (1)$$

Figure 1 reproduces his phased eclipse curve. The primary is deep and well-defined, and part of the extremely shallow secondary eclipse can be seen at the left edge. This is the eclipse curve of a brighter star transiting a dimmer star (secondary eclipse), then being occulted by it.



Mean Light Curve of W Volantis

Ordinates are photographic magnitudes; abscissae are hundredths of the period.

Figure 1. Waterfield's eclipse curve for W Vol, Reproduced from (Waterfield 1927).

The next event in its photometric history was a re-assessment of its ephemeris by Dvorak (2004) using epoch photometry from ASAS-3 (Pojmanski 1997). His ephemeris is:

$$T_0 = \text{HJD } 2452229.8 \text{ d}, P = 2.75815 \text{ d} \quad (2)$$

As Dvorak notes, the rather different period estimate likely indicates a real period change.

Very recently Ulas & Ulusoy (2023), using epoch photometry from TESS (Ricker *et al.* 2014), showed (along with IQ CMa and AW Men) that W Vol has a Delta Scuti component. The DSCT oscillations show up in its phased light curve (Figure 2), especially in the secondary minimum, indicating the DSCT star is the primary. They showed that the binary was semi-detached, with the DSCT component at 7500 K, spectral type A-F, and with a hotspot.

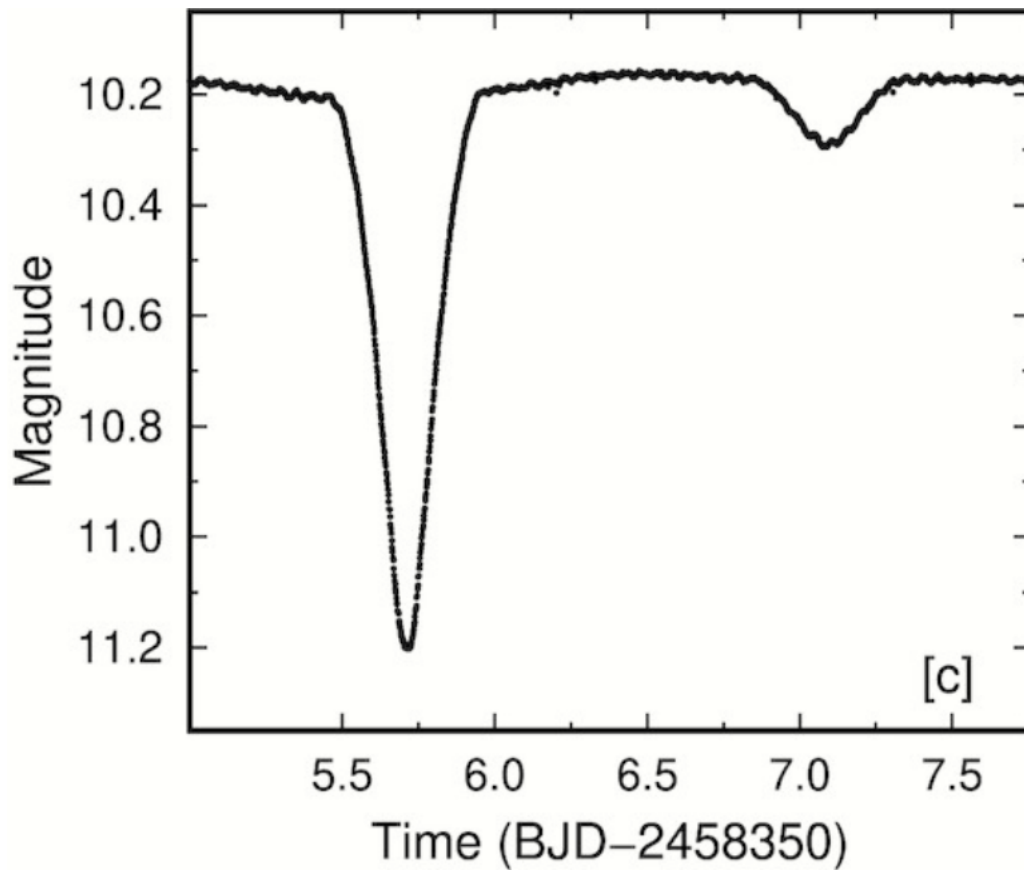


Figure 2. *W Vol light curve showing DSCT oscillations. Reproduced from (Ulas & Ulusoy, 2023)*

The presence of a pulsating component and a hotspot (and associated stream) makes finding of long-term period trends somewhat elusive. Over shorter periods, folding epoch photometry into a phased light curve can produce errors larger than usual; in the long term erratic as well as secular period changes can be expected, as this paper will show.

Method

Eight minima estimates were culled from available sources, as in Table 1.

Table 1. Minima estimates

HJD of min	Error	Source
2416846.411000	0.008	W'field
2452229.800000		Dvorak
2452508.383735	0.008	ASAS-3
2454135.703447	0.009	ASAS-3
2456698.060740	0.0019	TR
2458355.710102	0.0016	TESS
2458479.826670	0.0017	TESS
2458921.127169	0.0019	TR

The Waterfield estimate does not include a heliocentric correction. That makes no significant difference to his error estimate, so the estimate is treated here as HJD. The two ASAS-3 estimates are by the author from ASAS-3 epoch photometry, covering the first and second halves of the ASAS-3 data range. The data were phased on their best period fit using ANOVA in Peranso (Paunzen & Vanmunster, 2016) with phase 0 set as a time halfway through the data range of the dataset. Then the phase of minimum was found using a polynomial fit and converted to a time of minimum. The two TR estimates were

from photometry by the author, and the estimates from TESS data were by Brent Joyce and Roy Axelsen.

These minima estimates were then analysed for ordinary least squares regression fits using a code by the author.

Results

Figure 3 shows the (O-C) diagram of the minima estimates, using the Dvorak ephemeris (2) for reference. Plainly it is a poor fit to the data, indicating a different period.

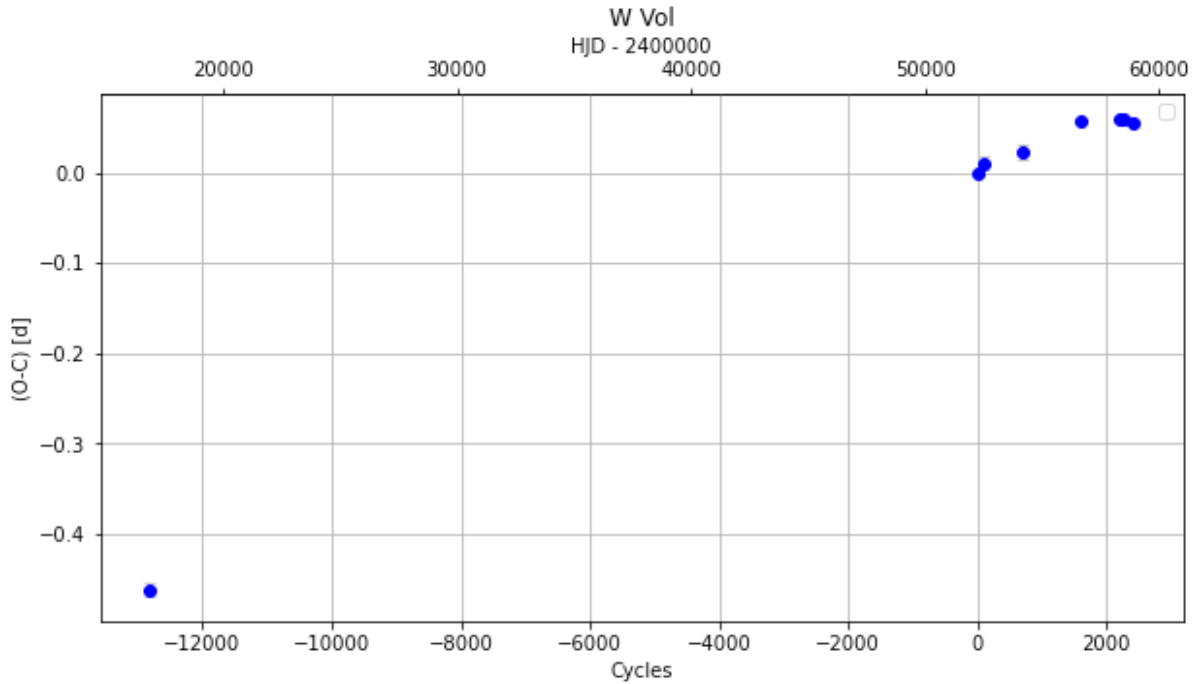


Figure 3. (O-C) diagram using the Dvorak reference ephemeris (2)

To find a better period, a linear ordinary least squares fit was made to these data as shown in Figure 4.

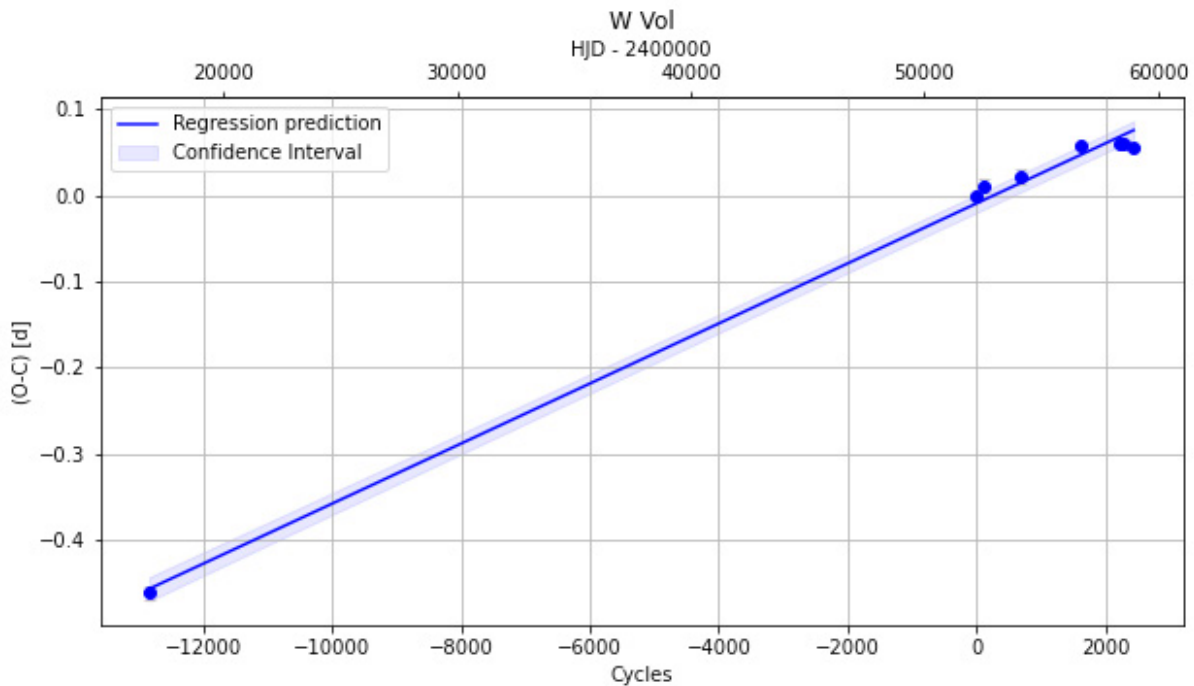


Figure 4. Linear fit to the (O-C) data in Figure 1.

For this fit, the Adjusted $R^2 = 0.994$, but the standard error of the regression (an indicator of goodness of fit) $S = 0.014$ d, is poor. Moreover, the Waterfield data point, as calculated by this ephemeris, is a secondary minimum – which it is not. The ephemeris for this regression is

$$T_0 = \text{HJD } 2452229.790(5) \text{ d}, P = 2.7581848(10) \text{ d} \quad (3)$$

Note the high standard error for T_0 .

The inclusion of the Waterfield data point at the left edge may be seen to force the linear fit, so that without it the fit would be different. This is indeed the case. Figure 5 shows a linear fit on all data except the Waterfield datum, again using Dvorak as reference ephemeris.

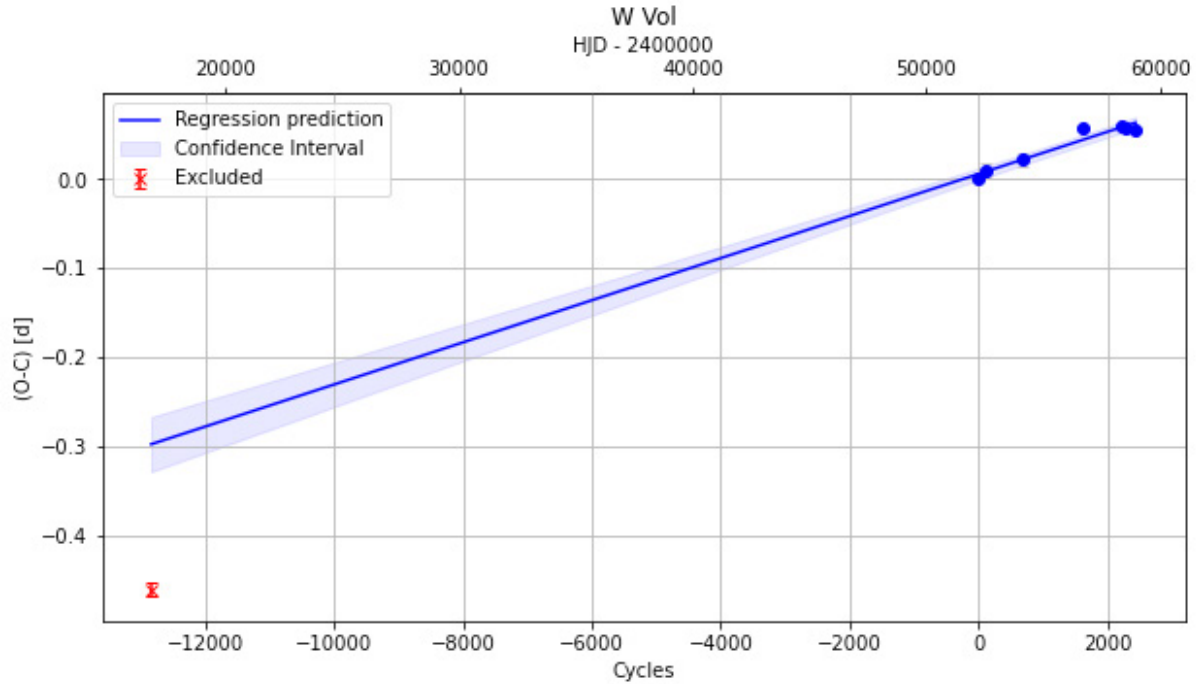


Figure 5. Linear fit on all data except Waterfield.

Here, Adj. $R^2 = 0.914$, $S = 0.008$ d – still high. The ephemeris is

$$T_0 = \text{HJD } 2452229.806(5) \text{ d}, P = 2.758174(3) \text{ d} \quad (4)$$

The T_0 standard error is still large. This ephemeris correctly calculates the Waterfield datum as a primary minimum. However since not forced to fit the Waterfield datum, this regression is the best fit to the other data. The standard error of the regression $S = 0.008$ d. Some residuals for this fit clearly exceed reasonable errors in time-of-minimum estimation. They are shown in the (O-C) diagram in Figure 6, using Ephemeris (4) as reference. The leftmost datum is Dvorak, with an unlikely residual. The next two are ASAS-3, close to prediction and well within their error bounds. The two close together on the right are TESS – again within prediction. But the highest and lowest (O-C) values are TR, and those residuals are well outside the error bars of the two estimates. So this diagram is capturing the effect of small variations in time of photometric minimum.

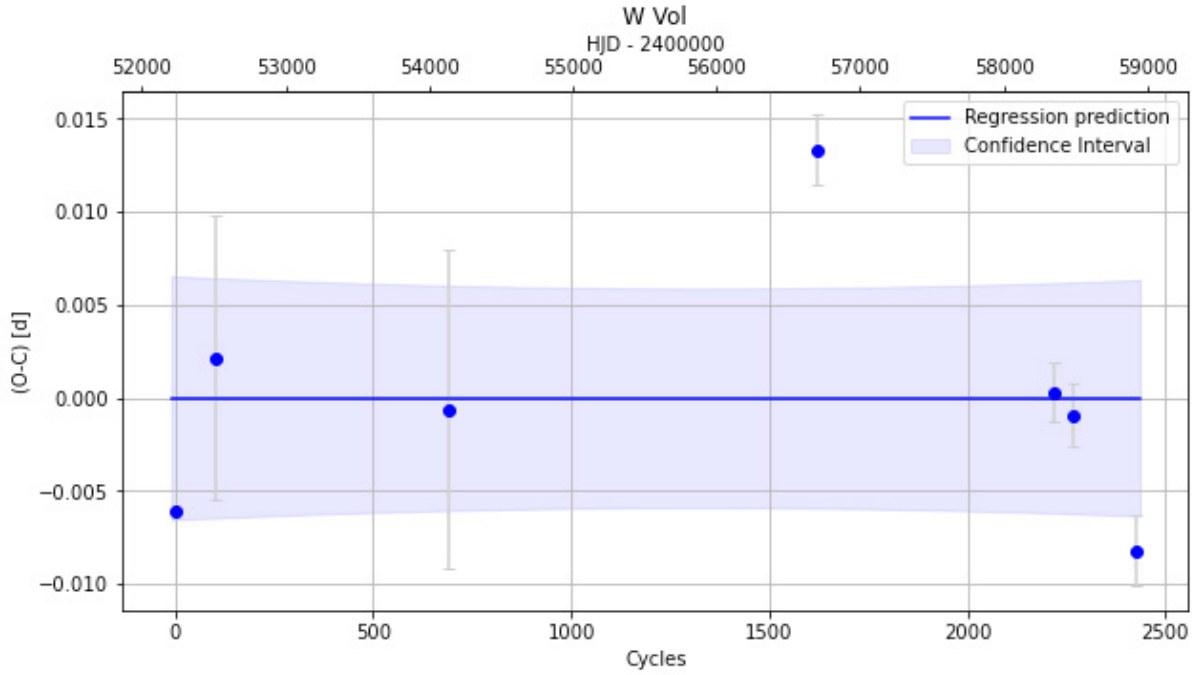


Figure 6. (O-C) diagram with (4) as reference ephemeris, showing only sources ASAS-3, TESS, TR.

Figure 6 makes it clear there is no acceptable quadratic fit to the data shown – which would indicate a constant change in period. Nor is there an oscillating trend. So the best result is the linear ephemeris (4) as shown in Figure 5, with poor fits to much of the data as shown in Figure 6 – and to Waterfield in Figure 5.

Conclusion

The best ordinary least squares linear fit to the recent (non-Waterfield) data produces Ephemeris (4) above. Its period only agrees with Dvorak's to within 3×10^{-5} d and the agreement with Ephemeris (1) from Waterfield is an order of magnitude worse. Whilst this may suggest that a change of period, perhaps abrupt, occurred after that time, the large gap in the data prevents that being more than speculation uncorroborated by the linear trends in Figures 4 and 5.

Since W Vol contains a Delta Scuti type star, there is a level of short- and medium-term activity – the DSCT pulsations, the hotspot and the stream to it – such that a photometric eclipse minimum time may be significantly different from the time of centre of the geometric eclipse, i.e. well outside the measurement error of the minimum. Thus while Ephemeris (4) is the best linear estimate of a period over the last two decades and the best predictor of a geometric eclipse centre, a prediction of a future eclipse in coming years is likely to be in error by more than given by the ephemeris uncertainties.

Despite – or because of – these problems there is much value in obtaining future minima estimates over a period of decades. They may reveal in the medium-term a pattern to the residuals that does not show up in Figure 6. They may indicate more definitively a long-term change in period as the dynamics of the system evolve due to mass transfer and/or mass loss.

Acknowledgements

The author acknowledges the assistance of Brent Joyce and Roy Axelsen in obtaining minima data from TESS epoch photometry, and to Roy for reviewing this article for publication.

This paper includes data collected by the TESS mission, which are publicly available from the Mikulski Archive for Space Telescopes (MAST).

References

Dvorak, S.W. 2004. IBVS 5542, 1-4. Online via <https://ui.adsabs.harvard.edu/abs/2004IBVS.5542....1D/abstract>

Samus N.N., *et al.*, (2017) *General Catalogue of Variable Stars*: new version. GCVS 5.1, *ARep*, 2017, 60, 1. Online at <http://>

- Paunzen, E., Vanmunster, T., 2016, *Astronomische Nachrichten* 337, 23. Peranso website at <https://www.cbabelgium.com/peranso/>
- Pojmanski, G., 1997, *Acta Astronomica*, 47, 467. Database online at <http://www.astrouw.edu.pl/asas/?page=acvs>
- Ricker, George R. *et al.* 2014, *Journal of Astronomical Telescopes, Instruments, and Systems*, 1:1. Database access via <https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html>
- Ulas, B & Ulusoy, C. 2003. *MNRAS* 518, 4180-4190. Online at <https://academic.oup.com/mnras/article/518/3/4180/6832286>
- Waterfield, W.F.H., 1927. *HCO Bull.* 853. Online at <https://ui.adsabs.harvard.edu/abs/1927BHarO.853....3W/abstract>
- Watson, C.L., Henden, A. A., and Price, C. A. 2006, *The Society for Astronomical Sciences*, 47. Database access at <http://www.aavso.org/vsx>
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Telescope seeks new home – *Tom Richards*

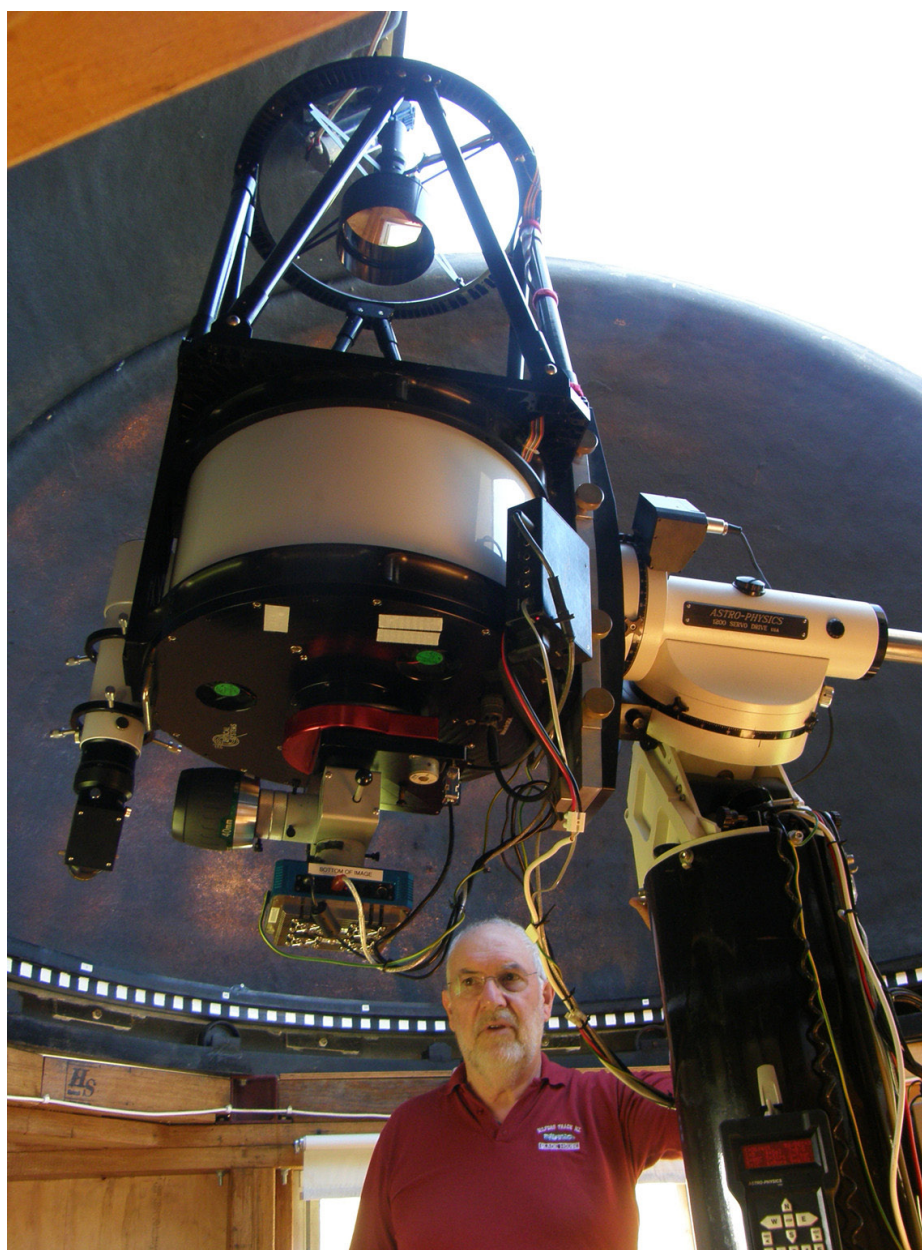
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The time has come to end my observing career and concentrate on analysis.

I suppose I've been observing the universe for over seventy years, ever since I saw the bright comet of 1946 over the Karori hills. My present observatory started life in our back yard in Eltham, Vic. Later we transported the dome and equipment to our new home in Kangaroo Ground where it is conveniently located through a door from the study.

The 16-inch RCOS Ritchey-Chrétien, which I bought in 2008, has never even needed re-focusing. On top of an Astro-Physics AP-1200 GEM it tracks within an arcsec or so for minutes at a time, giving me years of high-quality time-series data on eclipsing binaries – much of which awaits further analysis.

So now, scope and mount are up for sale. Any offers? When they have a new home I'll get around to dismantling the observatory. I plan to continue period analysis of eclipsing binaries for publication – ones I've observed or not – and contributing to this newsletter.



Measuring another planet: Exoplanet XO-1B – *Simon Sikora*

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Astronomy first interested me during a period of quarantine when I began reading, watching, and learning about black holes, space-time, and other phenomena. I had heard of these theories before, when as a kid I would watch PBS TV programs. Later, during high school I began learning physics, the topic underlying all these astronomical phenomena. This interest led me to reach out to Harper College, a two-year community college on the outskirts of Chicago. It led to me working with Dr. Timothy Banks (adjunct faculty at Harper College and a data scientist at Nielsen) to study the exoplanet XO-1b. This exercise taught me how “physics” and “astronomy” can complement each other and even intertwine. The project stretched from researching to publishing and so introduced me to academia and how science is used to make discoveries today.

Our project was interested in learning the orbital period, inclination, planetary radius, and mid-transit times of XO-1b. Why this planet? It was the suggestion of Frank Sienkiewicz, of the Harvard-Smithsonian Center for Astrophysics, who already had imaging data collected and kindly made it all available to me to analyze. There were many nights of data, each centered on a transit of XO-1b. A transit is when a planet crosses the disc of its host star (in our line of sight) causing a dimming in light coming from the system. By modeling the periods of these dimmings, we could notice variations among the mid-transit times. Such transit timing variations (TTVs) could suggest that an additional planet is part of the XO-1b system, and its gravitational effect is impacting XO-1b’s orbital period. The shape of the dimming, and its duration, gave us information about the relative size of the planet compared to its host star, as well as into the orbit of the planet. In passing please note that we could not see the exoplanet and the host star as separate objects, instead we measure the light of the total system and have to apply mathematical models to understand the dimming of the host star as some of its light is blocked from our view as the exoplanet passes in front of it (from our viewpoint).

To first observe these mid-transit times we analyzed CCD images of XO-1b’s transits from 2018 to 2021. This data came from the Harvard-Smithsonian Center for Astrophysics MicroObservatory (MObs) robotic telescope in Arizona. We used the Python software package “Exotic” (developed by the Jet Propulsion Laboratory’s “Exoplanet Watch” program) to reduce all the transit data and produce a transit light curve for each individual night. Part of using Exotic meant choosing a couple of “comparison stars” for Exotic to measure against the brightness of XO-1b’s system. In order to choose these “comparison stars” we would first use a technique called “plate solving” to know where XO-1b is in the CCD image by using the RA and DEC coordinate results that “plate solving” would provide. After locating XO-1b, we would use a finding chart (provided by AAVSO) to identify bright nearby stars to use as “comparison stars”.

In the end, we modeled 11 transits from clear nights, and only 2 of these were complete transits (showing the dimming from start to finish). An example of a complete transit is shown in Figure 1, Telescope time is a precious commodity, so we knew that the observing time for the transits would have been carefully chosen. Because the majority of transits were incomplete, it might indicate transit timing variations. To further analyze this we used additional data from the TESS space telescope, and amateur astronomers’s sourced data (from the NASA Exoplanet Archive, NEA) to model more light curves for XO-1b and see what this additional evidence would suggest. There were 11 further transits available from amateur astronomers, expanding the data set nicely.

Using Exotic we modeled 4 transits from the TESS data and then using a code written in R estimated an orbital inclination from mathematical models of the expected dimming caused by transits. There was some variation in the estimates for different transits, as it seems that the host star is varying in brightness itself a little. For example, the orbital inclination in one transit measured by TESS was 89.03 ± 0.04 degrees, while in another it was 88.26 ± 0.12 degrees. The formal errors do not overlap, suggesting that they are underestimates and that we were not accounting fully for the stellar variation. This is something later researchers might like to look into. Using data from TESS allowed us to estimate an orbital radius around 11.10 ± 0.15 times the radius of the host star and the planetary radius 0.1300 ± 0.0016 times the stellar radius. We therefore used the TESS data to derive estimates for the physical parameters of the system since it is of very high accuracy. We could still use the ground-based photometry to measure the mid-transit times, and in turn look into period variations.

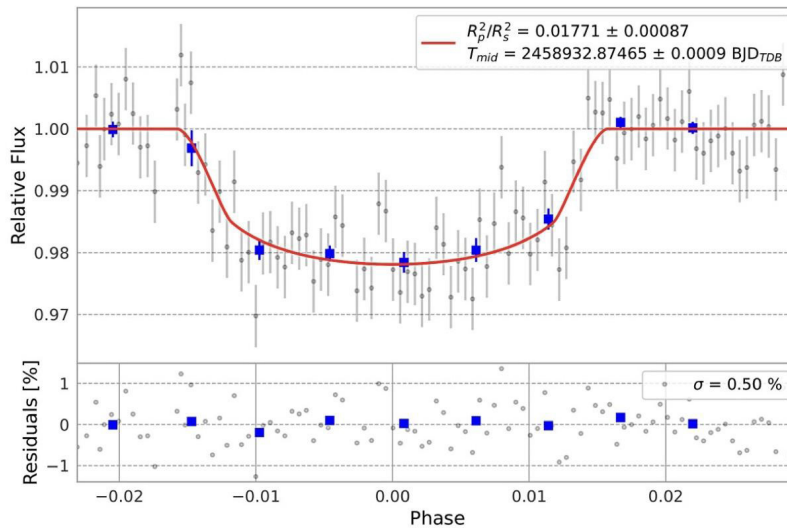


Figure 1. An example of a complete XO-1b transit. It plots the measured flux vertically against time (the horizontal axis). We can clearly see the dimming caused when the exoplanet passes in front of its star. This light curve was modeled by Exotic for data from the night of March 23, 2020. The red line is the model fit to the data (which are the points with error bars). The blue dots represented average data. The lower chart plots the residuals (the difference between the data and the model).

Using data from the NEA, we first chose data sets with complete or nearly complete transits, and created transit models for them using Exotic. Based on these models, Exotic estimated the mid-transit times which we then used in regression analyses across all of these mid-transit times. We estimated that XO-1b completes an orbit in around 3 (3.9415049 ± 0.0000008) days. This agrees with estimates from previous scientists studying XO-1b. In addition, we found no evidence to suggest that XO-1b has transit timing variations. This was a little disappointing, but at least we have confirmed that there is not another planet influencing the orbit of XO-1b through its gravitational attraction — at least that we could confirm with the current observational data and the simple transit models we applied.

I am very grateful to Prof. Banks for his guidance that brought the XO-1b project to fruition and his always willing support to make sure my questions were answered. Not only did I learn a lot about astronomy, but I also learned about how much dedication scientists put into making discoveries. As mentioned in our paper, because of the large and continuously growing database of imagery available these types of exoplanet and variable star projects are available for interested individuals and are “worthwhile” (S. Sikora and T. Banks, 2023, JAAVSO Volume 51, page 148). Hopefully these results will contribute to further ongoing research and help the world know more about XO-1b. There is a lot of data online, so interested students could make use of that to study other exoplanet systems, even if they do not have access to a suitably equipped telescope. Exotic is also an easy to learn software tool and makes reducing the data easy. If you’re interested in contributing to our knowledge about exoplanets, I’d encourage you to give it a go. You’ll certainly enjoy the experience!

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Ed Budding along with several other VSS members published a paper in MNRAS on VV Ori

Budding, Edwin; Southworth, John; Pavlovski, Krešimir ; Rhodes, Michael D. ; Zihao, Wu ; Love, Tom; Blackford, Mark G. ; Banks, Timothy S. ; Alexander, Murray, *The enigmatic multiple star VV Ori*, Monthly Notices of the Royal Astronomical Society, Volume 527, Issue 3, pp.6389-6405

Abstract

New photometry, including TESS data, have been combined with recent spectroscopic observations of the Orion Ib pulsating triple-star system VV Ori. This yields a revised set of absolute parameters with increased precision. Two different programmes were utilized for the light-curve analysis, with results in predictably close agreement. The agreement promotes confidence in the analysis procedures. The spectra were analysed using the FDBINARY programme. The main parameters are as follows: $M1 = 11.56 \pm 0.14$ and $M2 = 4.81 \pm 0.06$ ($M_{\odot}$). We estimate an approximate mass of the wide companion as $M3 = 2.0 \pm 0.3 M_{\odot}$. Similarly, $R1 = 5.11 \pm 0.03$, $R2 = 2.51 \pm 0.02$, $R3 = 1.8 \pm 0.1$ ($R_{\odot}$); $Te1 = 26600 \pm 300$, $Te2 = 16250 \pm 420$, and $Te3 = 10000 \pm 1000$ (K). The close binary's orbital separation is $a = 13.91$ ($R_{\odot}$); its age is 8 ± 2 (Myr) and its photometric distance is 396 ± 7 pc. The primary's β Cep type oscillations support these properties and confirm our understanding of its evolutionary status. Examination of the well-defined $\lambda 6678$ He I profiles reveals the primary to have a significantly low projected rotation: some 80 per cent of the synchronous value. This can be explained on the basis of the precession of an unaligned spin axis. This proposal can resolve also observed variations of the apparent inclination and address other longer term irregularities of the system reported in the literature. This topic invites further observations and follow-up theoretical study of the dynamics of this intriguing young multiple star.

Phil Evans was a co-author on an arXiv paper with first author Jack Schulte.

Schulte, J et al. *Migration and Evolution of giant ExoPlanets (MEEP) I: Nine Newly Confirmed Hot Jupiters from the TESS Mission*. arXiv:2401.05923.

Abstract

Hot Jupiters were many of the first exoplanets discovered in the 1990s, but in the decades since their discovery, the mysteries surrounding their origins remain. Here, we present nine new hot Jupiters (TOI-1855 b, TOI-2107 b, TOI-2368 b, TOI-3321 b, TOI-3894 b, TOI-3919 b, TOI-4153 b, TOI-5232 b, and TOI-5301 b) discovered by NASA's TESS mission and confirmed using ground-based imaging and spectroscopy. These discoveries are the first in a series of papers named the Migration and Evolution of giant ExoPlanets (MEEP) survey and are part of an ongoing effort to build a complete sample of hot Jupiters orbiting FGK stars, with a limiting Gaia G-band magnitude of 12.5. This effort aims to use homogeneous detection and analysis techniques to generate a set of precisely measured stellar and planetary properties that is ripe for statistical analysis. The nine planets presented in this work occupy a range of masses ($0.55 M_{\text{Jupiter}} < M_p < 3.88 M_{\text{J}}$) and sizes ($0.967 R_{\text{Jupiter}} < R_p < 1.438 R_{\text{J}}$) and orbit stars that range in temperature from $5360 \text{ K} < T_{\text{eff}} < 6860 \text{ K}$ with Gaia G-band magnitudes ranging from 11.1 to 12.7. Two of the planets in our sample have detectable orbital eccentricity: TOI-3919 b ($e=0.259^{+0.033}_{-0.036}$) and TOI-5301 b ($e=0.33^{+0.11}_{-0.10}$). These eccentric planets join a growing sample of eccentric hot Jupiters that are consistent with high-eccentricity tidal migration, one of the three most prominent theories explaining hot Jupiter formation and evolution.

About

Variable Stars South is an international association of astronomers, mainly amateur, interested in re-searching the rich and under-explored myriad of southern variable stars.

Renamed from the Variable Star Section of the Royal Astronomical Society of New Zealand, it was founded in 1927 by the late Dr Frank Bateson, OBE, and became the recognised centre for Southern Hemisphere variable star research.

VSS covers many areas and techniques of variable star research, organised into projects such as Beginners' Visual Observations and Dual-Maxima Miras. The goal of each project is to obtain scientifically useful data and results. These may be published in recognised journals, or supplied to international specialist data collection organisations.

VSS is entirely an internet based organisation, working through our website <http://www.VariableStars-South.org> and its e-group <http://groups.google.com/group/vss-members>. It also encourages members to work in with major international organisations such as the British Astronomical Association, the Center for Backyard Astrophysics and the American Association for Variable Star Observers.

To find out more, please visit our website, where, incidentally, you will find PDF copies of all our newsletters. Our website has a great deal of information for VSS members, and for anyone interested in southern hemisphere variable star research. All VSS project information and data is kept here too.

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These are welcomed and should be sent to the Editor (phil@astrofizz.com). I'd prefer Microsoft Word (or compatible) files with graphics sent separately. Don't use elaborate formatting or fancy fonts and please do not send your contribution as a fully formatted PDF file.

Publication dates are January, April, July and October, nominally on the twentieth day of these months and the copy deadline is the thirteenth of the month though earlier would always be appreciated.

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