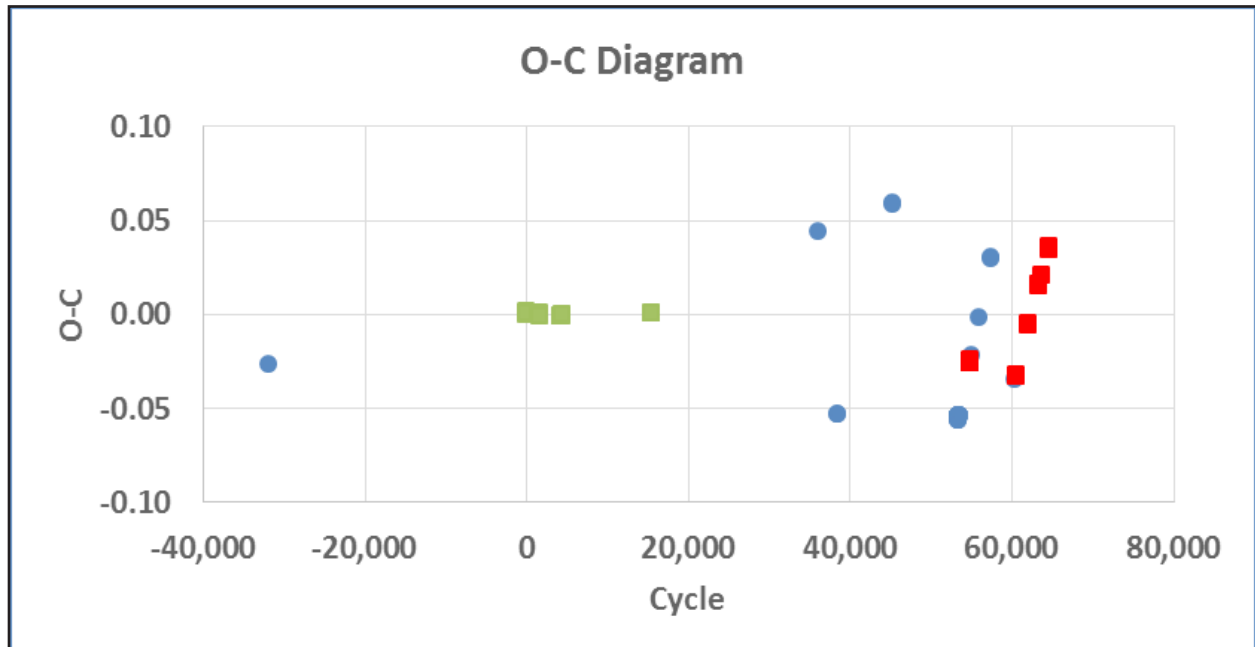




Mark Blackford (page 5) has been examining the times of minimum for the variable star RV Grucis. The observed minus calculated (O - C) diagram of all available Times of Minimum for this star is shown using the VSX reference epoch and period. Red squares are VSS data, green squares are Covino (1988) data and all others plotted as blue circles. Mark notes that one thing stands out: that the early data points lie more or less on a horizontal line whereas from cycle 60,000 onwards they are steeply sloping, suggesting that the period is changing. In turn this means that the cycle count of the later points is likely wrong since it is based on the early VSX period. Also in this issue Tom Richards and Greg Crawford delve into possible period changes signaled by a confusing O - C plot for the variable star FM Vel.

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From the Director – *Mark Blackford*

As I write this column the 2021 RASNZ Conference in Wellington is wrapping up. Unfortunately I could not attend but the scientific and social programmes looked very interesting. Hopefully the presentations were recorded and will be made available online sometime soon.

The much anticipated eclipse of V777 Sgr was successfully recorded by Cameron McEwing in New Zealand, Dave Blane in South Africa and yours truly in Australia. Between us we managed to capture both the ingress phase in late April and egress phase in late June. It will take some time to analyse these new observations along with those from previous eclipses.

In early July I participated in the AAVSO's "A Quick Guide on VSX" How-to Hour presented by Sebastián Otero. It was an excellent introduction to using the Variable Star Index database, a treasure trove of variable star information that AAVSO makes freely available to the amateur and professional communities. The meeting was recorded and should soon be available on the AAVSO YouTube channel along with previous webinars and How-to Hours (https://www.youtube.com/playlist?list=PLnZ_rvnR35re3ZxnumCnlesanWvUyy9eB). The schedule for AAVSO's future free online webinars and how-to hours can be found at <https://www.aavso.org/2021-webinars>.

Congarinni Observatory has enjoyed quite a good run of clear night-time skies in recent months. This has allowed me to record many Times of Minimum for the VSS Southern Eclipsing Binary Project, some of which have proved difficult to reconcile with previous observations. Elsewhere in this newsletter I present my analysis of the perplexing Observed minus Calculated diagram of RV Gru.

Wishing you all clear skies and good health,

Mark Blackford



Summary

The variable ZZ Car has been known since 1904, but its exact position is still a little uncertain, even today. This investigation resolves the matter beyond reasonable doubt.

Introduction

A list of ten new variables in Carina, discovered on Harvard plates, was published by Pickering (1904). Nine have subsequently been studied and classified, but the remaining star, no. 18 in his list, is still poorly known, though it has been named ZZ Car. My purpose is to establish its precise position, by studying archival material, and comparing with modern photometry.

Basic data

ZZ Car = HV 807 = No. 18 (HC 79). Range 13.4 - 14.5p. Period / class unknown.

Nominal position; (1900) $10^{\text{h}}50^{\text{m}}.4$ $-58^{\circ}15'$ (2000) $10^{\text{h}}54^{\text{m}}28^{\text{s}}$ $-58^{\circ}46'58''$

No finder chart was published. However, Innes (1914) had a plan to map 36 variables, then known, in the vicinity of Eta Car. He chose to blink two of his own plates (1911 April 18, 1914 April 27, mag. limit 16p). Variables would be recovered by observing magnitude variations between plates. This method succeeded in finding about 50% of the targets. For the remainder the variation, if present, was too small, and did not work. A subset of nine stars, ZZ Car included, was dismissed with the terse remark “*Not found*”.. It turns out that almost all of this group of nine are true variables, and were within reach of his plates, being brighter than 14.0p at part, or all, of their cycle.

For a portion (enlarged) of the Innes chart see **Figure 1**. “25” = WX Car, “26” = WY Car and “27” = ZZ Car appearing with an open circle, to indicate that no variation was found at the spot, nor positive identification. ZZ Car lies 9' NE of **u Car** = **NSV5011**, and just NW of HD94663.

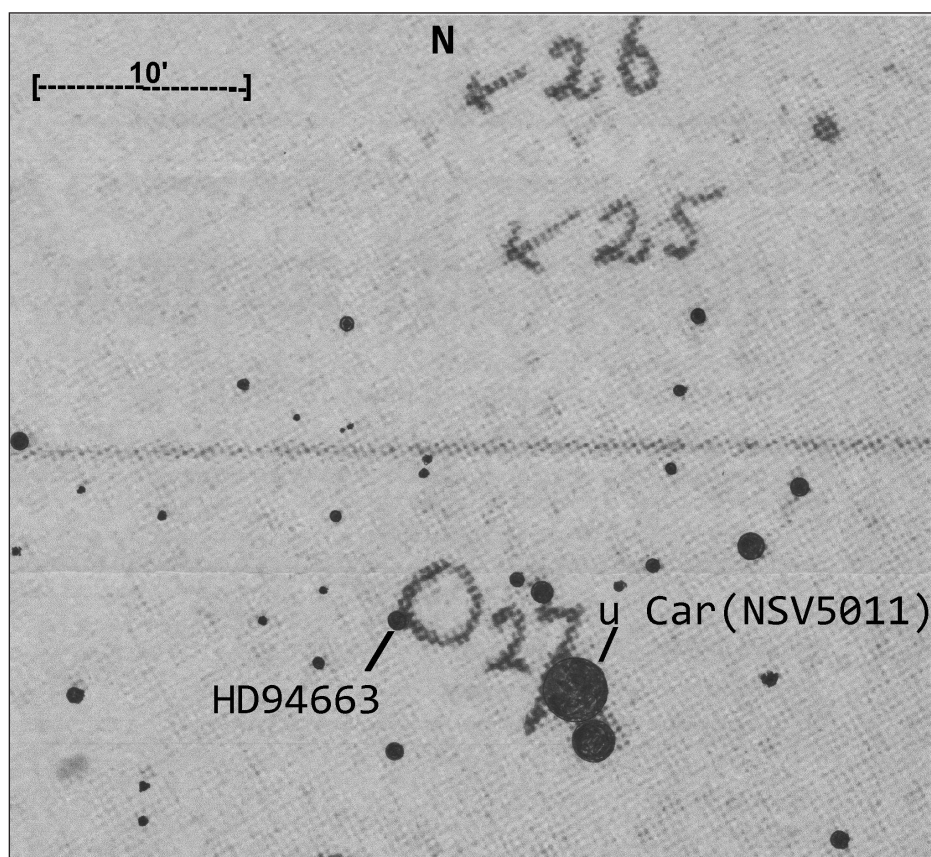


Figure 1. 27 = ZZ Car, from UOC 18.

Stars of interest

Three stars near Innes' error circle for ZZ Car are as follows.

A	(J2000)	10 54 23.71	-58 46 55.9		Wrong identification? (VSX)	15.65B	15.14V	APASS
B	"	10 54 29.160	-58 47 4.88	G=13.53	Gaia EDR3	14.01B	13.58V	"
C	"	10 54 32.64	-58 46 40.2		GDS_J1054326-584640	15.31B	14.78V	"

Stars A, B and C are shown in **Figure 2**, a reproduction of a UKST IR plate (less crowded than blue or red). The nominal position of ZZ Car is shown by a cross, close to star **B**.

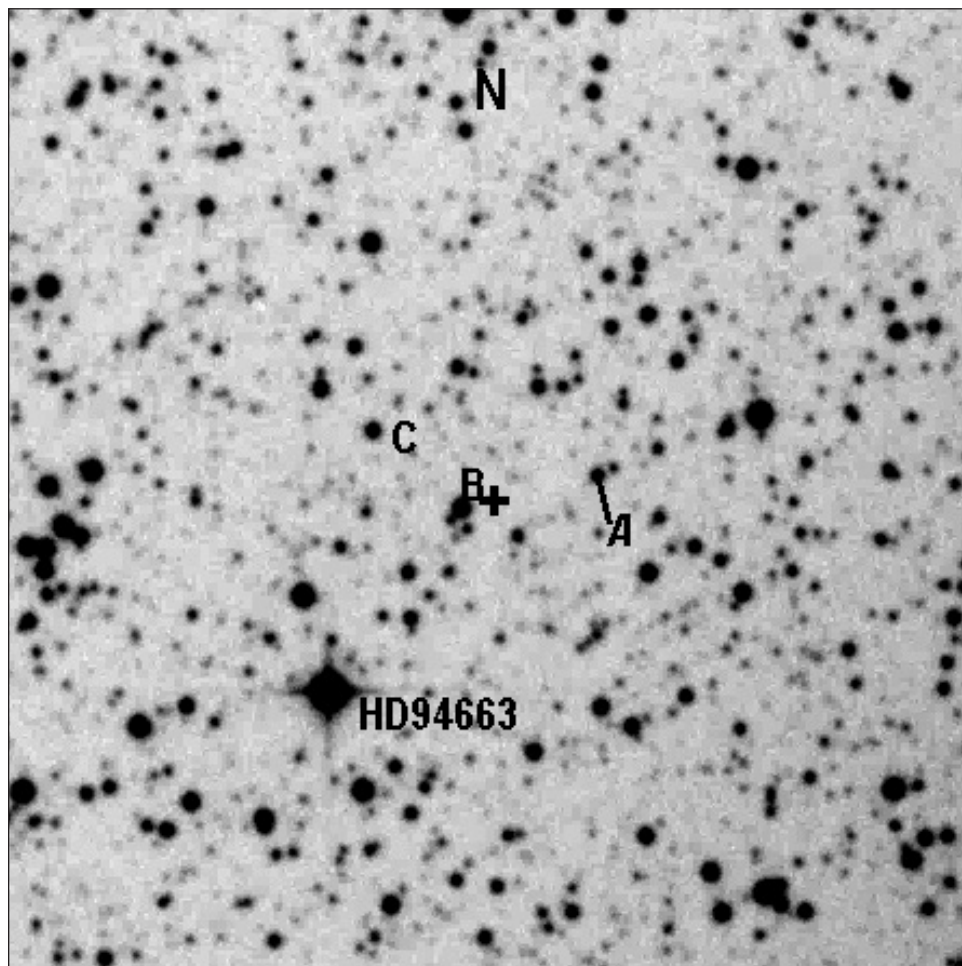


Figure 2. *Star B = ZZ Car. IR plate.*

Archival photos

From the DASCH server I have examined at least a dozen plates of the **mf**, **a** and **b** series, from the early 20th century. Star **A** is rarely, if ever, seen even on the best Bruce plates, and generally below the plate limit, and can be discounted. Star **B** is frequently seen, though faint. Star **C**, at 15,3B, is occasionally glimpsed on archival plates, but at the plate limit. From Gaia EDR3 I find that Star **B** has a close companion to the north at (J2000) 10 54 30.145 -58 47 03.36 G= 16.54. There are other companions to the south, and south-east.

Conclusion

By taking into account all material, archival and modern, I conclude that star **B** is ZZ Car, at **(J2000) 10 54 29.160 -58 47 04.88**. EDR3. 69.5" NW of HD94663. Doubtful var.

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Deciphering the RV Grucis O-C diagram – *Mark Blackford*

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RV Grucis is an 11th magnitude W Ursae Majoris-type (EW/KE) eclipsing variable with a very short period of about 0.2595d and almost identical minima. It has been observed as part of the VSS Southern Eclipsing Binaries Project by Tom Richards since 2014 and myself since 2020. Figure 1 shows the Observed minus Calculated (O-C) diagram of our 15 measured Times of Minimum, calculated using the epoch and period listed in AAVSO's Variable Star Index (VSX). Something odd is happening with this O-C diagram, this article is my attempt to understand the underlying cause.

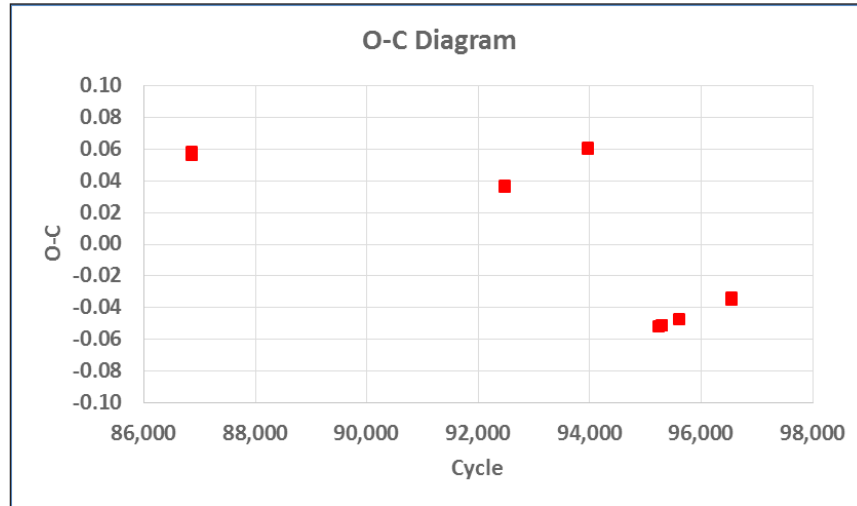


Figure 1. RV Gru O-C diagram of VSS observations using the VSX reference epoch HJD 2434356.434 and period 0.2595186 days. In all Figures the error bars are much smaller than symbols.

Clearly more data were needed. Table V in Covino et al., 1988 lists 19 Times of Minimum recorded between 1975 and 1986. The OC Gateway database (<http://var2.astro.cz/ocgate/>) lists a further 22. I measured 4 from the All Sky Automated Survey (Pojmański 2002), 2 from the All Sky Automated Survey for Supernovae (ASASSN, <https://asas-sn.osu.edu/>) and 1 from observations by the Transiting Exoplanet Survey Satellite (TESS). These are plotted in Figure 2 along with the VSS data.

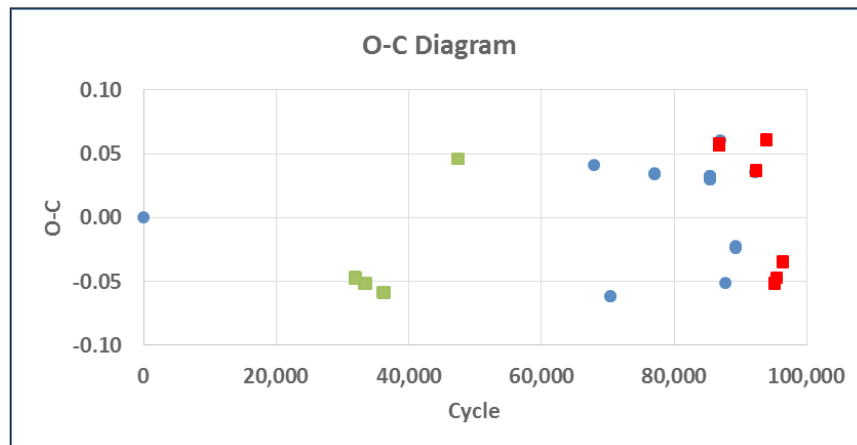


Figure 2. O-C diagram of all available Times of Minimum using the VSX reference epoch and period. Red squares are VSS data, green squares are Covino data and all others plotted as blue circles.

This O-C diagram is no less confusing than Figure 1. I began to suspect that the VSX period might be incorrect. The VSX epoch and period were most likely derived from magnitudes measured from photographic survey plates recorded over several years. They were reported in Hoffmeister, 1956 but I was unable to find a copy of this paper. Covino presented a revised epoch HJD 2442655.7905(2) and period 0.25951625(4) days which yield the O-C diagram in Figure 3.

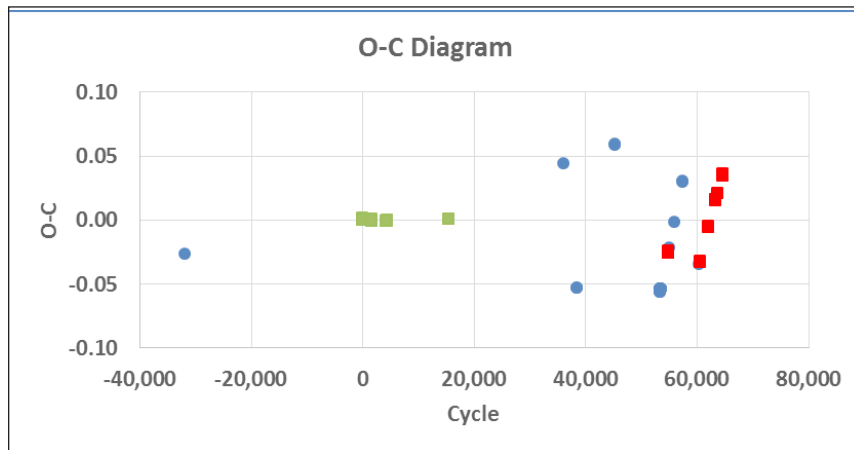


Figure 3. *O-C diagram of all available Times of Minimum using reference epoch HJD 2442655.7905(2) and period 0.25951625(4) days (Covino et al.,1988).*

Some trends were beginning to become apparent. The Covino data points all lay in a horizontal line; whereas the VSS data points from cycle 60,000 onwards lay on a steeply sloping line. This suggested that the orbital period of the binary had become longer, which was confirmed by calculating the average orbital period in 1975-78 and in 2018-20, see Table 1.

Table 1. *Average orbital period derived by linear regression.*

Date range	No. data points	Derived period	Source
31/7/1975 – 13/10/1978	17	0.2595160(1) days	Covino et al., 1988
27/8/2018 – 14/11/2020	8	0.2595333(3) days	Variable Stars South (VSS)

The next piece of the puzzle fell into place when I realized that the increasing period had led to errors in the calculated cycle count (i.e. number of orbital periods between the reference epoch and an observed eclipse). The formula in Excel for calculating cycle number is:

$$\text{Cycle} = \text{ROUND}(((\text{measured ToM} - \text{reference epoch})/\text{period}) * 2, 0) / 2 \quad (1)$$

Equation 1 returns integer (primary eclipse) or half integer (secondary eclipse) values and works well when the reference period is close to the true period and the true period is constant. However, when the reference period is significantly wrong rounding errors can cause primary eclipses to be erroneously identified as secondary eclipses and vice versa. This results in apparent jumps in the O-C diagram whenever the O-C value reaches one quarter of the period. See Tom Richards' article in the previous VSS Newsletter (Richards, 2021) for a detailed treatment of cycle count errors in relation to GZ Puppis.

The situation is somewhat more complicated for RV Gru as the true period appears to be increasing quite rapidly. In order to test this hypothesis I created a simulation in an Excel spreadsheet using the Covino epoch and period as the initial reference values. A fixed rate of period increase of 1.03E-9 days/day (arrived at by trial and error) was then applied. The solid blue line in Figure 4 is the simulated O-C trend. As the period linearly increases the O-C value increases parabolically. The horizontal green line at $O-C = 0.0649$ indicates $\frac{1}{4}$ of the reference period.

When the O-C value reaches 0.0649 for the first time (cycle 22033) Equation 1 incorrectly calculates the cycle number to be 22033.5, i.e. it thinks the primary eclipse is a secondary eclipse, and the O-C value steps from 0.0649 to -0.0649. The O-C value then increases in subsequent cycles until again reaching 0.0649 at which point the calculated cycle number jumps by a further 0.5. The solid orange line shows this sawtooth pattern. The measured data points fall on or close to the orange line.

After correcting for the 0.5 phase jumps we get the O-C diagram in Figure 5. This is now much simpler and is typical of eclipsing binaries with increasing orbital periods (Case e page 282 in Budding and Demircan, 2007). An example is R Ara (Blane et al., 2011) which has an orbital period of about 4.425 days increasing at the rate of 5.16E-9 days/day (Reed, 2011).

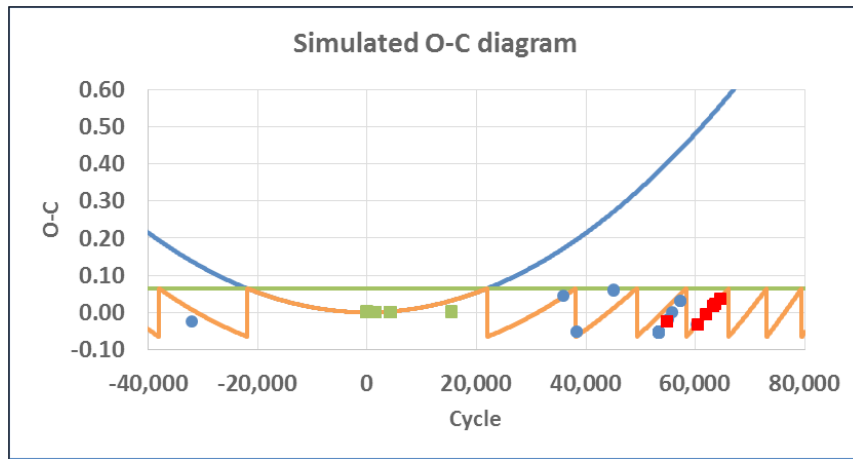


Figure 4. The blue parabolic line shows a simulated O-C diagram for steadily increasing period. The orange saw tooth line shows the effect of cycle count errors arising from Equation 1.

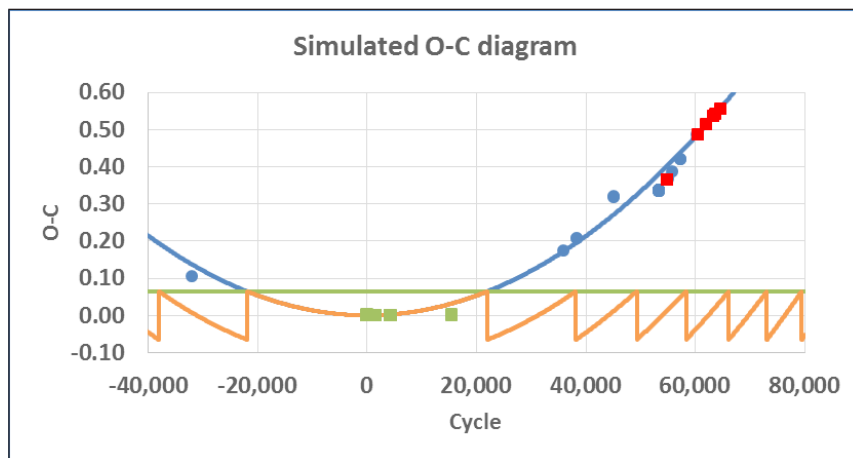


Figure 5. Same as Figure 4 after correcting cycle numbers.

The O-C diagram for R Ara (Figure 3, Blane et al., 2019) does not yet show steps due to cycle count errors despite having 5 times the rate of period change compared with RV Gru. This is because its orbital period is about 17 times longer. The R Ara O-C value in mid-2018 was 0.316 days and needs to reach 1.1 days (i.e. $\frac{1}{4}$ of the orbital period) before a cycle count error occurs. At the current rate of period increase that won't happen for another 50 years or so.

Conclusions

I have demonstrated that the initially complicated O-C diagram of the eclipsing binary RV Grucis was due to cycle count errors as a consequence of the very short orbital period and rapid period change. This showed up as sawtooth steps in the O-C diagram each time the O-C value reached $\frac{1}{4}$ of the reference period.

Correcting cycle count errors resulted in a much simpler O-C diagram typical of eclipsing binaries with increasing orbital periods. However, Figure 5 suggests that the rate of period increase has varied slightly over the 69 years of observations.

Based on the Covino reference epoch and period, and assumed rate of period change, the next cycle count error for RV Gru should occur around mid-2022. New Times of Minimum in coming years will help refine the rate of period change.

This is a work in progress. More data and analysis are required before considering publication in a peer reviewed journal.

Acknowledgements

This research made use of the SIMBAD and VIZIER databases, operated at CDS, Strasbourg, France and of 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).

I gratefully acknowledge the use of the ASAS-3, ASASSN, O-C Gateway and AAVSO VSX databases.

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The eclipsing binary FM Vel has an irregular period – *Tom Richards*¹, *Greg Crawford*²

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Abstract

Minima data from Variable Stars South and online sources were analysed to determine a period for the EW/KW eclipsing binary FM Vel. The analysis shows no ephemeris can be derived that can be expected to be reasonably accurate in the longer term. However a linear ephemeris was derived that will be sufficiently reliable for minima prediction over the next 10 or so years to enable observers to capture minima light curves.

Introduction

FM Vel (RA 09 47 42.27 Dec -53 28 10.6, J2000) is listed in the General Catalogue of Variable Stars (Samus et al, 2017, hereafter GCVS) as an EW/KW eclipsing binary (late-type contact or near-contact system) with photographic magnitude 12.2 to 12.9. The GCVS ephemeris is from 1938, apparently from van Houten (1951). It is also listed in AAVSO Variable Star Index (Watson, Henden, & Price, 2006, hereafter VSX):

$$E = \text{HJD } 2429043.238, P = 0.3895262 \text{ d} \quad (1)$$

Except for occasional minima epoch records (discussed below) and catalogue positional and flux data, no analyses of the system appear to have been carried out. Its southerly declination and shallow eclipses ensured that between the discovery datum and the era of CCD photometry no minima epoch data have been recorded. This study looks at the epoch data recorded since then — mainly from Variable Stars South (VSS) observers — in an attempt to characterize its orbital period P and any changes therein.

Data

The following minima epoch data have been found in the online literature and in VSS records.

Min (HJD 2400000 +)	min_err	filter	source
29043.238000			VSX
52500.151200			Kreiner
53499.680234	0.000740		ASAS3
54994.298000	0.002000		OEJV
57081.984300	0.000300		Nelson
57425.159470	0.000060	V	TR
57445.999730	0.000040	V	TR
57746.130845	0.000164	V	GC
57748.078365	0.000690	V	GC
57749.052975	0.000394	V	GC
57764.638960	0.000000		ASAS-SN
57770.087914	0.000591	V	GC
57804.949327	0.001477	V	GC
57810.987710	0.000400	V	TR
58506.102763	0.000670	SR	TR
58538.043791	0.000750	SR	TR
58539.018103	0.000990	SR	TR
58539.212175	0.000920	SR	TR
58896.022076	0.001020	SR	TR
58896.216614	0.001090	SR	TR
58917.056221	0.000960	SR	TR
58917.251241	0.001300	SR	TR
59290.030576	0.001200	SR	TR
59290.225511	0.001100	SR	TR

Table 1, VSS sources are GC: Greg Crawford, TR: Tom Richards. Online sources are: VSX, ASAS3 (Pojmanski 2002), ASAS-SN (Kochanek et al 2017), Kreiner (2004), Nelson (in Bob Nelson's O-C files, 'Vel FM.xls' accessed via VSX. Data point credited to Pavlov), OEJV (Paschke 2009).

Method and results

The initial process is to try to find a constant period for the variable. The first attempt was to calculate an ordinary least squares (OLS) linear regression on all the minima data, using the VSX ephemeris as a reference. The regression ephemeris, illustrated in Figure 1, is

$$E = \text{HJD } 24529043.227 \pm 0.008, P = 0.3895273 \pm 0.0000001 \text{ d} \quad (2)$$

The regression line is a very poor fit to the data. It lies outside the error bars of all but one data point and the mean residual is the rather high 0.008 d. That is sufficient to rule out a constant period (linear regression line in an O-C diagram) unless there is a cycle count jump in the O-C calculation (Richards 2021). With FM Vel's period of ~ 0.4 d this would occur when data points plotted in the O-C diagram reach $\text{abs}(\text{O-C}) = P/4 \sim 0.1$ d. Such a cycle count jump arises because predicted minima epochs corresponding to observed minima times are calculated from the reference ephemeris to integral orbital cycles (and half-integral for secondary minima). When those predictions are sufficiently different from the corresponding observed minima times to exceed $P/4$, the next calculated minimum jumps by $P/2$. In an O-C diagram that shows cycle count jumps, or would if the right observed data are present, the slope of the data points provides the correction to the reference ephemeris to get a true linear ephemeris – as in the

case of non-jump O-C diagram.

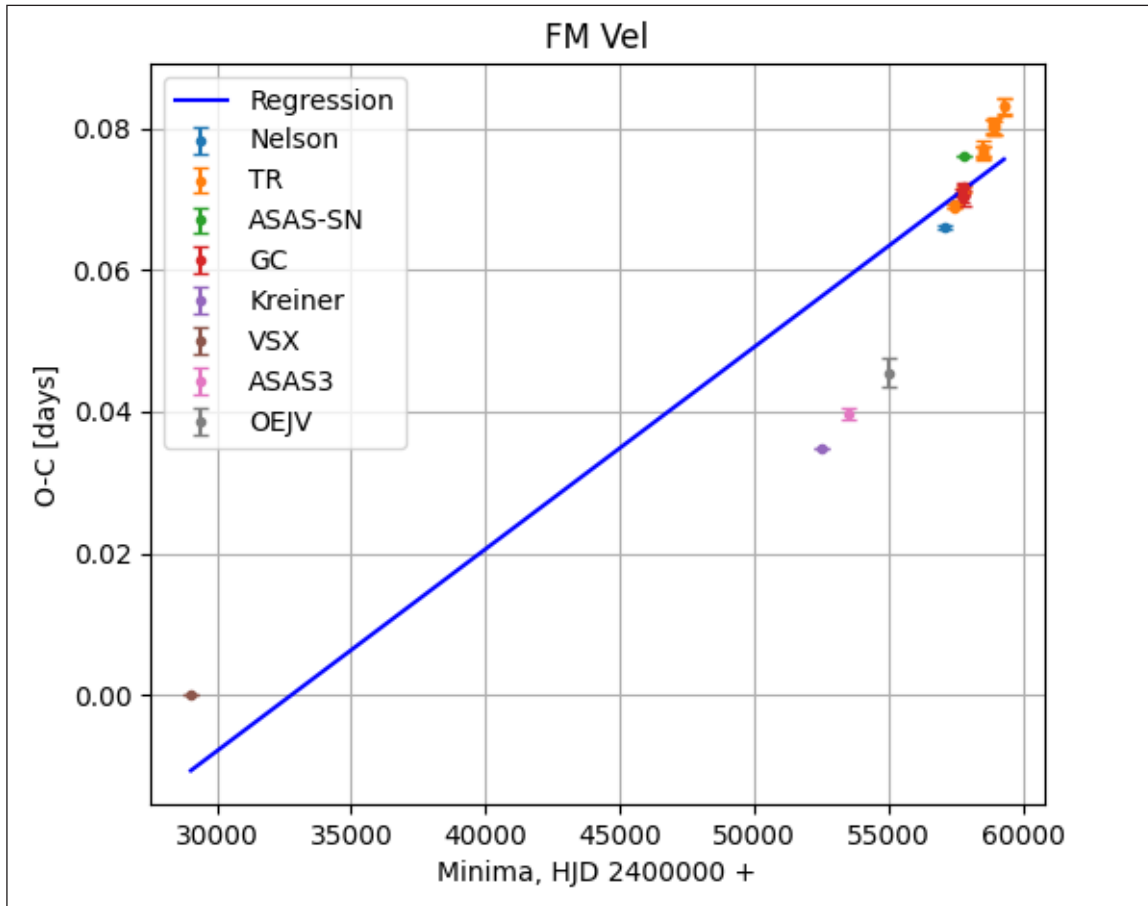


Figure 1. *O-C regression diagram for FM Vel with the VSX ephemeris as reference ephemeris, and showing the linear best fit.*

The latest data points in Figure 1 are approaching the P/4 threshold; so the question is whether, if data were available in the gap from HJD 2430000 to 2450000, would the plotted points climb to $O-C \sim 0.1$ then continue at $O-C \sim -0.1$? That would happen at approximately HJD 2445000. In the present case the data points except for VSX appear roughly linear, indicating a constant period. Even if the nonlinearity of the data in Figure 1 is due to a cycle count jump, the minima points excluding VSX are sufficiently dense and spread in time to provide a linear ephemeris which over the time interval for those points would not contain a cycle jump. But could there be one in the aforementioned data gap?

To investigate this a new reference ephemeris was used with the second TR data point (a primary – deeper – minimum) as epoch and with the regressed period in (2). The VSX data point was excluded from the regression calculation. The result is in Figure 2.

This fit is substantially better than the regression in Figure 1. Mean residual is down to 0.002 d, and the regression line is within most error bars. The regression ephemeris is

$$E = \text{HJD } 2457445.9997 \pm 0.0007, P = 0.38952912 \pm 1.3 \times 10^{-7} \text{ d.} \quad (3)$$

There are three poor data point fits in Figure 2, at approximately 2452500 (Kreiner), 2455000 (OEJV), and 2457700 (ASAS-SN). The last two seem to be erroneous; this is seen more clearly in Figure 3, where the reference ephemeris is (3).

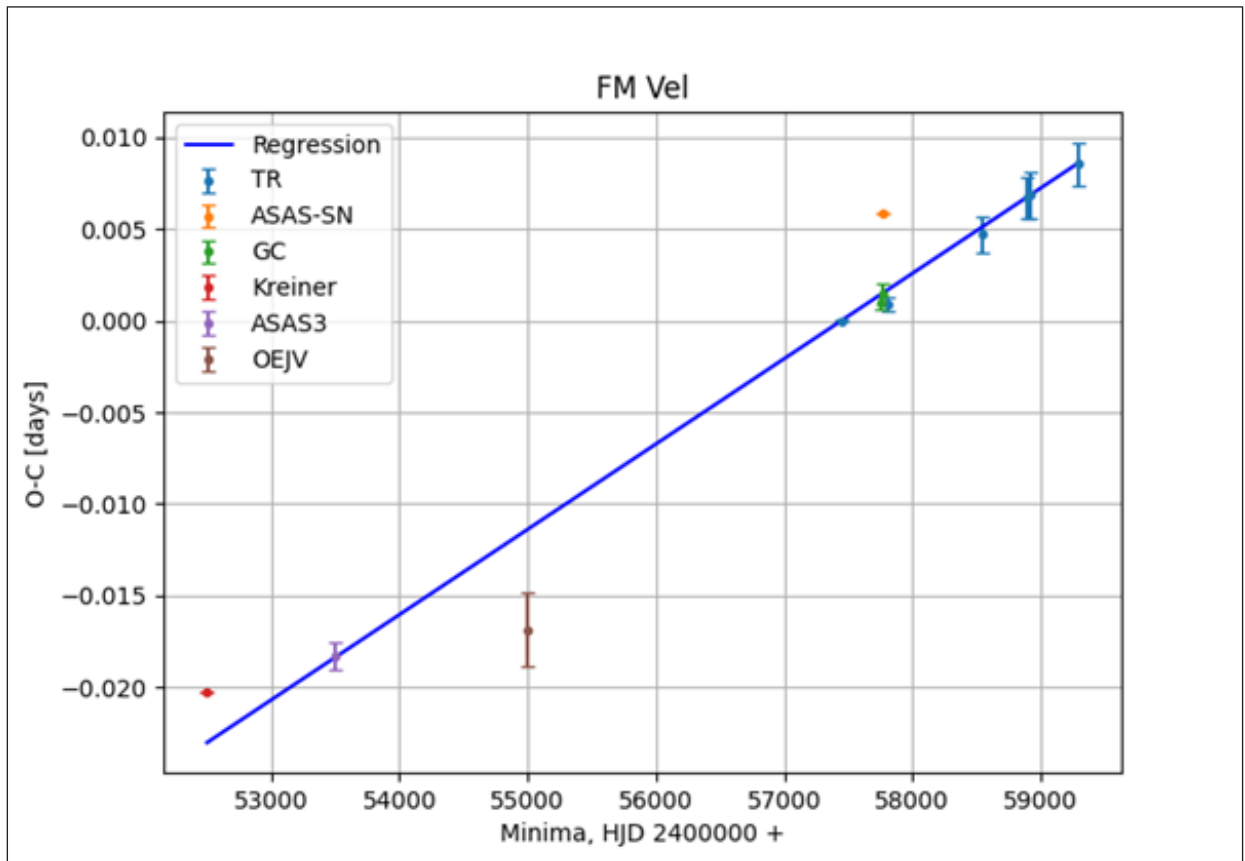


Figure 2. Linear regression excluding the VSX data point, and with a recent epoch instead of the VSS epoch.

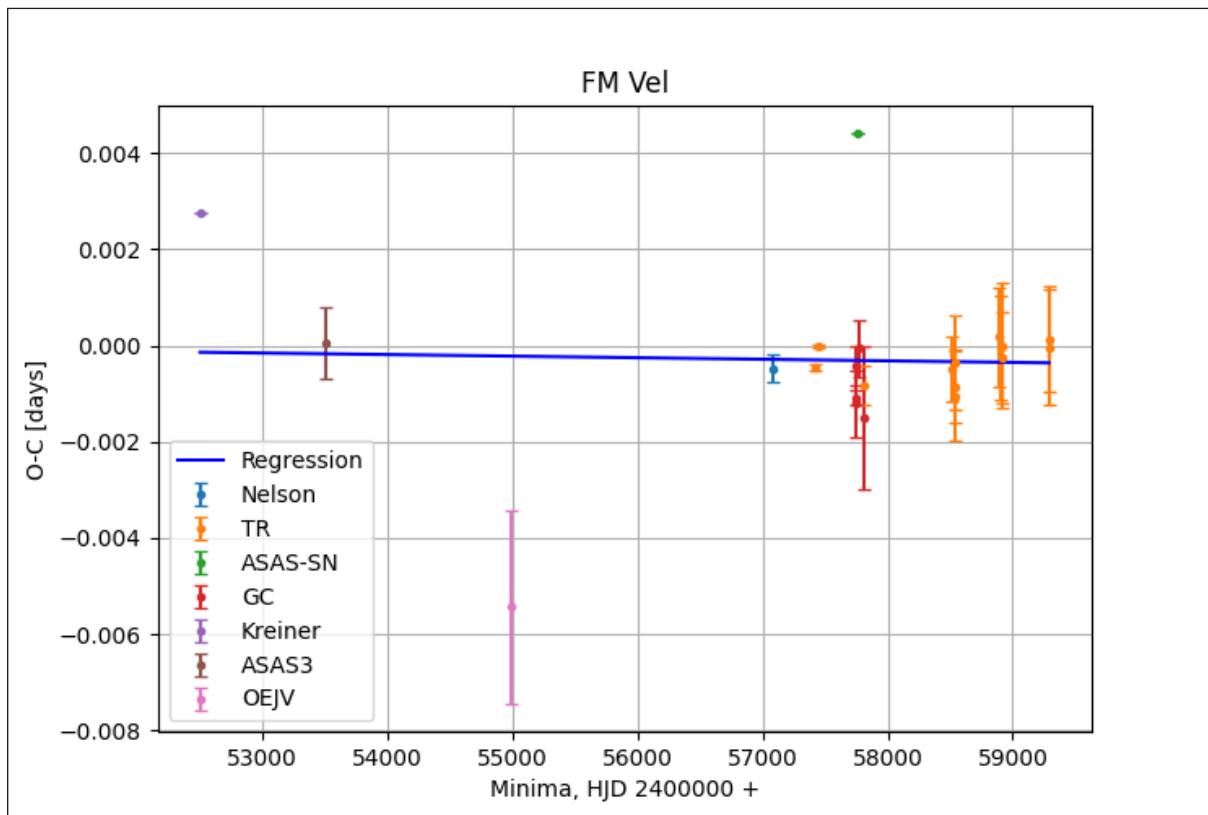


Figure 3. Linear regression using (3) as reference ephemeris.

Comparing the regression ephemeris (2) with (3), there does appear to be a cycle count jump occurring

in one or other of the O-C calculations, since on ephemeris (2) the number of orbital cycles from the VSX epoch to the last epoch in Table 1 is 77650.5, but on ephemeris (3) it is 77650.0. That in itself doesn't decide between the two ephemerides however.

In Figure 3 the new regression line is not quite at O-C = 0.0; since it used the regressed epoch for the second TR data point. So the best linear fit (excluding the VSX point but including the three poor fits referred to above) is

$$E = \text{HJD } 2457445.9994 \pm 0.0004, P = 0.38952911 \pm 8 \times 10^{-8} \text{ d.} \quad (4)$$

The data points in Figure 3 cover a sufficient time interval, and sufficiently densely, to be confident that no cycle count jump has occurred over that period. This is confirmed by the near-zero O-C value of the regression line, whose slope is quite insufficient to create a cycle jump (requiring O-C ~ 0.1 d) before it is extended to the VSX data point. So ephemeris 3 (and 4) will not contain a cycle count jump over the period from the VSX datum onwards.

This seems to eliminate a constant period for FM Vel, if the VSX (GCVS) datum is considered reliable. Parenthetically, experience shows early discovery data in the GCVS are often unreliable, but in this case the discrepancy may be considered too big to be entirely erroneous. Figure 4 shows the same regression as Figure 3, but includes the VSX datum (bottom left, O-C ~ -0.05 d), which is not used in the regression calculation.

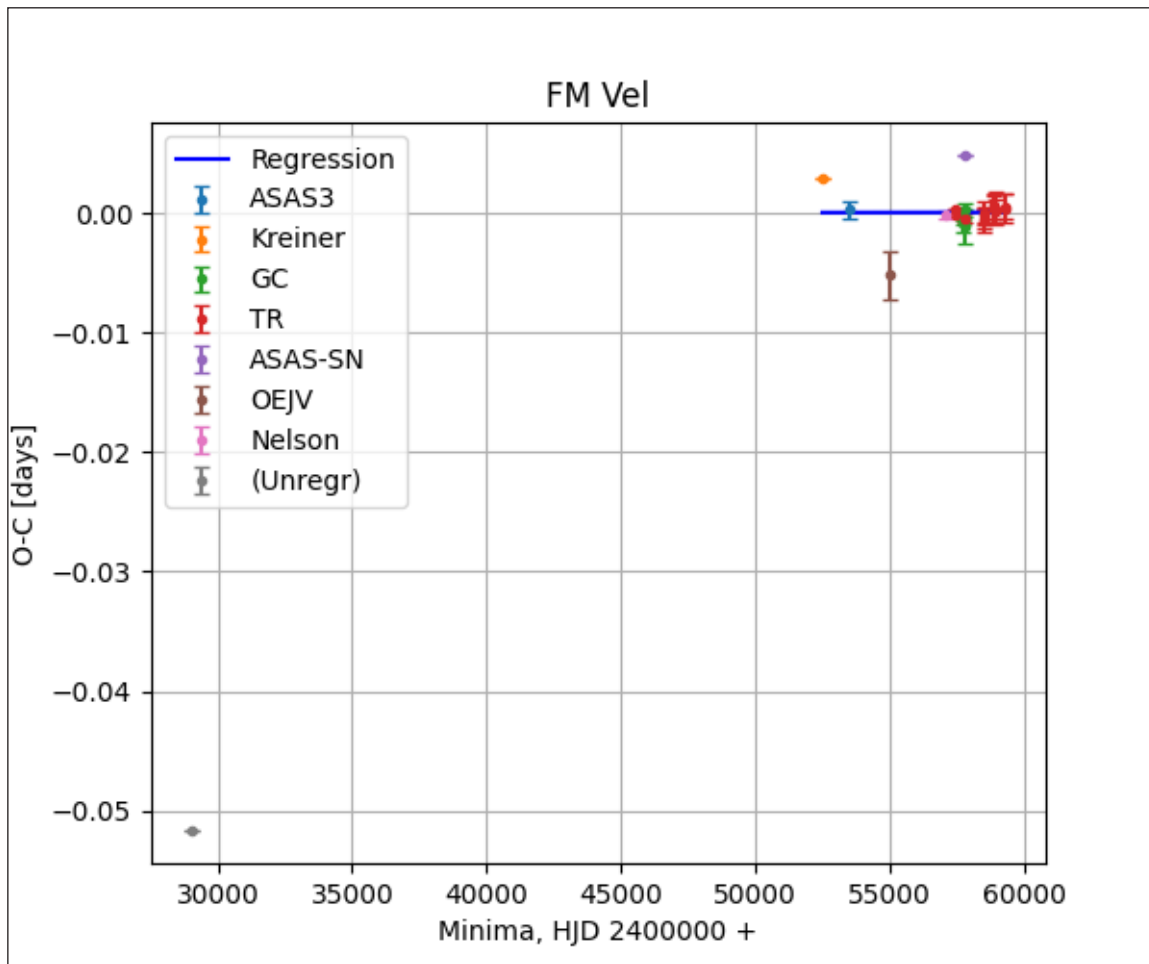


Figure 4. The same O-C regression plot as Figure 3, but including the un-regressed VSX datum.

Is there then some other period behaviour, if a constant period is ruled out? It is apparent that there may be some curvilinear structuring to the residuals in Figure 3 – convex downwards – which may indicate a nonlinear period, though the ASAS-SN point at OC~0.004 does not fit that trend. To investigate this, a second-order polynomial was fitted by OLS to all data points, as in Figure 5.

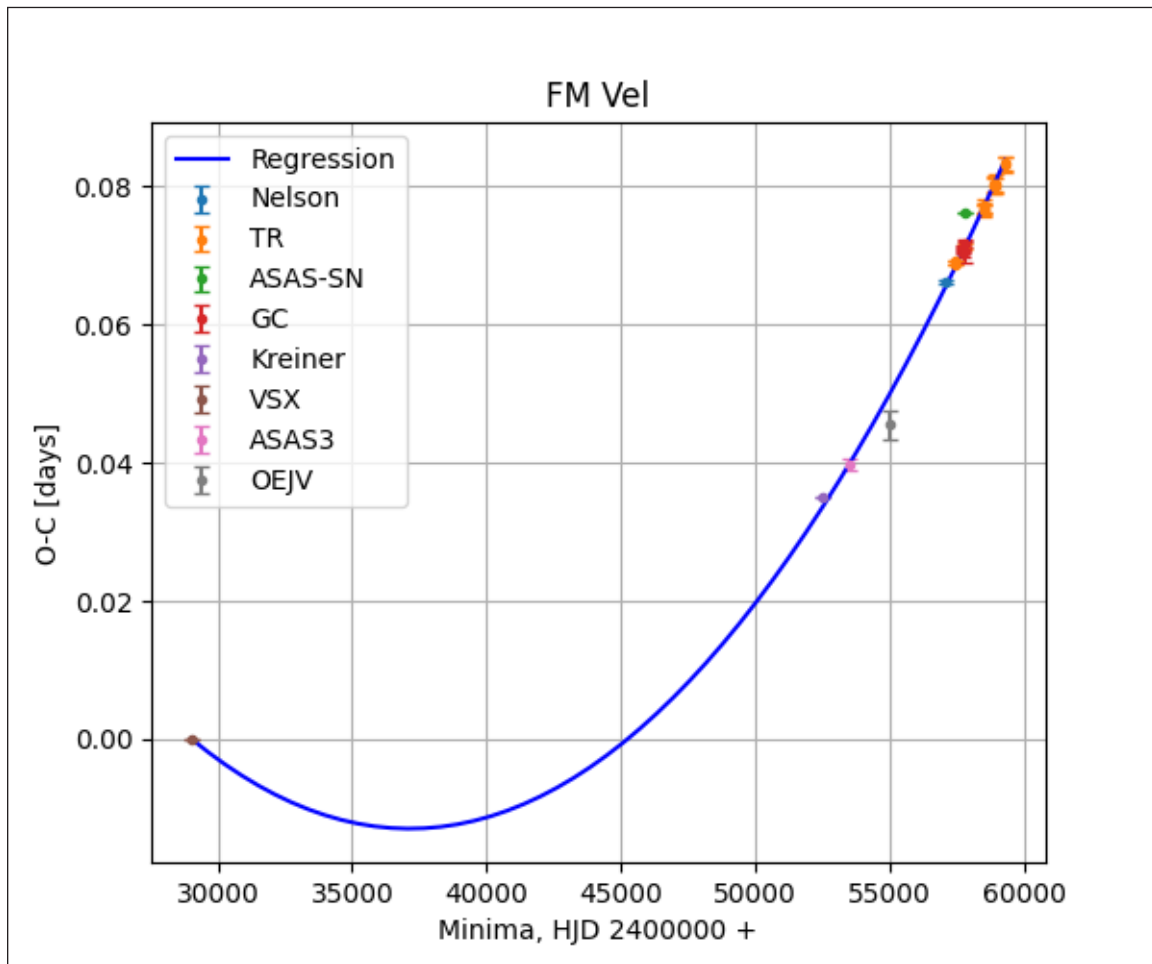


Figure 5. Parabolic fit to all data points; reference ephemeris is VSX.

The quadratic equation for this fit is (where t_n is the time of the n th minimum after E)

$$t_n = \beta_0 + \beta_1 n + \beta_2 n^2$$

$$\beta_0 = 2429043.2380 \pm 0.0016$$

$$\beta_1 = 0.38952496 \pm 1.0 \times 10^{-7}$$

$$\beta_2 = 2.992e-11 \pm 1.220e-12$$

The ephemeris is

$$E = \beta_0 = \text{HJD } 2429043.2380 \pm 0.0016,$$

$$P \text{ at } E = 0.38952496 \pm 1.0 \times 10^{-7} \text{ d},$$

$$\dot{P} = 6.495 \pm 0.26 \times 10^{-13} \text{ s/yr}$$

On the data available, no confidence can be placed in this equation or ephemeris, since the nonlinear component $\dot{P}$ is far smaller than can be detected in the more recent and reliable data (far right of Figure 5, see also Figure 3). And that term is only the size it is to accommodate the out-of-line VSX data point.

So how else can the apparent structure visible in Figure 3 be analysed? Except for the Kreiner OEJV and ASAS3 outliers, the regression line in Figure 3 is well within most error bars so there is in fact no imputation of structure from those data. It is only when the unreliable data from Kreiner and OEJV are considered does the convex-downwards structure of residuals in Figure 3 becomes apparent.

Conclusions

Analysis of the available minima epoch data for FM Vel is sufficient to eliminate a constant period. The linear regression (ephemeris 4) is calculated from all data except the VSX (GCVS) datum (see the regression line in Figures 3 and 4). It misses the VSX datum by ~ 0.05 d, and because it has negligible slope will

not contain a cycle count jump. So if FM Vel has a constant period (linear regression in an O-C diagram) it will be very close to ephemeris (4) and the VSX datum has to be completely discounted. Conversely if the epoch of the VSX datum is considered reasonably close to the minimum it is measuring (say within a very generous 0.02 d), then FM Vel does not have a constant period.

Nor does the Table 1 data support a linearly changing period. Some of the later data could be interpreted to support a nonlinearly changing period, but they are far too insufficient to characterize it. So all that can be said as of now is that FM Vel has a nonlinearly changing period. Minima epoch data between HJD 2430000 and 2450000 would have provided far greater constraints on the period behaviour. This sort of data gap is very common with southern eclipsing binaries; and as with FM Vel creates a real decision problem when the discovery datum cannot be reconciled with a reliable constant period derived from data in the CCD era.

All that can be done now is to obtain another ten years of good minima data and see what we get. The bet is that it will show nonlinear period change. For astronomers wishing to predict a minimum for observing, ephemeris (4) should be safe to use for the next few years, but surprises cannot be ruled out (and should be welcomed!)

Acknowledgements

We gratefully acknowledge access to the GCVS, AAVSO VSX, ASAS3 and ASAS-SN online databases.

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Abstract

The classical approach to analysis of close binary systems involves combining observational data (when available) of astrometry (including O-C measures), spectroscopy and photometry. This leads to the determination of absolute stellar parameters. We consider the particular case of U Oph, whose parameters have been checked against theoretical models of the components. Recent evaluation of the distance of the system compares well with a photometric result, on the basis of a conservative estimate of the interstellar absorption in the line of sight to the system. Determined ages and compositions clarify the circumstances of the stars' formation in the local galactic environment, particularly in relation to the Gould Belt.

Introduction

Many stars in the Galaxy are thought to have originated in OB associations: those large stellar groups made conspicuous by their relatively bright and massive young stars of early spectral type. Detailed knowledge of the formation and properties of such 'stellar nurseries' should contribute to a broader understanding of the structure and history of the Galaxy.

Still, available information remains largely summary in character, even for the nearest OB associations. This is partly because their large angular extent makes the identification of member stars not obvious (cf. Preibisch & Zinnecker, 2007). Proving the membership of particular stars has sometimes been a protracted task. Considerable progress was achieved with the completion of the HIPPARCOS survey (de Zeeuw et al., 1999). More recently, information from Gaia has been used to examine the incidence of binarity in OB associations (cf. Kervella et al., 2019).

Overarching these formations in the local neighbourhood of the Galaxy is the Gould Belt: a large and relatively near flattened formation in the Milky Way, tilted by ~ 20 deg to the Galactic plane. The Belt seems to link the relatively closer OB associations to one great superstructure that may have much to reveal about star formation processes in the Galaxy. In recent years the original 'belt' model has given way somewhat to the 'Radcliffe Wave': a more clearly marked, less symmetric, local superstructure stretching over part of the original Belt location. Young stars related to this have ages estimated to be in the range 30 to 50 million years. The explanation of the Gould Belt is still far from clear and the possible role of Dark Matter has been raised in recent literature.

The accurate parametrization of stars in such associations is important in order to have a better factual appraisal, both to check existing modelling and also to guide future studies. Eclipsing binaries, in particular, are of great interest due to the scope they offer to quantify stellar properties. This present short report is first of an intended series highlighting studies of young early type binaries, with a special emphasis on those accessible from the southern hemisphere. The relevance of young stars for information on the evolution of the local region of the Galaxy was highlighted by Vaz et al. (2007).

U Oph

The well-known eclipsing binary U Oph, just over 1 degree north of the equator, has been a prototype case in the parametrization of young stars (see e.g. Holmgren et al., 1991; Vaz et al., 2007). This is perhaps related to the object's relative brightness ($V = 5.903$; $B - V = 0.021$; SIMBAD), near-equator accessibility, and the long historical background of awareness of its behaviour that has been discussed in many papers since the identification of its photometric variability by Benjamin Gould (discoverer of the Gould Belt) (1879). Later studies have shown that indeed U Oph can be associated with Gould's Belt. A history of observations was given by Koch & Koepler (1977). John Herschel, on following in his father's footsteps in observational astronomy, reported the existence of a faint companion to the eclipsing binary in 1820. Interestingly, an eclipse of U Oph was noted by the 19th Century frontline astronomer/mathematician F.W. Bessel in 1823 (JD 2386717.38), that allows a very accurate determination of the mean period over the last couple of centuries ($P = 1.67734543$ d, if we accept the reference epoch of JD 2444416.38565 of Wolf et al., 2002).

Budding et al (2009) included a brief review of the large background of studies of U Oph. This was one of the first stars to be included in the southern binaries programme that utilizes spectrographic observations from Mt John Observatory, as well as available photometry. Of special interest are the O – C data that come from checking the differences between observed (O) times of minimum light and those calculated (C) from the given ephemeris. U Oph shows small shifts of the secondary minimum from the midpoint between primary minima, attributed to the effect of orbital eccentricity. The variation repeats and a period of about 20 y has been found, corresponding to the rotation of the major axis of the elliptical orbit: ‘apsidal motion’. The rate of such apsidal motion informs about the degree of central condensation, which is in turn dependent on the age and metal-content of the component stars.

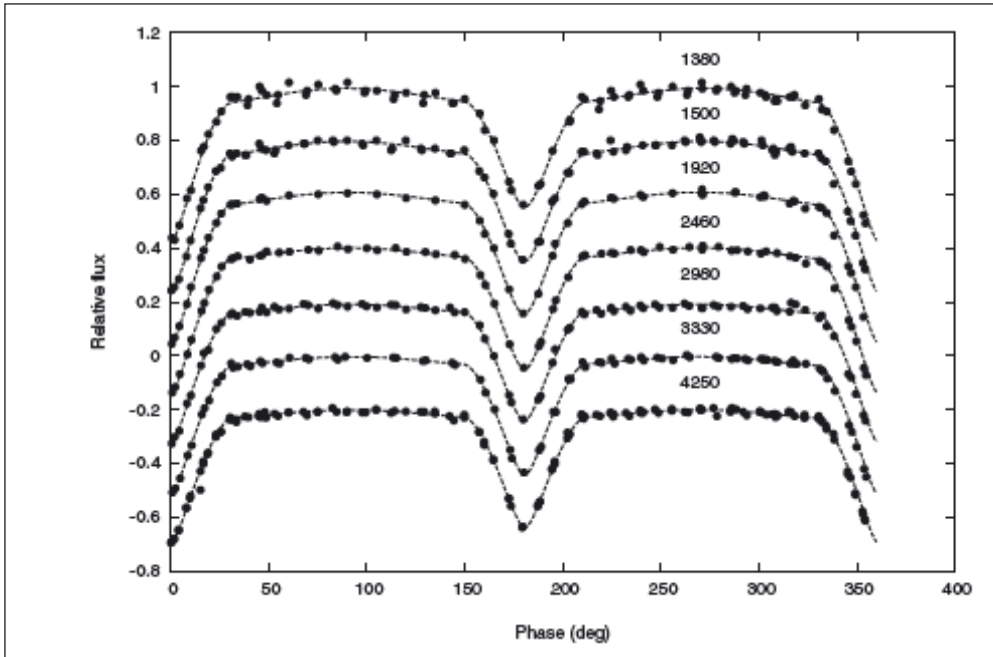


Figure 1. *OA02 (UV) light curves of U Oph from Eaton & Ward (1973). The curves are in order of increasing wavelength from the top down (as marked), but shifted progressively by 0.2 in the relative flux levels to allow distinct visibility.*

As well as the apsidal motion, the O-C data on U Oph indicates the presence of a companion star, closer in than the visual partner. Such an hierarchical arrangement has been frequently encountered in massive young stars of this kind. The effect in question shows up as a light travel time (LTT) variation with an amplitude of about 20 minutes and a period of around 40 years. The body responsible for this wide orbit effect (U Oph C) is thought to be of around one solar mass.

Bayesian optimization techniques, utilizing physically realistic fitting functions were applied by Budding et al. (op. cit.) to the data shown in Figures 1 (satellite photometry) and 2 (MJUO radial velocities) to yield new sets of absolute parameters $M_1 = 5.13$, $M_2 = 4.56 \pm 0.1$; $R_1 = 3.41$, and $R_2 = 3.08 \pm 0.03$ (solar units) for the early type eclipsing binary that dominates the system. The surface temperatures of the stars derived using the UV flux ratios and spectral types come out at $T_1 = 17200$ K and $T_2 = 16200$ K, with uncertainties of the order of 500 K.

O-C data relating to the triple system that makes up the wider system containing U Oph (ADS 10428A) were analysed, utilizing the orbit model of Wolf et al. (2002) as well as HIPPARCOS astrometry (ESA, 1997) (see Fig 3). In this way, the mass of the third star was found to be about $0.8 M_{\odot}$. The age of the system was estimated to be around 30-40 My, using available theoretical models, such as those of the ‘Paczynski code’ (Paczynski, 1970; Odell & Pesnell, 1998), or the Padova group (Girardi et al, 2007). This age and other details are consistent with a possible origin in Gould’s Belt.

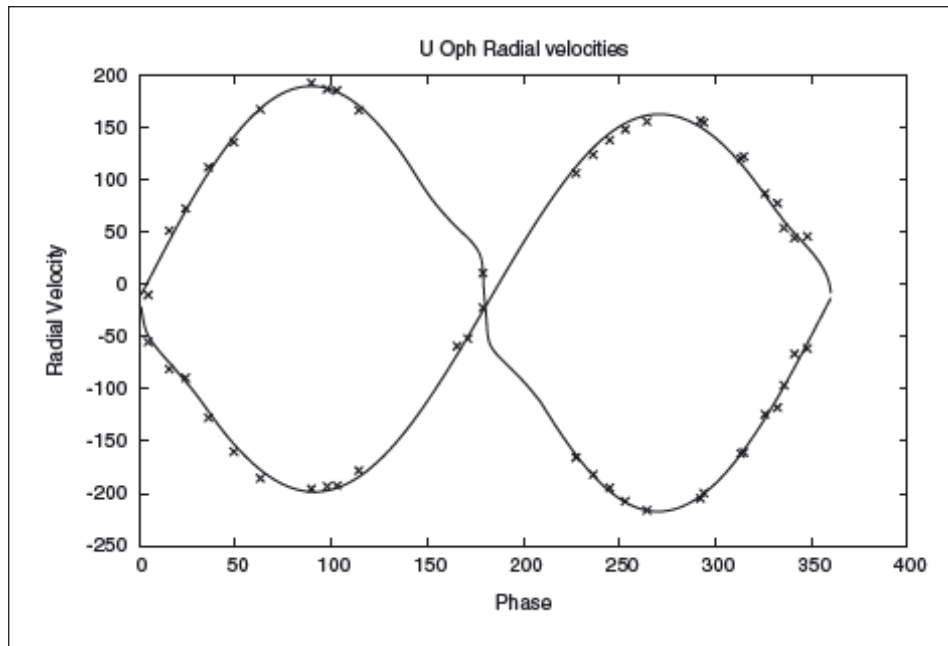


Figure 2. *The radial velocity curve of U Oph, derived from observations with the Hercules spectrograph at Mt John University Observatory in May 2006. The combination of radial velocity and light curve data allow absolute parameters of the component stars to be evaluated.*

In that (2009) study of Budding et al. a rather low photometric distance of ~ 150 pc was derived, which was within the adopted error of the HIPPARCOS distance of 180 pc. Budding et al.'s distance was influenced by an adoption of rather unusually high interstellar absorption in the direction of U Oph. This matter was considered in more detail by Clements & Neff (1979), who found no clear corroborative evidence of a reddening excess. Clements & Neff preferred the more conservative B- V colour excess of 0.15, noting the role of instrumental effects in colour measurements. Their derived photometric distance of 275 pc is close to more recent high accuracy astrometric distance determination (SIMBAD: Gaia – cf. Bertelli, 2002).

Anomalous absorption might connect with the discussions of photometric and polarimetric irregularities. Eritsian et al. (1998) concluded that there is essentially no correlation between polarization and the light curve phase of the system, although there are wavelength-dependent rapid variations. They interpreted the polarization behaviour in terms of secular wind effects (long-term), punctuated by eruptive episodes (short-term). Anomalous absorption effects are possibly consistent with a relatively recent star-formation region in the young Disk.

Vaz et al. (2007), using new uvby photometry with older coudé spectrograms from the 1.5m ESO telescope at La Silla, had found slightly more massive and bigger stars in U Oph AB than those of Budding et al (2009), but the parameters were within the accepted uncertainties of each other. Vaz et al. compared their findings with several other derivations for similar early type stars and were able to locate them all within the Main Sequence band. However, minor differences were suggestive of local variations of metallicity (which affects the size of stars of a given mass), implying that young Disk stars form with significant local variation of metal content.

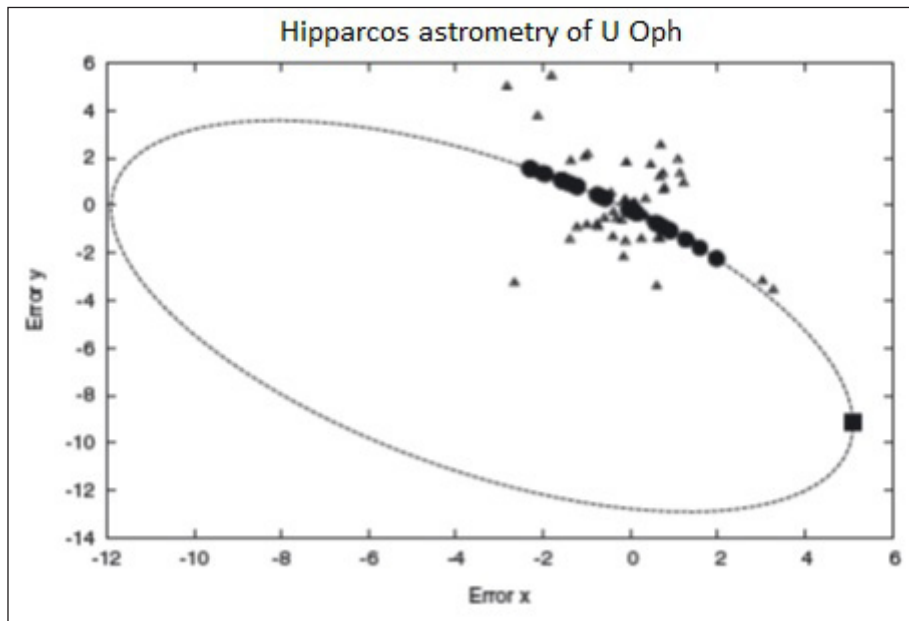


Figure 3. *Fit of HIPPARCOS measured differential positions (in milliarcsec, referred to the origin) for U Oph (triangles) with the sky-projected orbit of Wolf et al. (2002) (continuous ellipse). Full circles mark the corresponding orbit model positions for the HIPPARCOS observations. The full square indicates the periastron position.*

Conclusions

The information on U Oph derived from combining the observational data of astrometry (including O-C results), spectroscopy and photometry, possible in the case of such young, bright, and multiple stars, lead to the determination of absolute parameters, like masses, sizes and surface temperatures. These findings allow checks on theoretical stellar models. From this, ages and compositions can be inferred that lead to a clearer knowledge of the circumstances of the stars' formation in the local galactic environment.

In these ways, information gathered about U Oph and comparable young multiple star systems (to be described in later articles) are helping to clarify general properties of star formation and the subtle interactions of stars and their environment.

Acknowledgements

The observations of U Oph (taken at University of Canterbury Mt John Observatory in 2006) were enabled with financial support from the Turkish Science Research Council, TÜBİTAK, and supporting office accommodation was provided at the former Carter National Observatory of New Zealand. The Observatory's former Manager J. Marchand and former Senior Astronomer B. Carter provided well-received encouragement in this regard.

Generous allocations of time on the 1m McLennan Telescope and HERCULES spectrograph at the Mt John University Observatory were made available through its TAC and supported by its former Director Prof. J. Hearnshaw. Useful assistance at the telescope were provided by the former MJUO management: A. Gilmore and P. Kilmartin, as well as (particularly) Duncan Wright and other students and staff of the Department of Physics and Astronomy, University of Canterbury, Christchurch.

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Publication watch

From RASNZ Alan Baldwin reports

Roberts, Rich - LPV of the Month (2021 July): RV CEN

The LPV column of AASO features a particular variable each month; in July 2021 this was RV Centauri, classified as a Mira variable. The article presents the data available on the star which covers more than 100 years. The convenor of the LPV group is concerned that the numbers of observations per year of this variable are decreasing and is requesting a few more regular visual observers to include this star in their schedule.

For information on the particular features of this star, refer to the full article in the LPV Section of the website.. Here is a link (which may not be permanent) <https://www.aavso.org/lpv-month>

Carl Knight and Phil Evans are co-authors of a new exoplanet publication on the arXiv from their collaboration with the astronomy group at the Pulkova Institute in St Petersburg.

R. V. Baluev, E. N. Sokov, I. A. Sokova, V. et al. *Massive search of spot- and facula-crossing events in 1598 exoplanetary transit lightcurves.* 2021 arXiv:2105.01704

Abstract

We developed a dedicated statistical test for a massive detection of spot- and facula-crossing anomalies in multiple exoplanetary transit lightcurves, based on the frequentist p-value thresholding. This test was used to augment our algorithmic pipeline for transit lightcurves analysis. It was applied to 1598 amateur and professional transit observations of 26 targets being monitored in the EXPANSION project. We detected 109 statistically significant candidate events revealing a roughly 2:1 asymmetry in favor of spots-crossings over faculae-crossings. Although some candidate anomalies likely appear non-physical and originate from systematic errors, such asymmetry between negative and positive events should indicate a physical difference between the frequency of star spots and faculae. Detected spot-crossing events also reveal positive correlation between their amplitude and width, possibly owed to spot size correlation. However, the frequency of all detectable crossing events appears just about a few per cent, so they cannot explain excessive transit timing noise observed for several targets.

Phil Evans is a co-author in three TESS exoplanet publications:

Nolan Grieves et al, *Populating the brown dwarf and stellar boundary: Five stars with transiting companions near the hydrogen-burning mass limit.* 2021 arXiv:2107.03480

Abstract

We report the discovery of five transiting companions near the hydrogen-burning mass limit in close orbits around main sequence stars originally identified by the Transiting Exoplanet Survey Satellite (TESS) as TESS Objects of Interest (TOIs): TOI-148, TOI-587, TOI-681, TOI-746, and TOI-1213. Using TESS and ground-based photometry as well as radial velocities from the CORALIE, CHIRON, TRES, and FEROS spectrographs, we found the companions have orbital periods between 4.8 and 27.2 days, masses between 77 and 98 MJup, and radii between 0.81 and 1.66 RJup. These targets have masses near the uncertain lower limit of hydrogen core fusion (~73-96 MJup), which separates brown dwarfs and low-mass stars. We constrained young ages for TOI-587 (0.2 ± 0.1 Gyr) and TOI-681 (0.17 ± 0.03 Gyr) and found them to have relatively larger radii compared to other transiting companions of a similar mass. Conversely we estimated older ages for TOI-148 and TOI-746 and found them to have relatively smaller companions.

ion radii. With an effective temperature of 9800 ± 200 K, TOI-587 is the hottest known main-sequence star to host a transiting brown dwarf or very low-mass star. We found evidence of spin-orbit synchronization for TOI-148 and TOI-746 as well as tidal circularization for TOI-148. These companions add to the population of brown dwarfs and very low-mass stars with well measured parameters ideal to test formation models of these rare objects, the origin of the brown dwarf desert, and the distinction between brown dwarfs and hydrogen-burning main sequence stars.

F. Murgas. et al. *TOI-674b: An oasis in the desert of exo-Neptunes transiting a nearby M dwarf.*
2021arXiv:2106.01246

Abstract

We use TESS, Spitzer, ground-based light curves and HARPS spectrograph radial velocity measurements to establish the physical properties of the transiting exoplanet candidate TOI-674b. We perform a joint fit of the light curves and radial velocity time series to measure the mass, radius, and orbital parameters of the candidate. We confirm and characterize TOI-674b, a low-density super-Neptune transiting a $\odot$ nearby M dwarf. The host star (TIC 158588995, $V=14.2$ mag, $J=10.3$ mag) is characterized by its M2V spectral type with $M_* = 0.420 \pm 0.010 M_\odot$, $R_* = 0.420 \pm 0.013 R_\odot$, and $T_{\text{eff}} = 3514 \pm 57$ K, and is located at a distance $d = 46.16 \pm 0.03$ pc. Combining the available transit light curves plus radial velocity measurements and jointly fitting a circular orbit model, we find an orbital period of $1.977143 \pm 3 \times 10^{-6}$ days, a planetary radius of $5.25 \pm 0.17 R_\oplus$, and a mass of $23.6 \pm 3.3 M_\oplus$ implying a mean density of $\rho_p = 0.91 \pm 0.15$ [g cm $^{-3}$]. A non-circular orbit model fit delivers similar planetary mass and radius values within the uncertainties. Given the measured planetary radius and mass, TOI-674b is one of the largest and most massive super-Neptune class planets discovered around an M type star to date. It is also a resident of the so-called Neptunian desert and a promising candidate for atmospheric characterisation using the James Webb Space Telescope.

Jiayin Dong et al. *Warm Jupiters in TESS Full-Frame Images: A Catalog and Observed Eccentricity Distribution for Year 1.* 2021 arXiv:2104.01970.

Abstract

Warm Jupiters – defined here as planets larger than 6 Earth radii with orbital periods of 8–200 days – are a key missing piece in our understanding of how planetary systems form and evolve. It is currently debated whether Warm Jupiters form in situ, undergo disk or high eccentricity tidal migration, or have a mixture of origin channels. These different classes of origin channels lead to different expectations for Warm Jupiters’ properties, which are currently difficult to evaluate due to the small sample size. We take advantage of the TESS survey and systematically search for Warm Jupiter candidates around main-sequence host stars brighter than the TESS-band magnitude of 12 in the Full-Frame Images in Year 1 of the TESS Prime Mission data. We introduce a catalog of 55 Warm Jupiter candidates, including 19 candidates that were not originally released as TESS Objects of Interest (TOIs) by the TESS team. We fit their TESS light curves, characterize their eccentricities and transit-timing variations (TTVs), and prioritize a list for ground-based follow-up and TESS Extended Mission observations. Using hierarchical Bayesian modeling, we find the preliminary eccentricity distributions of our Warm-Jupiter-candidate catalog using a Beta distribution, a Rayleigh distribution, and a two-component Gaussian distribution as the functional forms of the eccentricity distribution. Additional follow-up observations will be required to clean the sample of false positives for a full statistical study, derive the orbital solutions to break the eccentricity degeneracy, and provide mass measurements.

About

Variable Stars South is an international association of astronomers, mainly amateur, interested in researching 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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