



W. H. (Bill) Allen was a dedicated New Zealand amateur astronomer for over 50 years. In this issue of the newsletter Ed Budding writes a moving obituary for Bill who passed away earlier this year. In the photo above, taken at the opening of the MOA 1.8m telescope at Mt John on December 4, 2004, Bill Allen is third from left. From left is Mark Conway, Phil Yock, Bill Allen and Michinori Sakata. Photo supplied by Phil Yock.

Contents

From the Director - <i>Mark Blackford</i>	2
W Dor revisited – <i>Mati Morel</i>	4
Undergrad project applying optimization to double star orbits – <i>Isabella Soh Xiao Si</i>	7
Modelling light curves – <i>Akshay Dalvi</i>	12
Student projects – <i>Carl Knight</i>	14
Period change in CP Sculptoris - a study in period analysis – <i>Tom Richards</i>	17
Publication watch	26
About	27

From the Director – *Mark Blackford*

Welcome to the third edition of the Newsletter for 2023. There is a strong bias toward student projects in the following pages. An undergraduate and a high school student, both mentored by Timothy Banks, describe their projects. Also, Carl Knight gives an update on projects by several high school students he is mentoring. We also have articles by regular contributors Mati Morel on W Doradus and Tom Richards on CP Sculptoris.

In early June I attended the 2023 RASNZ Conference in Auckland and thoroughly enjoyed the event. The plenary talks were excellent as were those contributed by professional, amateur and student astronomers. I particularly enjoyed catching up with several Variable Stars South members, one of whom was presented with the Murray Geddes Medal for his contributions to astronomy in New Zealand. Congratulations Tom Love on this prestigious award.

Nelson will host the RASNZ conference in 2024. Before then NACAA XXXI will be held over the Easter weekend in Parkes, NSW. In conjunction with that event VSS will run a symposium on Good Friday. We hope to have as many in-person attendees as possible, but virtual attendance will also be an option. Details will follow in coming Newsletters and via the VSS Google Group.

In a recent post on the VSS Google Group Craig Young announced his observation of a very bright stellar flare from Crystal Lake Observatory in Te Awamutu, NZ. In a series of images, the star is seen to brighten from 18th to 13th magnitude in just 70 seconds before fading much more slowly (see [video](#)). Congratulation to Craig on his serendipitous discovery whilst undertaking a long-term observing program monitoring RRab pulsating variables.

Andrew Pearce has discovered yet another galactic nova, this time in Sagittarius. The nova was magnitude 10.3 on unfiltered images taken on 2023 July 15.4590 UT with a Canon 800D DSLR and 85mm f1.2 lens. It has been assigned the permanent GCVS designation V6598 Sgr. Andrew's systematic transient search program has been quite productive in recent times.

Winter has seen greatly improved observing conditions at Congarinni Observatory with many clear nights. Smoke from numerous controlled burn-offs in the area has affected some observing sessions, but this is a necessary precaution with the coming summer expected to be hot and dry. We don't want a repeat of the 2019/20 bushfire season.

My Atik One 6.0 CCD has been repaired and the sensor cleaned. Initial testing on an 80mm f6 refractor indicates all is well again after the communication issues earlier in the year. However, I'll be mothballing that camera for a short time while I commission a new ASI2600mm-pro CMOS camera on the refractor. The CMOS camera, filter wheel and filters were funded by a generous grant from the Edward Corbould Research Fund (ECRF) administered by the Astronomical Association of Queensland. Eventually a smaller, shorter focal length telescope or camera lens will be used for photometry of bright variables. I'll give progress reports in future VSS Newsletters.

Wishing you all clear skies and good health,

Mark Blackford



Bill Allen: A lifelong passion for astronomy

W. H. (Bill) Allen was a dedicated amateur astronomer for over 50 years. He became seriously interested in the subject while studying electrical engineering at Canterbury University in the 1960s. He went on to build and observe with his own telescopes and measuring equipment, participate in international astronomy projects, and even had an asteroid named after him.

From the 1980's Bill was based in Blenheim, where he set up his private observatory with a couple of sizeable telescopes. He became a respected member, and later fellow and president, of the Royal Astronomical Society of New Zealand, and the Bootes-3 Observatory. Bill's research interests included variable stars, supernovae, gamma ray bursters and the search for exoplanets. He published his work in scientific journals and made presentations at astronomy conferences around the world. His optical light curves of the early stages of Supernova 1987A (RASNZ Pub. VSS, 14, pp82–84, 1988) are frequently cited. Bill carried out observations of the later stages of SN 1987A from Black Birch.

There was then a natural connection with the JAN-ZOS cosmic-ray detection experiment (1987–94), organized by Profs. Y Muraki of Tokyo and P Yock of Auckland. Bill, as Chief Engineer for MEPB, oversaw the laying of the power cable to the summit of Black Birch. He made himself available for all kinds of extra assistance with operations at Black Birch and was prominent in the Blenheim-based campaign to save the observatory in the mid-nineties. The JAN-ZOS project led on to two others: the MOA project on exoplanets and dark matter, also involving Prof Muraki and other international collaborators; and the gamma ray bursters project with Prof A. Castro-Tirado of Spain.

In addition to his research, Bill was passionate about sharing his love of astronomy with others. He gave public talks, conducted astronomy workshops, and led stargazing tours. He was the principal organizer of the successful international conferences on photoelectric photometry (PEP3 and PEP4) held in Blenheim (1989) and Hanmer (1994). He was a regular contributor to astronomy magazines and websites. His enthusiasm for astronomy was infectious. A man of many parts, Bill was a gifted communicator and educator who inspired many others to look up at the stars. Always positive and with a ready smile, Bill was a true ambassador for the subject; his dedication is a glowing example for astronomy enthusiasts everywhere.

Some footnotes about Bill Allen:

- President of the Dunedin Astronomical Society in the 1970s.
- Former president (1978–9) and fellow of the RASNZ
- Contributed to the recognition of Pluto's atmosphere.
- Asteroid was named in his honour (10967 Billallen).
- Regular writer for astronomy magazines and websites.
- Gifted communicator and educator.

Rest in peace, Bill.

Edwin Budding



Bill Allen, centre, at right is Prof Brian Warner of Cape Town (recently deceased, former Honorary Fellow of the RASNZ) and left, examining a poster contribution, is Dr William Tobin (also now deceased). The photograph was taken at the PEP3 conference in Blenheim (March 1989). Photo supplied by Stan Walker

Abstract

A thorough study of the tables and data published in UOC 53 (pp85-103) has enabled me to construct a log of plates used, relevant to the report on the variable later named W Dor. Together with the use of modern sources of astrometry and photometry, I conclude that the reported fading of W Dor in 1919 was spurious, an instrumental issue rather than a real event. W Dor is most likely a nearby field star. GSC 8891 1620 is proposed as the candidate, and not known to be variable.

Introduction

W Dor was reported as variable by Innes (1921) as a by-product of a proper motion (pm) campaign in the -66° zone north of the LMC. At (1875) 05^h30.4^m -66°44', range is 13p - (inv.). No other details were provided, though it appeared steady between 1897 Jan, and 1918 Dec 11. The history of this variable and the surrounding field were studied previously by Morel (2009) but the data sources available back then permitted only a tentative conclusion about W Dor. Now, armed with superior data sources, I have carefully re-examined Innes' extensive tables of proper motion results. These yield very useful information as to plates used, remarks on quality and approximate magnitudes of programme stars. These magnitudes are pretty noisy but by taking a large number of them one can construct a table, to convert Innes' magnitude scale into modern B.

Innes' magnitude scale.

The pm program of Innes spanned a wide range of RAs and magnitudes (10 - 14p). Only magnitudes 12 and fainter are relevant to this study, and I have derived a workable conversion to B, after comparing dozens of his magnitudes to modern B. Mags 13 and 13½ are treated as one - even Innes stated that he found it hard to accurately judge the difference between them.

Innes M	B (ave)
12	12.77
12½	13.25
13 / 13½	13.9
14	14.9

However an individual star may differ somewhat from the average.

Melbourne Observatory plates

As part of the pm program Innes arranged for 2nd-epoch plates (also called "new") to be secured at the Melbourne Observatory, Victoria, Australia. These were shipped to Johannesburg. I have compiled the plate numbers and quality remarks made by Innes (Table 1), for the dates of special interest to me. Melbourne Observatory was situated close to sea level and only 2km from the centre of a major city. Unfortunately, from early January 1919, into February, there was a major bushfire event, which blanketed eastern Victoria and south-eastern Australia with smoke from fires, which were widespread. This is attested from newspaper reports of the time, such as the *Argus (Melbourne)* of Fri. 31 Jan. 1919 with this headline: **"BUSH AND GRASS FIRES - Worst for Twenty Years"**.

Many plates were secured during this period, but the poor and variable viewing conditions would have had an impact on the quality of plates. Innes remarks only on the very poorest plates.

Selected reference star

In Innes' list of pm targets, there is one (not studied for pm) at (1875) 05 31.8 -66 39. It is actually double with rough magnitudes, according to him, of 12½ and 13p. I have chosen this star as a reference star as it lies less than 10' NE of W Dor, and therefore in the same field. It is easily identifiable, and the remarks Innes provides about plate quality are equally applicable to W Dor.

Table 1. *Melbourne Observatory plates taken near Jan. 31, 1919*

Centre		Plate No	Date	Remark (Innes)
4h30m	-66°	4142	1919 Jan 31	
5 06	-66	4143	1919 Jan 31	Poor image on “new”. [Useful only down to mag 12½]
5 42	66	4144	1919 Jan 31	
6 18	-66	4145	1919 Jan 31	
6 54	-66	4146	1919 Jan 31	
7 12	-66	4150	1919 Feb 4	New plate very poor in stars.

The log of observations is summarized in Table 2.

Table 2. *Log of Observations for W Dor and Reference Star 0531.8-6639. (W Dor 05 31.8 - 66 39)*

Date	Plate No	Quality	Mag.Limit	Observed?	Mag-p	Observed?	Mag-p
1897 Jan 29	1639	Good	15.0B	Yes	13		
1897 Dec 26	1764	Good	15.0B	Yes	13		
1918 Dec 11	4141	Good	15.0B	Yes	13	Y ?	12½ -13
1919 Jan 3	4143	Poor	>13B	No	Invisible	No	Poor image

Innes makes the following remark (Note 2, p102) about my reference star:

“Double star. 05 31.8 -66 39. 12½ and 13 magnitude. Change in angle certain.

1897.5 286° 4.6”

1918.9 302° 4.6”

Images too poor on plate [4143] of 1919 Jan 31”.

His measurements were made with a visual refractor. Compare modern data:

Mean posn. (J2000) 05^h31^m51^s.02 -66°33'26.5” $V_{\text{comb}} = 13.303$ $B_{\text{comb}} = 13.515$ APASS (29)

The two stars are known to be an optical pair. The separation was much smaller in Innes’ day, as the separation has increased to almost 10”; due to the northwards drift of the brighter star.

Discussion

In a previous study (Morel 2009) an attempt at identifying W Dor had focused on a tight group of five stars about 1’ north of Innes’ position, at (J2000) 05 30 24.8 -66 38 21.3. Magnitudes from the US-NO-A2.0 catalogue, back then, had suggested a combined brightness of 14.5B. A check of APASS shows that this group has $V_{\text{comb}} = 16.32$. which is too faint for any of Innes’ plates. This is corroborated by Gaia EDR3, which resolves all of the stars in this group. The five brightest, from $G_{\text{mag}} = 16.85$ to $G_{\text{mag}} = 19.87$, when combined, yield a figure of 16.1, in fairly good agreement. It can be safely said: **This star group has nothing to do with W Dor.**

It should be noted that Innes never stated the mag. limit of his plates. This parameter was inferred by other authorities who did not take into account the possibility that the mag limit of a particular plate was different, rather than the fading of the star. The assumed threshold figure, 15p. is not applicable to the plate in question, 4143, whose limit, >13, is brighter than the others. On the face of it, W Dor is not a star cluster or a transient, but a field star which was recorded several times on good plates over a period of twenty years. It attracted attention when looked for, without success, on a particularly poor plate. That alone should have raised a red flag, as we say. Now we ask the question: where is the true W Dor? In the immediate vicinity, the best candidate is at (J2000) **05^h30^m14^s.14 -66°39’00”.**3 EDR3 $G = 13.30$, $BP = 13.74$, $RP = 12.70$, $V = 13.48$, $B = 14.35$ This star is known today as GSC 8891 1620, 1’ due west of Innes’ rough position. See Figure 1.

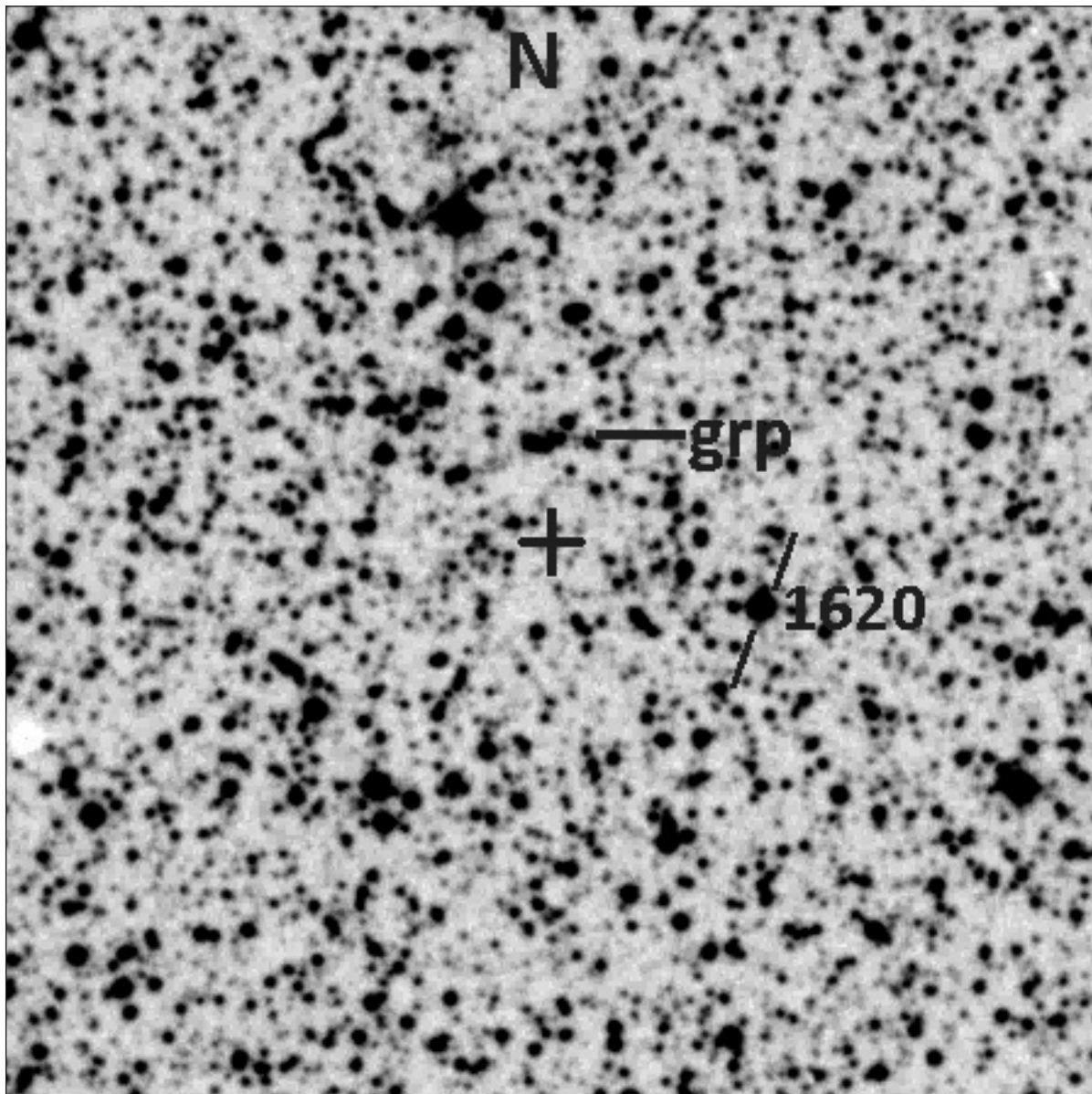


Figure 1. 5' field of W Dor from UKST blue plate. The central cross marks Innes' approximate position. The star group, "grp", once thought to be connected to W Dor is shown accordingly. The most plausible candidate for W Dor is marked as "1620", full name is GSC 8891 1620.

Conclusion

In this study of W Dor I have collected as much information as possible from all of the material published by Innes in UOC53. When blinking old and new plates W Dor was evidently seen comfortably above the threshold on the old plates, but dropped out (became invisible) on the new plate (no. 4143) which had a brighter threshold. This was recognized by Innes, in his own words, but probably had no backup to the poor plate. The threshold had changed rather than the star.

Though the field is just north of the LMC 13^{mag} (sic) stars near W Dor are few. The best candidate for W Dor, in position and magnitude, is GSC 8891 1620, as discussed above.

References.

- Innes, R. T. A. 1921 Union Obs. Circ. 53, 85-103
 Morel, M. 2009 Open European J. Var. Stars 101 2009OEJV..101....1M

Undergraduate project applying optimization to double star orbits – *Isabella Soh Xiao Si*

Dept. Statistics & Data Science, National University of Singapore

During my final year research project spanning September 2022 to March 2023, I had the rare opportunity to conduct research on the orbits of double stars; an opportunity gifted to me by the National University of Singapore in collaboration with Nielsen (a global marketing research company) and my mentor there, Dr. Timothy Banks. I conducted research on Bayesian optimization methods using Markov Chain Monte Carlo (MCMC) techniques on 25 double star systems from Sir Frank Dyson's *Catalogue of Double Stars from Observations Made at the Royal Observatory, Greenwich* (Dyson, 1921) and compared my results to existing literature, such as results from Prof. Michael Rhodes' and Dr. Edwin Budding's *Win-Fitter Program*. Prof. Rhodes and Dr. Budding provided valuable input to my project, together with Prof. Lim Tiong Wee (National University of Singapore).

Double stars are pairs of stars that appear close together when viewed from Earth and which orbit around each other. We can track their changing positions with time. In the case of final optimal solutions to their orbits, I first had to understand the parameters of the fitting function of these orbits. These parameters are period, semi-major axis, eccentricity, the angle of inclination, the argument of periastron, and the longitude of ascending node (see Aitken, 1964, for more details). These are parameters that measure how long the secondary star takes to orbit around the primary star, how 'stretched' the path of the orbit is, as well as several angles that the body will be orbiting at with respect to reference planes.

I used the R programming language for this research (R Core Team 2021), and the STAN language for the MCMC modeling (STAN Development Team, 2021).

Initially, I created artificial datasets simulating real orbits with added noise and tested simple optimizers on them to determine if solutions could even be returned. I tested these datasets using Gaussian noise levels of sigma 0.1 to 0.5, and used the Nelder-Mead and other nonlinear minimization methods of optimization on these orbits to determine if results could be obtained. Once I was certain that these optimizers could successfully converge for the given use case of double star positions, I proceeded to test the real data of the 25 systems using these algorithms as well as with a more advanced algebraic optimizer, the Limited Broyden-Fletcher-Goldfarb-Shanno (L-BFGS) algorithm. For all these optimizers, I created my own objective function using the chi-squared statistic as a measure of the goodness-of-fit of the optimizer's results versus the positions of the orbit of the stars (the observations). I was able to obtain decent results from the initial plots of these results. Figure 1 is an example of an L-BFGS fit for the system labeled Dyson-10, demonstrating that the model solution fits the observations well.

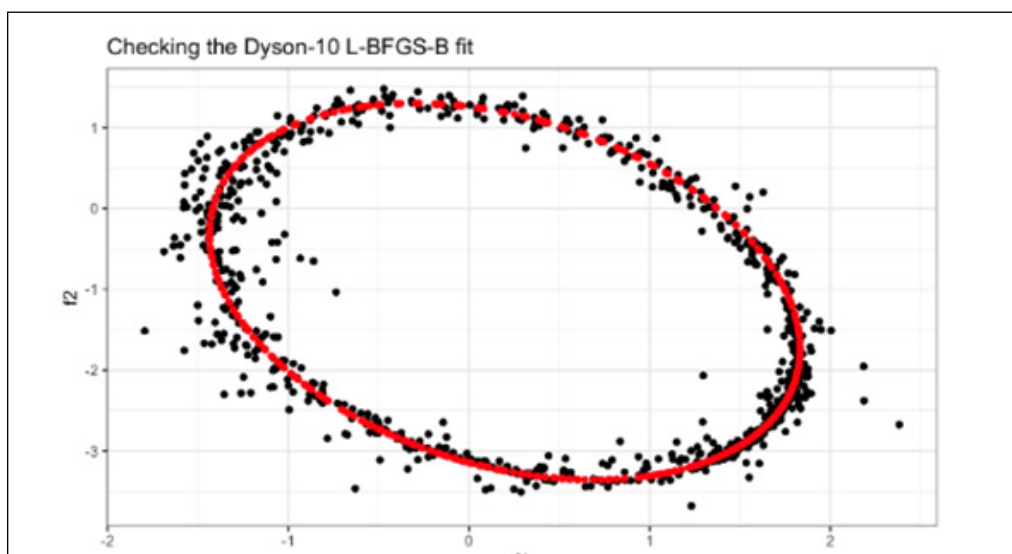


Figure 1. Historic data from WDS for the system Dyson-10 is plotted as black dots. The red line plot the best-fitting orbital solution. $F1$ and $F2$ are cartesian axes, corresponding to declination and right ascension, and are in arcseconds. The primary star is taken to be located at the zero coordinates.

To further test the accuracy of my results, I compared my results to Rhodes' program by plotting for each parameter a least squares regression line and observing the R-squared value as a measure of goodness of fit. I was able to obtain results that showed a large degree of agreement with Rhodes' results, indicating that my optimizers were successful. Figures 2 and 3 are example comparisons of the parameter results.

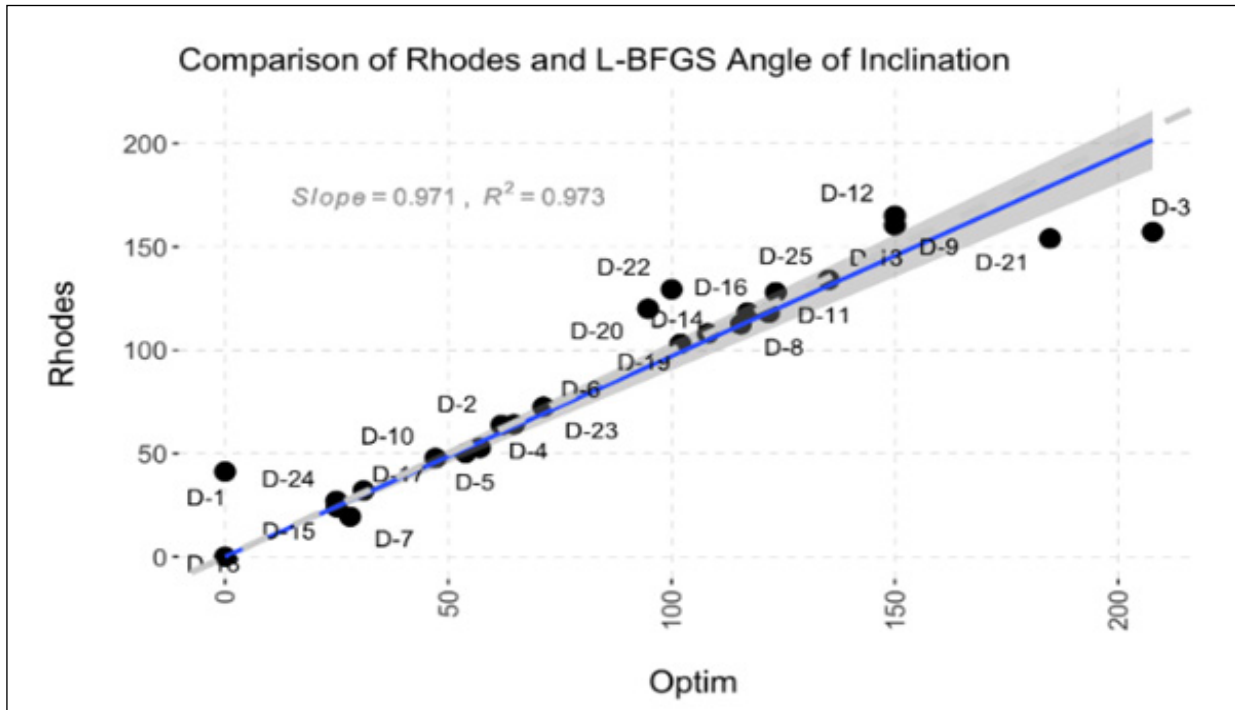


Figure 2. An example plot comparing the parameter estimates for inclination from Rhodes et al. (2023) on the y-axis versus those from the current study (the x-axis). Units are in degrees for both axes. To save space on the plot, Dyson has been shortened to D in the system names, i.e., Dyson-1 is shown as D-1. The grey shading gives the 95% confidence interval

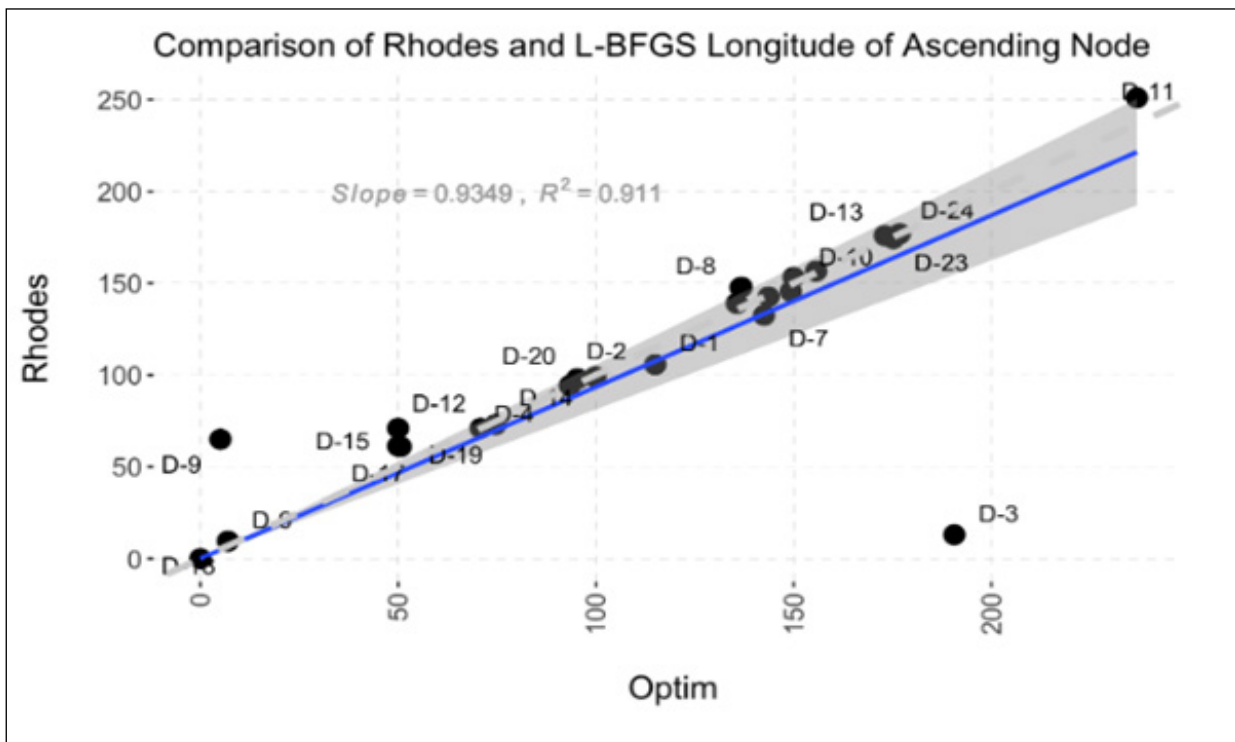


Figure 3. A comparison of the estimated parameter values for the longitude of the ascending node from Rhodes et al. (2023) and the current study, showing good agreement.

Despite the positive feedback regarding my optimizer results, I wanted to further generate results that provided uncertainty intervals and more information regarding the posterior distributions of the parameters. With that in mind, I decided to use a Markov Chain Monte Carlo method to optimize the orbits as well as provide information about the posterior distribution of the parameters.

MCMC can be explained as a Bayesian statistical method that is able to simulate complex distributions. MCMC works by creating one or several chains of simulations that sample the probability distribution of each parameter, whereby each simulation only depends on the previous simulation before itself, but not any others. The “Monte Carlo” part comes in where random sampling is used to generate the simulations itself. To use MCMC, we would first define the probability distribution that we wish to sample, and we create a starting point and simulate chain points that will move around the distribution. Over time, the chains sample more and more points from the distribution and hence give us better approximations of that distribution. Privault (2013) gives good additional background for anyone wishing to learn more about MCMC.

Using this technique, I was able to model the posterior distribution of the parameter space describing the orbit of the double stars and applied this statistical technique to our data. I realized that we obtained good results, as well as posterior distributions for the parameters. The method provides us with information such as the posterior distribution of the parameters, the correlation matrix between variables and the MCMC trace plots. Figure 4 is one of these diagnostic plots.

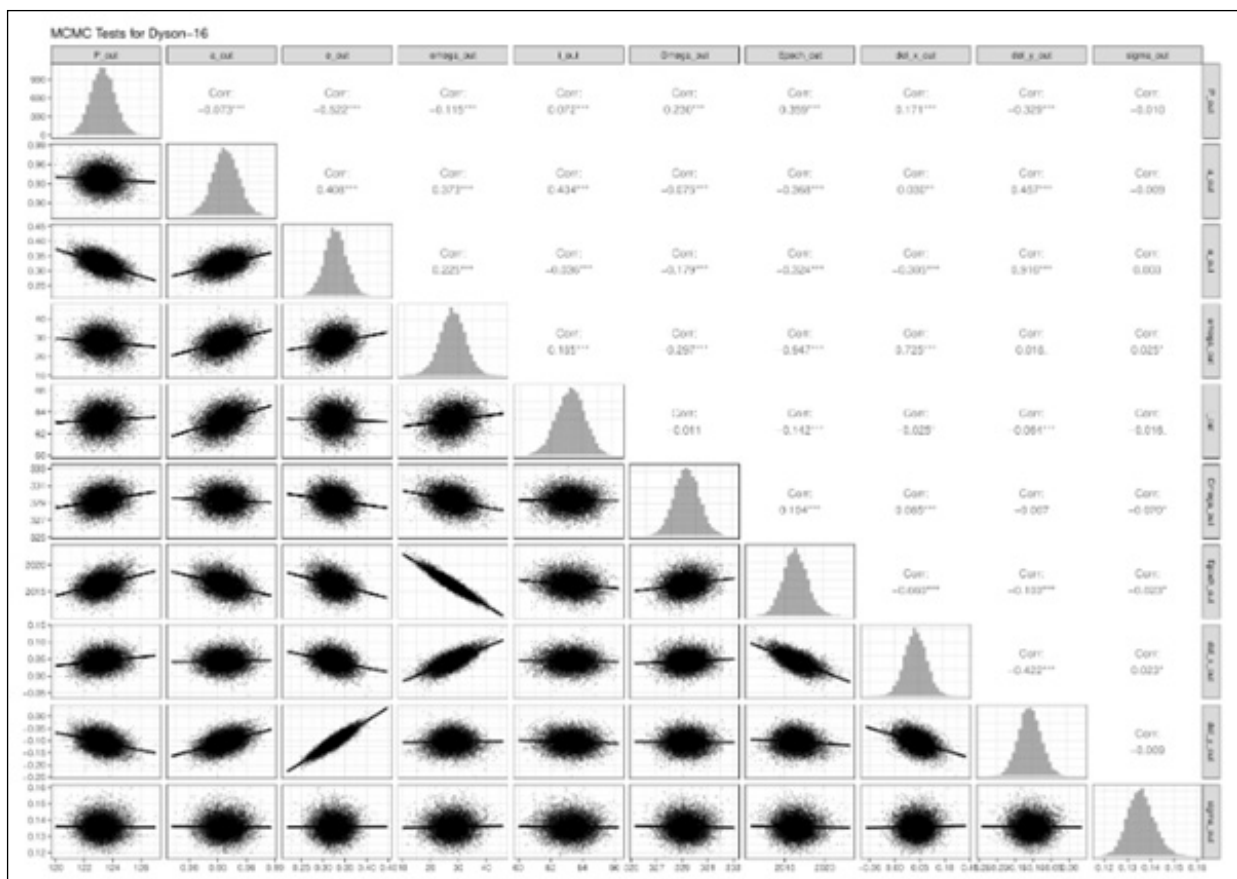


Figure 4. Example “corner plot”, in this case for Dyson-16. The upper right corner give the correlations between the variables, the diagonal plots the parameter estimates, and the lower right corner plots the individual estimates across pairs of the parameters.

The plot tells us that the convergence was of a success, given the nice Gaussian profiles for the parameter estimate plots, which I confirmed with the Gelman-Rubin diagnostic, which shows that the convergence of the MCMC was successful. Following this, I compared these results to those Rhodes et al. and was able to further conclude that my results were in very good agreement with Rhodes’ (see Figure 5).

I also compared my results to the original Dyson results and was thrilled to discover that my results agreed well with Dyson’s (see Figure 6), but that there were some interesting intricacies about the sym-

metry of some angular parameters revealed. This was because without information about the radial velocity of the stars, I could not determine the orientation of the star, if it was tilting *towards* or *away* from us on Earth. This leads to an ambiguity for some of the parameter estimates, as can be seen in Figure 6.

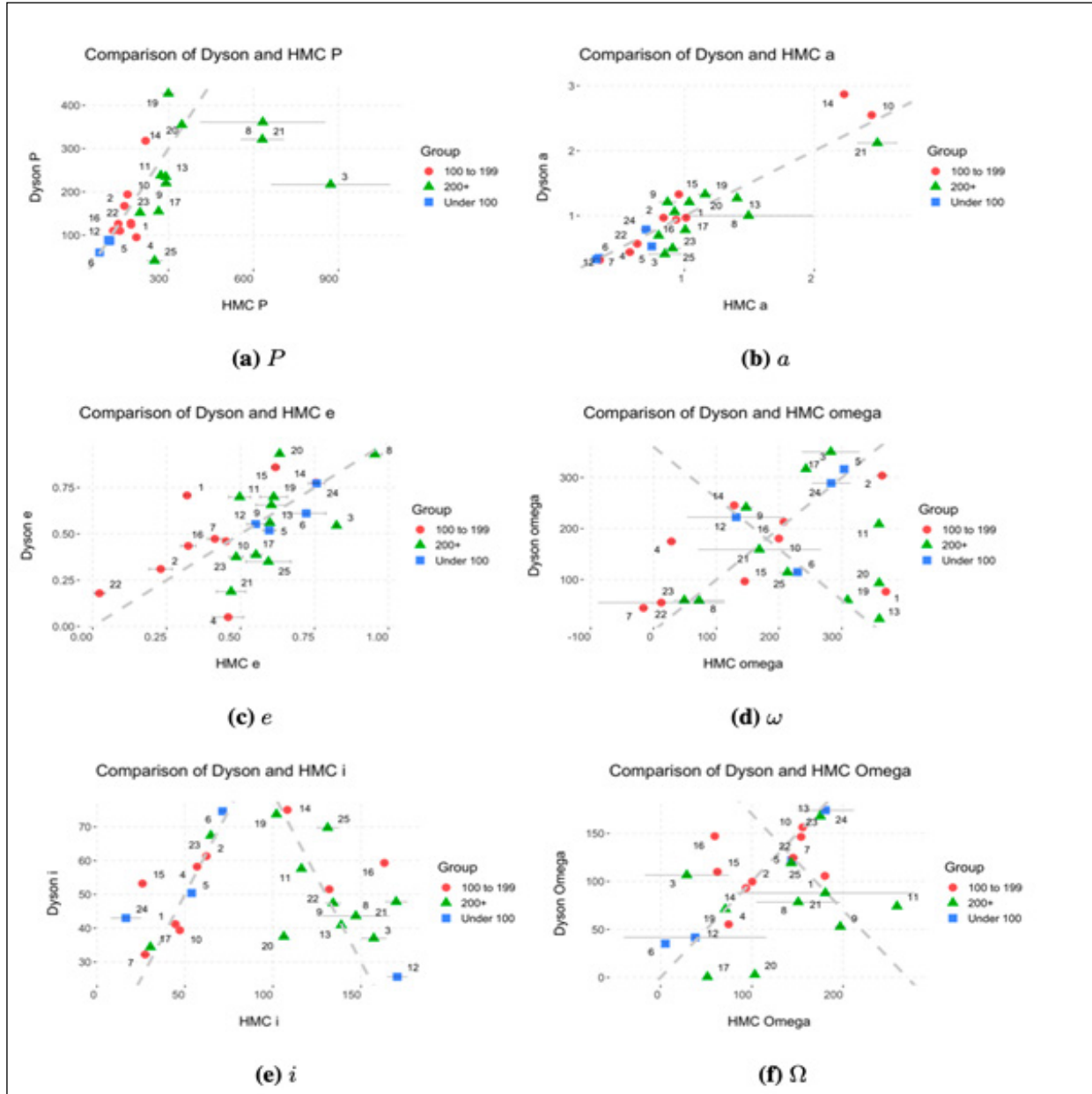


Figure 6 Comparison is made against the results of Dyson (1922) and those from this study. The systems are grouped into three groups by their orbital periods (less than 100 years, 100 to 199 years inclusive, and 200+ years). Dyson did not present formal error estimates. The dotted lines are linear regressions to the data. Overall agreement is good between the studies, although some of the longer period systems have lower agreement (see for example subfigure a). This is not unexpected, as Dyson was working with a shorter time period than I was able to, a century later.

Following this, I used the obtained solutions together with the parallaxes from *Gaia* and *HIPPARCOS* to calculate the dynamical masses of the 25 systems, along with providing uncertainties. My results are shown in Table 1.

The first columns identifies the system (1 means Dyson-1), the second column gives the system mass (in solar units) using the Hipparcos parallaxes and the MCMC results from this study, and the third gives the system mass using the Hipparcos parallax and the orbital parameter estimates from Rhodes et al. (2023). The final two columns on the right repeat the calculations, but using the *Gaia* parallaxes instead of the Hipparcos ones.

Dyson ID	Hipparcos HMC	Hipparcos (Rhodes)	Gaia HMC	Gaia (Rhodes)
1	2.00 ± 0.20	2.01 ± 0.17		
2	1.74 ± 0.29	1.77 ± 0.17		
3	1.83 ± 2.64	2.21 ± 0.17	4.83 ± 4.58	5.82 ± 1.71
4	5.81 ± 4.12	5.37 ± 3.06		
5	3.20 ± 0.90	3.23 ± 0.77	4.07 ± 0.53	4.11 ± 0.35
6	2.87 ± 1.28	2.49 ± 0.58		
7	14.4 ± 4.83	15.12 ± 4.96		
8	6.11 ± 11.32	4.47 ± 2.02	5.05 ± 8.58	3.7 ± 1.11
9	1.75 ± 0.77	3.86 ± 0.67	1.33 ± 0.48	2.94 ± 0.26
10	1.44 ± 0.06	1.43 ± 0.05		
11	0.85 ± 0.20	1.77 ± 0.81	0.89 ± 0.07	1.85 ± 0.56
12	2.53 ± 0.71	2.37 ± 0.51		
13	1.37 ± 0.05	1.93 ± 0.18	1.75 ± 0.24	2.46 ± 0.25
14	1.75 ± 0.17	1.74 ± 0.12		
15	7.86 ± 1.05	7.74 ± 0.78		
16	1.07 ± 0.19	1.17 ± 0.17		
17	2.88 ± 0.52	2.91 ± 0.32	3.71 ± 0.36	3.74 ± 0.10
18	1.54 ± 0.76			
19	2.85 ± 1.13	3.02 ± 0.45		
20	2.48 ± 0.84	2.91 ± 0.80	2.13 ± 0.21	2.49 ± 0.08
21	4.98 ± 2.46	5.68 ± 0.64	4.07 ± 2.01	4.64 ± 0.53
22	2.37 ± 0.44	2.19 ± 0.35		
23	2.88 ± 0.59	3.28 ± 0.50	2.86 ± 0.32	3.25 ± 0.19
24	1.36 ± 0.44	1.34 ± 0.26		
25	1.45 ± 0.81	1.55 ± 0.63	1.48 ± 0.63	1.58 ± 0.44

Table 1. Comparison of HMC Dynamical (Solar) Masses versus Rhodes' Dynamical (Solar) Masses based on Hipparcos and Gaia DR3 parallaxes (where available). It can be observed that the uncertainties for HMC are generally higher than for Rhodes. This could be due to the fact that Rhodes assumed a mean 5% observational error for all systems, which might be an underestimate. Dyson numbers are used to identify the systems. Errors are one standard deviation.

Upon calculation of the dynamical masses, I realized that my uncertainties were much larger than Rhodes', which was most likely due to Rhodes' assumption of a 5% observational error.

The hope for this project was that I would be able to ascertain that the MCMC method would be a reliable and useful method in being able to optimize and provide solutions for systems that are even unknown in the future. With this project, I am able to say with confidence that MCMC is an excellent method for obtaining solutions for double star systems as it is not only accurate, but able to give us valuable information about the distributions of the parameters that govern the orbit. With these, the team can look to try out MCMC on systems with undiscovered solutions and be optimistic in the quality of the solutions that MCMC can provide.

Acknowledgment: I thank the USNO and WDS for making available the positional data used in this study.

References

- Aitken, R.J., 1964, The Binary Stars, Dover Publications, New York
- Dyson, F.W., 1921, Catalogue of Double Stars, H.M. Stationary Office, London
- Privault, N, 2013, Understanding Markov Chains, 2013, Springer Undergraduate Mathematics Series, Springer Singapore, <https://doi.org/10.1007/978-981-13-0659-4>
- R Core Team, 2021, R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria.
- Rhodes, M.D., Banks, T.S., Budding, E., & Love, T., 2023, submitted to Observatory
- Stan Development Team, 2021, RStan: the R interface to Stan, <http://mc-stan.org/>

Modelling light curves – *Akshay Dalvi*

William Fremd High School, 1000 S Quentin Rd, Palatine, IL 60067, USA

As a high school student, I was intrigued at the prospect of conducting research in a scientific field I was passionate about. Astronomy has always been an area of study that has fascinated me and I was excited at the prospect of contributing to this discipline by exploring a project of my own making. Even though astronomy requires years of education and understanding, interested students can also get involved through practical projects such as the observation of short period variable stars. An example of this is the recent note submitted by a group of undergraduate students who used a network of photometric telescopes to look at the RR Lyrae stars (Parker et al, 2022). Under the mentorship and guidance of Dr. Timothy Banks of Harper College, I was given the opportunity to model three exoplanets and one eclipsing binary via light curve analysis while also learning how to process and prepare the data using the R statistical programming language and how mathematical optimization works. In addition, through the completion of online courses such as “Exoplanet Observing” of the American Association of Variable Star Observers (AAVSO), and the Open University course “An Introduction to Exoplanets”, my understanding and ability to extract meaningful conclusions from my data analyses grew considerably. This ultimately led to the publication of my findings in the “Southern Stars” journal of the Royal Astronomical Society of New Zealand.

Flux and phase data was initially sourced via two sources: NASA’s Kepler mission for the exoplanets and the Transiting Exoplanet Surveying Satellite for the eclipsing binary Algol. The systems studied in this project (Kepler-1, Kepler-12, Kepler-8, and Algol) were chosen very specifically. The three exoplanet systems gradually became more difficult to model due to a variety of reasons and allowed me to develop my skills working with the data and my understanding of the various parameters. Algol then represented the final challenge as this system was much more complicated to model due to additional effects involved in an eclipsing binary (Algol Aa1 and Aa2), for instance where the two stars gravitationally distort each other from being spherical.

This analysis portion of the project was made possible through the use of the Winfitter application, a program developed by Prof. Michael D. Rhodes and Dr. Edwin Budding over the past 50 years that allows for efficient, Windows-based light curve fitting of many different kinds of systems. After proper manipulation of the data in order for it to be readable by Winfitter and the subsequent entry of the data into the application, plots were created for the four systems.

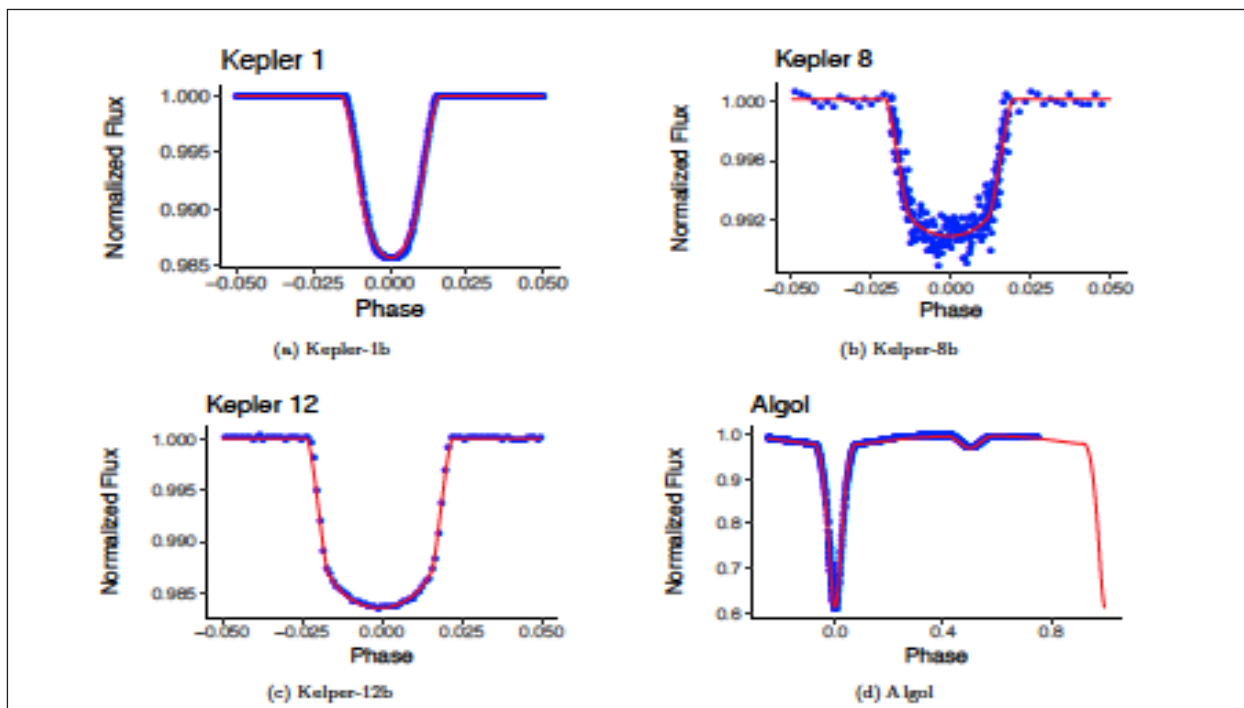


Figure 1. Light curves of the four systems modelled. For each system the red line represents the predicted light curve of the fitted model whereas the blue dots represent the observational data.

In each subfigure of the plot accompanying this note, the red line represents the predicted light curve of the fitted model whereas the blue dots represent the observational data. Overall, there was excellent agreement with the literature, which added to the authenticity of these findings.

Further information on the implications of these figures can be found in Dalvi (2023).

The main theme of this note is that motivated students, such as myself, gain a lot from such academic experiences, so please think twice before turning us away for fear of a lack of suitable data! The advent of the internet and readily accessible data has revolutionized science, and has allowed passionate students to take advantage of such opportunities as early as high school. Independent projects allow both high school and undergraduate students to develop a degree of enthusiasm and interest in a scientific career, and do not require researchers to maintain constant supervision. My project is a great example as I worked with three researchers who guided me in very specific areas of the project and connected me with other researchers when help was needed. In a similar fashion, there are many others out there who are keen to take their first steps in the world of academic research and will appreciate the chance to pursue their passions.

References

Dalvi, A., 2023, "Southern Stars", 62(1), 6

Parker, L., Parker, H., Parker, R., & Uddin, F., 2022, VSS Newsletter, January 2022, 11

I have been conducting student projects from my rural Rangitikei roll-off roof observatory now for several years. Most of these projects have been conducted under the aegis of the New Zealand Royal Society's CREST (Creativity in Engineering, Science and Technology) programme. Recently the society has abandoned CREST and promised, but not yet delivered, a replacement programme. Regardless, the student projects have continued using that framework in the absence of any other.

As much as is practical, I require that students make their own observations and that a parent is fully engaged in the project. I am quite happy to make additional observations on their behalf in recognition of the fact that it's not always practical or possible for a student to do so at every opportunity.

All of the projects essentially begin at the same place. The majority of projects are photometric so we start with the basics of light, frequency and wavelength, from there we can move on to the learning about the UBVRI standard photometric filters with an understanding of what the peak pass band (wavelength) means in each. The student is taught about how the difference in brightness in various filters can be a proxy for temperature and so on.

We move on to understanding dark subtraction, flat fielding, data reduction and frequency analysis. We also learn the physics of the phenomenon and the level varies depending upon the aptitude of the student.

Students learn to drive the equipment they use and all projects require they be able to give a reasonable explanation of what they did, how they did it, and what photometry is.

It is our experience at the local regional science fair that whilst many of the judges are scientists, there are no astronomers or photometrists among them. This led one student, Joseph Chamberlain, of years gone passed to exclaim, "I tried to explain photometry to them Carl, but they just didn't get it!" He was concerned his project would not get a good result in the science fair – Joseph took overall prize for the fair with his exoplanet project so his fears were unfounded.

Freyberg High School's HoD Science, Mairi Borthwick, continues to send students my way from their STEM Academy. Some have come to me mainly interested in mathematics, others in astronomy. Other students have come to the monthly meetings of the Palmerston North Astronomical Society (PNAS) and I make a point of introducing myself and discussing the possibility of a student project if they're interested.

In New Zealand, working with children and young adults requires a police background check, and each school or organisation requires their own. This is not too onerous. In addition to this safeguard I have the non-negotiable requirement of the involvement of a parent for all visits and communications. This is simply for the transparency of all contacts and the safety of all.

With the permission of the current students and their parents, here is a summary of the currently active projects.

Conan Strachan - year 12.

Conan commenced a project that had a mathematical focus in 2020. We commenced with getting to grips with making observations for photometry, darks, flats and the UBVRI filters. He learned the relationship between frequency and wavelength. He also learned how comparing brightness in particular filters can tell you something general about temperature.

In the second year of his project we expanded what he knew about colour and temperature by introducing black body radiation and how a star is like and unlike a black body. For instance, the distribution of energy over wavelength of a star differs from a blackbody in that there are emission and absorption features. He learned and was able to give what I call a "wavy hands" explanation of Wiens law to his assessor, Mark Blackford.

Using that knowledge and knowing the surface temperature and therefore peak emission for the components of a CV, TT Arietis in particular, (the WD peaks in hard UV/soft X-rays and the secondary in the R band) he was able to justify the filters he would choose (ideally and practically) based upon the components of TT Arietis.



Conan (right) gave a presentation of his project to the Palmerston North Astronomical Society. Conan's mentor, Carl Knight, is at left. Photo supplied by Carl Knight

We then moved on to develop his knowledge of frequency analysis. Using light curves he obtained of BV Centauri, he was able to identify by Fourier analysis, the fundamental orbital period of the BV Centauri system. Then, subtracting that fundamental, he was able to find what we described as a “blurred” average period for the accretion disk by analysing the modulation of the fundamental caused by the turbulent, heterogeneously bright accretion disk.

Conan has now moved on to learning about novae and I have secured Dr Yael Hillman, who spoke about her post-doc research at our 2018 Symposium in Christchurch, as his assessor.

Conan is learning nuclear reaction networks presently and has given a good explanation of the PI (proton-proton chain) network and has moved on to the CNO cycle that drives novae. We have also discussed electron behaviour (and as an aside emission/absorption) and electron degeneracy.

From there we will work on putting it all together. That is, how the accreted H envelope that accumulates on the WD, becomes dense enough, hot enough and at its base electron degenerate. It begins fusion by the proton-proton chain at the bottom of the H envelope in an electron degenerate medium that traps heat and develops a runaway CNO reaction. This thermonuclear runaway occurs for mere hundreds of seconds reaching temperatures in the order of $1.0 - 4.0 \times 10^8$ K depending upon WD mass. Further, when the Fermi temperature is reached ($\sim 7 \times 10^7$ K), the electron degeneracy ceases and the electrons return to behaving like an ideal gas. Expansion is ballistic and material is ejected in the order of $1.0 - 1.5 \times 10^3$ kms⁻¹ (Starrfield et. Al. 2016)

He's giving a report and update to Dr Hillman soon.

Piper Brookes - year 10

Piper is a young lady who shares a passion for astronomy with her father. She is making observations of UU Muscae (a Cepheid) and learning the ropes of photometry. She's grasped the basics of dark subtraction and flat fielding, and broadly the photometric filters and the significance of the brightness in each relative to one another.

We are looking for a Hertzsprung progression in the light curve of UU Muscae and this is going to lead to exploring asteroseismology as we learn about the mechanism of the progression and what that tells us about the interior of a Cepheid.

We are then going to further look at other Cepheids with and without progressions and see if we find anything common (mass/composition) to those with and without a progression.

Ollie Vullings - year 9

Ollie is a particularly bright young man. He is in his first year of high school. He came to the HOD sci-

ence (Mairi Borthwick) at Freyberg high school and said he was interested in astronomy and the elements in particular so she has referred Ollie to me.

His interests have pushed me to finally get working the SA200 diffraction grating I purchased some years ago.

We're going to do some bright star spectroscopy and see what we find in the way of spectral absorption/emission lines in stars of different composition.

In his project launch zoom meeting we discussed the absorption and emission of photons by electrons, and the nature of their orbitals and how electrons jump from one orbital to another, absorbing and emitting photons as they do. Ollie has produced a report indicating that he has a pretty good handle on what we discussed that is well beyond his tender years.

Ollie has since visited the observatory and made observations of UU Muscae that will be used for Piper's project. We took flats and darks and discussed their use in reducing noise and error in images generally. This also gave him an initial experience of using the telescope, camera and computer software for image capture. He has learned about celestial coordinates and how they're like and unlike the latitude and longitude he is familiar with as he had to locate the target (UU Muscae).

I now need to get some images with the diffraction grating and software to process the resulting spectra so I can boldly teach someone else something I've never done before!

Wanted: assessor for Ollie's project. This is a low intensity commitment. Assessment is conducted by zoom typically and is a free flowing Q&A of the student. Anything the student has covered and written about is fair game and broadly grades are achieved, not achieved or achieved with merit.

If you can help, please contact the author, details at the end of this article.

Evan Smith - year 10.

Evan is interested in doing an exoplanet project. His project is just getting under way and we are going to first learn about transit timing variation as a means of finding non-transiting bodies.

From there we will make our own observations of high priority transits that I have on my observing calendar. We will introduce how we use O-C mid-transit times and transit length variations before moving on to discussing the analysis of O-C that can lead to the development of extrasolar system models including non-transiting bodies that could produce the observed variation.

Author

Carl knight operates a small observatory in the rural Rangitikei district of New Zealand. Other than the student projects covered here, he has provided observations for use by professional astronomers on a semi-regular and ad-hoc specific request basis for photometry of asteroids and exoplanets. Up until the invasion of the Ukraine by Russia he regularly provided exoplanet transit observations to the EXPANSION (EXoPlanetary trANsit Search with an International Observational Network) project coordinated out of the Pulkovo Observatory, St. Petersburg, Russia – now not so much.

Email: ngileahobservatory@gmail.Com or personal, sleeplessatknight@gmail.Com

Bibliography.

Starrfield, S., Iliadis, E., Hix, W. R. (2016). *The thermonuclear runaway and the classical nova outburst*. Publications of the Astronomical Society of the Pacific, 128(965), retrieved from <https://www.Jstor.Org/stable/26659948>

Period change in CP Sculptoris, a study in period analysis – *Tom Richards*

tomprettyhill@gmail.com

This article is a study of the issues and difficulties in developing plausible period change models for short-period eclipsing binaries based on available minima estimates and ephemerides. The very fast eclipser CP Scl is used as an example, for which linear parabolic and sinusoidal models are investigated.

1 Introduction

CP Scl is a fast EW eclipsing binary ($P = 0.31366304$ d) and spectral type M3 located at RA 00 24 49.40, Dec $-27^{\circ} 44' 19.1''$ (data from AAVSO VSX (Watson *et al* 2014)). The first ephemeris for this system is from Pilecki *et al* (2007) – hereafter Pilecki –, referenced both in the VSX and the General Catalogue of Variable Stars (GCVS, Samus *et al*, 2017).

The Pilecki paper also reported a period change rate of $-2.3 \pm 0.05 \times 10^{-5}$ d/yr. Lohr *et al* (2015) analysed the SuperWASP data (Pollacco *et al* 2016) for the star, determining a very similar period (0.31366303 d) but a noticeably different change rate, $+1.20012 \pm 0.007 \times 10^{-6}$ d/yr.

2 Data

Minima data used in this analysis are shown in Table 1. Eclipse type (Primary or Secondary) is as calculated from the Pilecki ephemeris (see later) and agrees with the empirical light curves.

Table 1 Minima, their errors, eclipse type, and data source.

HJD_min	Error [d]	Type	Source
2451868.26500		P	Pilecki
2453350.32320	0.0043	P	ASAS-3
2453987.99303	0.0005	P	SWASP
2454362.81690	0.0002	P	SWASP
2456908.65700		S	OCG
2456921.98700	0.0010	P	TR
2456923.24200	0.0010	P	TR
2457098.26159	0.0035	P	ASAS-SN
2457315.00200	0.0030	P	TR
2457323.15500	0.0020	P	TR
2457324.09500	0.0010	P	TR
2457686.05779	0.0000	P	TR
2457829.08469	0.0023	P	ASAS-SN
2458066.05625	0.0005	S	TR
2458355.09107	0.0012	P	TESS
2458365.75490	0.0012	P	TESS
2458380.18321	0.0013	P	TESS
2458438.99522	0.0001	S	TR
2458778.21715	0.0010	P	MGB
2459472.97744	0.0012	P	TR
2459919.00254	0.0009	P	MGB

The complete dataset from which this table is derived can be downloaded [here](#). Secondary minima data immediately next to primary minima do not appear above in order to lessen statistical bias. Note that two

sources do not provide error estimates. Listed sources are Pilecki: Pilecki *et al*, (2007), ASAS-3: Pojmanski (2002), SWASP: Pollacco *et al* (2016), OCG: datum from the [O-C Gateway](#), TR: my VSS data, ASAS-SN: Shappee *et al*, (2014), [TESS](#): analysed by the Axelsen collaboration (Axelsen 2023), MGB: Mark Blackford's VSS data. ASAS-3 and ASAS-SN data were analysed by myself by folding the data on the best period, finding the phase offset of the primary minimum, and converting that to a JD near the centre of the data range from phases of data points of known JD times.

3 Method and results

3.1 Linear models

To explore possible changes in the period of CP Scl, a Python script was developed to compute Ordinary Least Squares regressions with linear, quadratic and sinusoidal terms. The regressed models are displayed in residuals diagrams (aka (O-C) diagrams); comprehensive statistics of each fit are collected, and ephemerides of the fits are calculated. Comparisons of the various models are investigated to determine the most likely model.

The first step in analysis is to check the data against an available ephemeris. The Pilecki ephemeris is the earliest one available; Its ephemeris (zero epoch and period) is

$$t_0 = \text{HJD } 2451868.265, P = 0.31366304 \text{ d (Ephemeris \#1)}$$

Figure 1 is an (O-C) diagram showing the residuals (observed – calculated differences) of the observed minima times from where they are predicted to be according to Ephemeris #1, which lie in the abscissa, $Y=0$.

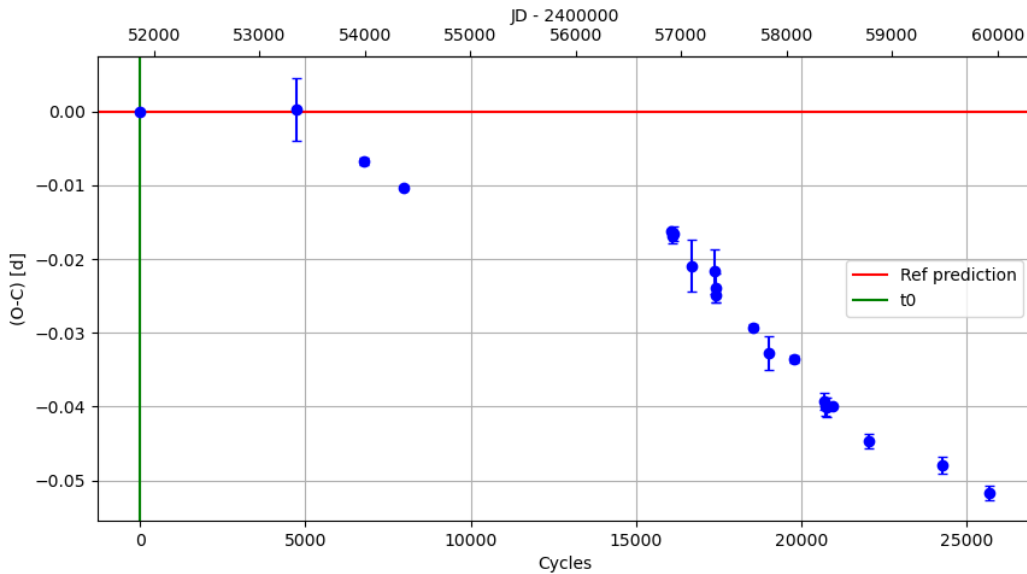


Figure 1. Table 1 data plotted against the Pilecki Ephemeris #1.

Plainly, from Figure 1 the Pilecki ephemeris is not doing a good job of predicting minima times; in fact the RMS residual here is large at 0.0304 d. The downwards slope of increasing negative residuals indicates a period shorter than Pilecki's. But also the Pilecki minimum (leftmost) does not lie on that downward slope.

But before trying to find a period that fits the observed minima better than Pilecki's, it is first necessary to check for a so-called cycle count jump.

3.1.1 Checking for cycle count jump

A cycle count jump is an artefact of the way the residuals from the reference ephemeris are calculated in an (O-C) diagram (Richards 2021). If the binary star's "true" rotation period is constant, an incorrect estimate of that period by the reference ephemeris will lead to an overall slope in the (O-C) diagram as

predicted minima steadily diverge from observed minima – the latter sticking roughly to reality. This is seen in Figure 1.

If over the period covered, the sloping (O-C) range *in the diagram* covers $P/2$ days top to bottom then the algorithm forces the slope of minima points to resume at $P/2$ d above or below where it reached the limit. The algorithm's predictions must always be exact cycles (or half-cycles for secondary eclipses), and that is how the jump artefact can arise. Here that range is 0.157 d. The diagram covers 8051 days, or 25667 orbital cycles according to the reference ephemeris. It requires a period error of only 6.11×10^{-6} d to force a jump somewhere in the diagram over that period, e.g. to predict the last observation should occur at 25667.5 cycles not 25667. The evidence in a diagram with a jump will be two (or more) parallel sloping lines of data points.

Is there a cycle count jump in Figure 1? Not on the evidence of the plotted points, where the (O-C) range is only 0.052 d, a third of that necessary for a jump. But, there is a “data desert” between cycles 7593 and 16069.5, and two separate but roughly parallel downward slopes on either side. If we had observed points in that desert, roughly close to reality and so following the depicted slopes, would they slope down and up sufficiently in the data desert to exhibit a jump, say at around cycle 55,500? By eye, the answer is definitely no – so I have not performed a simulation to test it. The mystery of why there are two apparent parallel slopes will have to be explored another way. Incidentally a cycle count jump in the data desert can be easily forced on the data by adopting the very close period of 0.31367 d, and is displayed in Figure 2. Here, $R^2 = 0.009$ – forget it! The blue band in Figure 2 is the 95% confidence interval: the confidence that 95% of all observations would lie in this band if the trend is linear, which it is not.

Any period outside the range 0.313658 to 0.313665 will plot out with a cycle count jump.

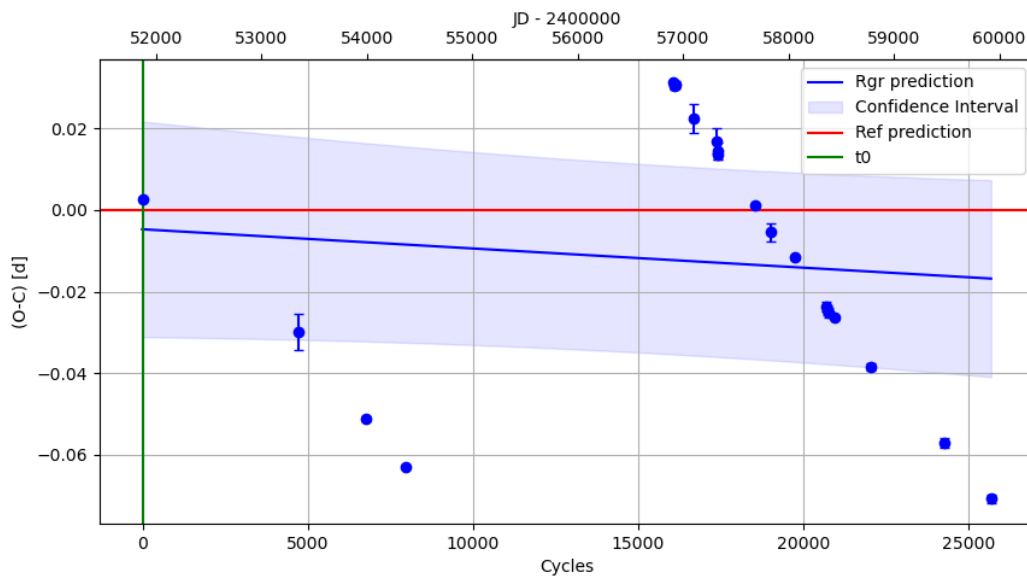


Figure 2. Minima data plotted using the Pilecki epoch and a period 0.31367 d incorporating a cycle count jump and showing a best-fit line with confidence interval.

It is necessary to do this cycle count check before trying to find a better period, because the best-fit calculation uses the predictions of the reference ephemeris. The best-fit line in Figure 2 attempts to cover the points to the left and to the right of the data desert, yielding nonsense.

3.1.2 Obtaining a valid best fit

In Figure 1 the Pilecki datum (leftmost) seems off-trend, so to play safe a new and reliable zero epoch t_0 is chosen – the first TR minimum in Table 1.

The resulting ephemeris is

$$t_0 = \text{HJD } 2456921.9879(15), P = 0.31366304 \text{ d} \quad (\text{Ephemeris \#2})$$

The result of changing the epoch is shown in Figure 3, a vertical shift in the diagram which by itself reduces the RMS residual by nearly a half to the still large 0.0182 d.

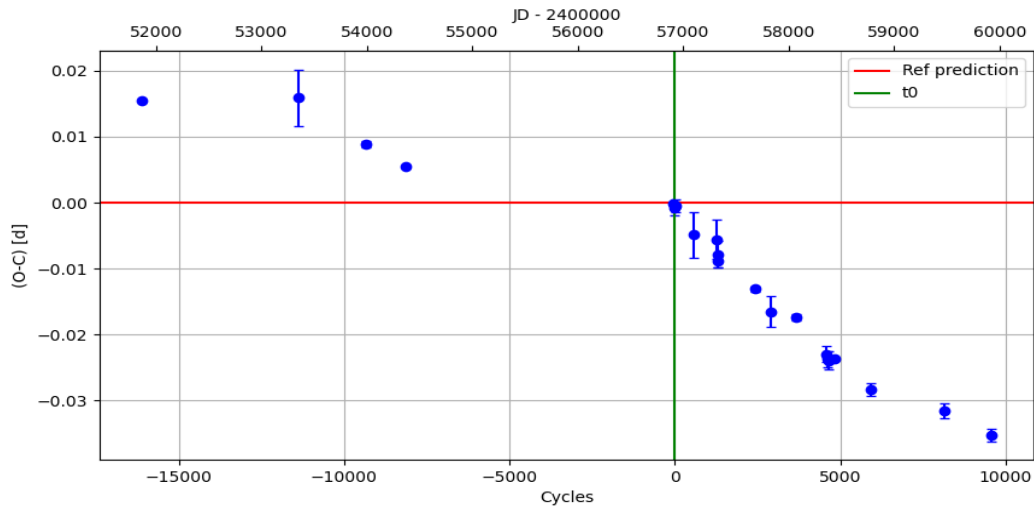


Figure 3. *The result of changing the reference ephemeris.*

Next, the aim is to find the best-fit model for the data in Figure 3. To do that an OLS regression is executed with a linear term, and using the new Ephemeris #2 as the reference ephemeris. The resulting regression fit is shown in Figure 4 (top), and its residuals (bottom).

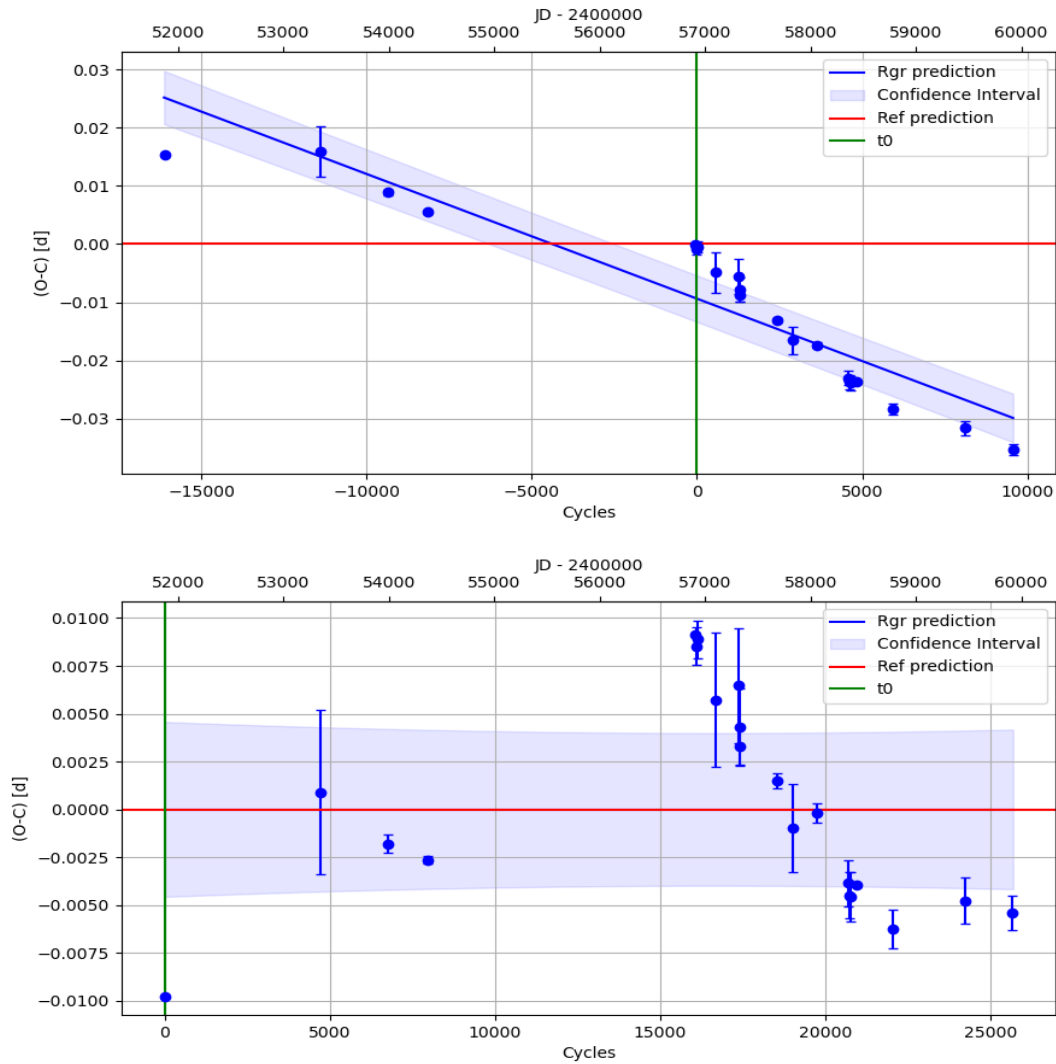


Figure 4. *Top: Linear fit using Ephemeris #2 as reference ephemeris. Bottom: Residuals from the linear model.*

The result is a great improvement over Pilecki. Here the RMS residual from the regressed predictions drops to 0.0054 d – still too large – and the coefficient of determination $R^2 = 0.869$, indicating the new fit explains the residuals well– compared to the reference ephemeris, which is not surprising. The ephemeris of this model is

$$t_0 = \text{JD } 2456921.978(2), P = 0.3136609(2) \text{ d} \quad (\text{Ephemeris \#3})$$

Again however, it's advisable to check if the new ephemeris yields a cycle count jump in the data. In Figure 3 bottom the new regression model behind Ephemeris #3 is used as a reference ephemeris and makes its own cycle counts, so could be different from those in Ephemerides #1 or #2 (the same). The (O-C) range here is 0.019 d, a third of that under the Pilecki ephemeris and a tenth of that needed to force a cycle count jump. So the model behind Ephemeris #3 can confidently be taken as valid and the best linear model for the data.

3.1.3 The Pilecki point anomaly

In Figure 4 the Pilecki datum (leftmost) is well outside the confidence band. There is a *prima facie* case it is an outlier. To explore the effect of omitting it, the above regression is repeated excluding the Pilecki point. Figure 5 is the plot of the result.

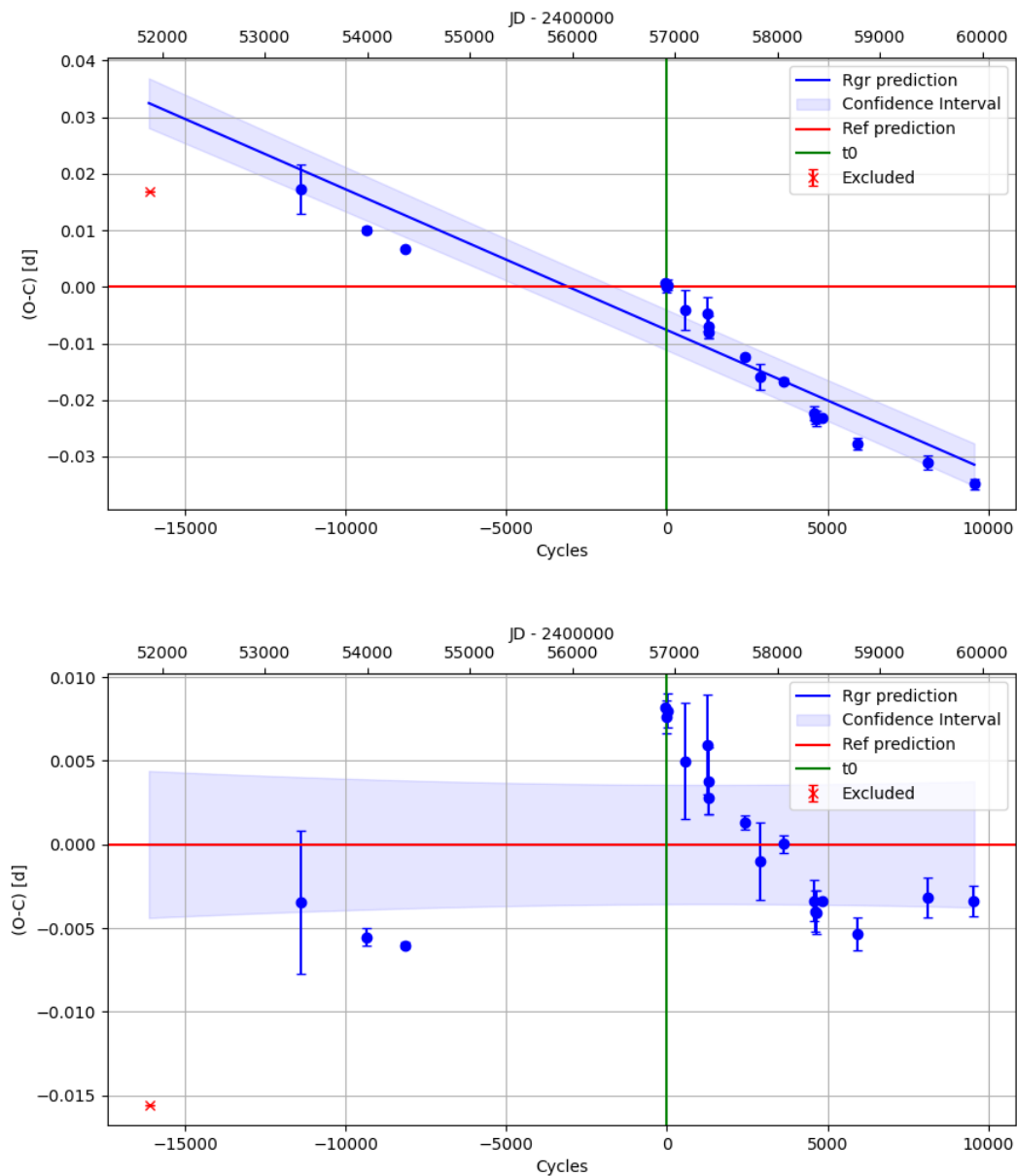


Figure 5. Top: Linear fit on all data except Pilecki, using Ephemeris #2 as reference ephemeris. Bottom: Residuals from the linear model.

This plot is more tilted (P shorter by 3×10^{-7} d), giving a better fit to the right of Cycle 0, but worse to the left. However R^2 increases a little to 0.883 but the RMS residual drops to 0.0048 d. Note how far off the fitted line the Pilecki point now lies. The ephemeris of this fitted model is

$$t_0 = \text{JD } 2456921.979(2), P = 0.3136606(2) \text{ d} \quad (\text{Ephemeris \#4})$$

Ephemeris #4 will be used below for further analysis of the effect of omitting the Pilecki point.

Figures 4 and 5 both show strong structure around the regression line which needs to be modelled if possible. Below I will investigate parabolic and sinusoidal models.

3.2 Parabolic models

A common feature of eclipsing binaries is a linear change in period, resulting in a parabolic fit to the observed minima. To test this, regressions with a linear and quadratic term are executed, resulting in the fits displayed in Figure 6.

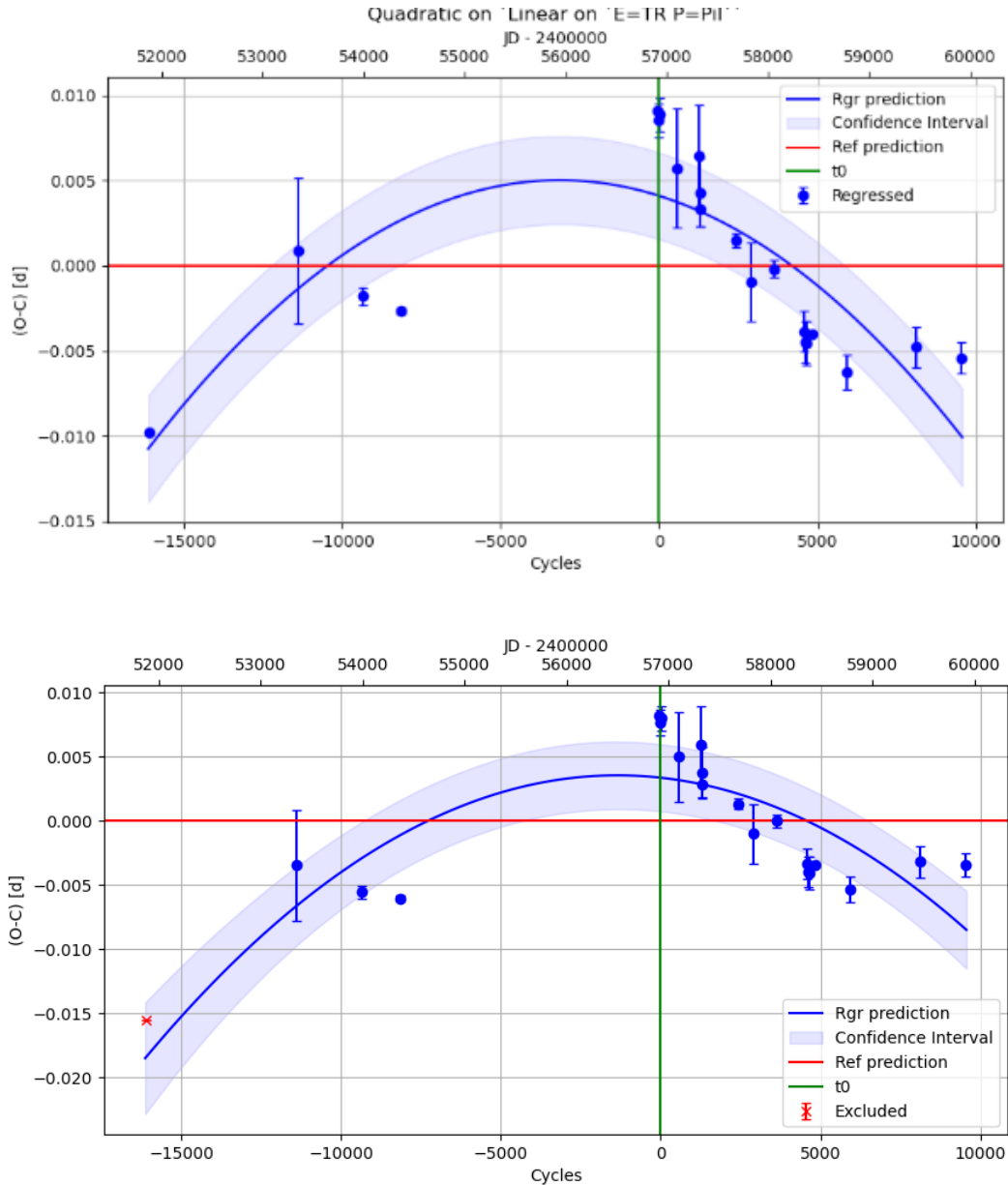


Figure 6. Fits of OLS regression models with quadratic term. Top: with Pilecki datum, Bottom: without Pilecki datum.

The two models are not very different; but with both having an R^2 around 0.5 and broad confidence bands, they offer insignificant improvement on the linear fits shown in Figures 4 and 5. A linear change in period can, on the data, be rejected.

3.3 Sinusoidal models

Both Figures 4 and 5 however suggest a wavy distribution of the residuals around the fit line, so a sinusoidal fit is the next regression to try. A sinusoid would indicate an oscillation in light time from the binary to us, with the pair orbiting a barycentre common to them and a third body in the system. Not, note, a period change.

OLS regressions incorporating sinusoidal terms were executed with and without the Pilecki datum and using the linear ephemerides that included and excluded the Pilecki datum respectively. The results are plotted in Figure 7.

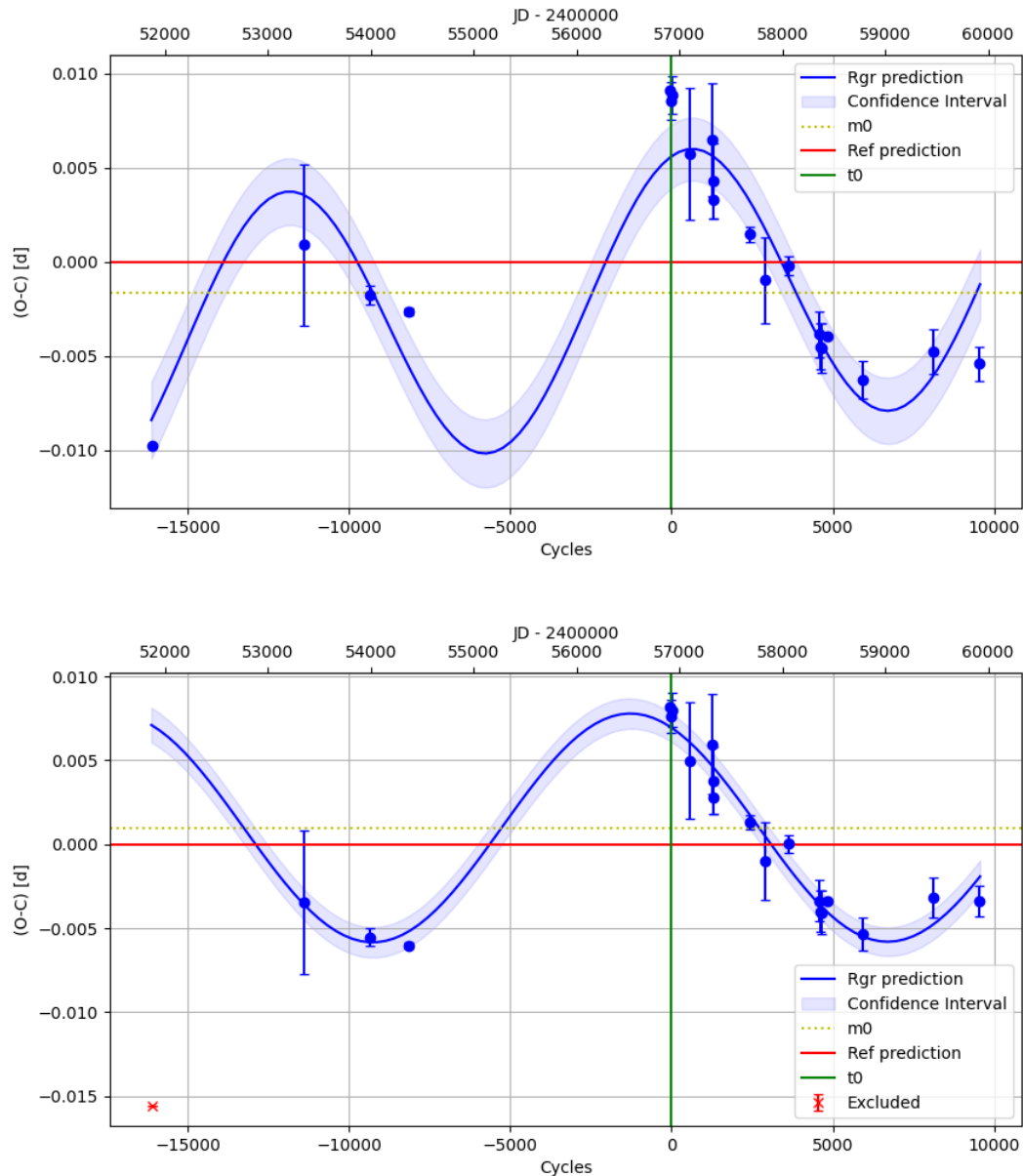


Figure 7, Sinusoidal fits to the residuals from the linear fits in Figures 3 and 4. Top: Reference Ephemeris #3 and with Pilecki datum, Bottom: Reference Ephemeris #4 and without Pilecki datum.

These two plots and associated statistics are very different; the only explanation being to do with the exclusion of the Pilecki datum. With it (top), the sinusoid is forced to bend down on the left to accommodate the Pilecki point, resulting also in an overall upward slope not captured by the linear fit of the reference ephemeris and hence most likely spurious. Without the Pilecki point (bottom) the sinusoid has zero linear slope component, and the Pilecki point is an outlier of some -0.023 d. Note the 95% confidence band is far narrower in the bottom plot. R^2 values are respectively 0.854 and 0.955, and RMS residuals are 0.002

and 0.001 d. The non-Pilecki sinusoid is clearly preferable. The parameters of the sine equation where t is time in days and y is the difference from the reference ephemeris, are as follows.

Table 2. *Parameters of the best-fit sinusoid.*

Parameter	Value	Error
Period, P_{sin} [d]	5007.01	6.38
Vertical offset, m_0 [d]	0.001	0.003
Amplitude, A [d]	0.0068	0.0012
Phase at cycle 0, ϕ [radians]	0.50	0.08

Based on all the above explorations of period change, my conclusion is that the preferred linear fit is Ephemeris #4, which does not use the Pilecki datum; and its residuals are best explained by the sinusoid model in Table 2, which also does not use the Pilecki datum.

4 Discussion

Fitting period change models to minima data has several difficulties and can be inconclusive. A typical Southern Hemisphere problem is the “data desert” between the discovery ephemeris and data from 21st Century fast electronic imaging technology. One or two minima estimates can be extracted from ASAS-3 and SuperWASP photometry in that interval if available, but ASAS3 in particular is noisy and hence error-prone. A data desert can conceal unnoticed jumps in constant periods, non-linear changes, and cycle count jumps (Richards 2021). Here, a cycle count jump can be ruled out as discussed in Section 3.1.1.

Another problem is in assessing the reliability of discovery ephemerides, on which later analysis usually has to rely, at least as a starting-point. Usually these are obtained by plate photography or 0-dimensional photoelectric photometry, with a cadence far too slow to capture much data in a fast eclipse – for CP Scl ~ 100 m. An ideal is ~ 100 data points in the useable part of the eclipse.

The Pilecki discovery ephemeris is different, being based on electronic imaging by ASAS-3, covering a 5-year period of 2003 November to 2009 July, with a typical cadence of 3 days in season. Why is the Pilecki epoch so clearly an outlier in some models? The median point of the ASAS-3 data range is $\sim$ JD 2453350, near which one would expect an interpolated epoch of minimum to be calculated to minimise errors. Instead the Pilecki epoch has been extrapolated to JD 2451868.265 – earlier by 4 years and ~ 4700 cycles. There is no way to estimate the error in the extrapolation. For these reasons, and because the final models without the Pilecki datum (linear and sinusoid) are an improvement over those with it, it is rejected here. Doing so is a disputable matter of judgement, which can happen even after all the statistics are in.

5 Conclusion

An analysis of eight period change models for CP Scl minima data acquired by various sources over 18 years indicates that the best linear ephemeris is Ephemeris #4 and Figure 4 above; and the best model fitted to its residuals is sinusoidal as in Figure 6 (bottom) and Table 2 above. There is no good evidence for period change, disagreeing with a Pilecki’s estimate (Pilecki *et al* 2007), based on the ASAS-3 data, and Lohr *et al* (2015) based on ~ 6 years’ SuperWASP data. However the Pilecki estimate is roughly consistent with the downward slope of the sinusoid around the time of ASAS-3 photometry, illustrating that data acquired over longer periods may lead to entirely different explanations of apparent period change.

The development of these models and the problems and unknowns in them illustrates the theme of this article, that period change modelling is not a simple or definitive procedure but is complex and has elements of judgement and experience.

Future minima data for CP Scl will be valuable to test the modelling here. I plan to apply the code and methods illustrated here to other southern close eclipsing binaries for which sufficient minima data are available.

Acknowledgements

I'm grateful to Col Bembrick for checking this article, and for development of a stellar model of CP Scl using light curve data of mine that was also used above. I look forward to a joint publication. I'm also grateful to Lyn Richards and Robert Jenkins for encouragement in the development of the Python script used here.

References

- Axelsen, R., 2023. *VSS Newsletter* 2023-2. Online at <https://www.variablestarssouth.org/vss-newsletter-april-2023>
- Lohr, M.E. et al 2015. *A&A*, 587A,136.
- Pilecki, B, Fabrycky, D, Poleski, R. 2007. *MNRAS* 3478, 757-767
- Pojmanski, G., 2002. *Acta Astronomica* 52, 397. Online at <http://www.astro.uw.edu.pl/asas/?page=acvs>
- Pollacco, D. L.; et al. 2016. *PASP*. 118 (848): 1407–1418.
- Richards, Tom, 2021. *VSS Newsletter* 2021-2, 14-20. Online at <https://www.variablestarssouth.org/vss-newsletter-april-2021>
- Samus N.N. et al, 2017. General Catalogue of Variable Stars: Version GCVS 5.1, *Astronomy Reports*, 61: 1, pp. 80-88. Online at <http://www.sai.msu.su/gcvs/gcvs/>
- Shappee, B.J. et al, 2014. *ApJ* 788:1.
- Watson, C.L. et al, 2014. Online at <http://www.aavso.org/vsx>

Publication watch

Phil Evans has two new arXiv TESS papers as co-author, three additions to a VizieR Online Data Catalog, and two previously noted arXiv papers have been updated to journal publications.

Priyashkumar Mistry, et al. *VaTEST II: Statistical Validation of 11 TESS-Detected Exoplanets Orbiting K-type Stars*. arXiv:2301.09865

Abstract

NASA's Transiting Exoplanet Survey Satellite (TESS) is an all-sky survey mission designed to find transiting exoplanets orbiting nearby bright stars. It has identified more than 329 transiting exoplanets, and almost 6,000 candidates remain unvalidated. In this manuscript, we discuss the findings from the ongoing VaTEST (Validation of Transiting Exoplanets using Statistical Tools) project, which aims to validate new exoplanets for further characterization. We validated 11 new exoplanets by examining the light curves of 24 candidates using the LATTE and TESS-Plot tools and computing the False Positive Probabilities using the statistical validation tool TRICERATOPS. These include planets suitable for atmospheric characterization using transmission spectroscopy (TOI-2194b), emission spectroscopy (TOI-3082b and TOI-5704b) and for both transmission and emission spectroscopy (TOI-672b, TOI-1694b, and TOI-2443b); One super-Earth (TOI-2194b) orbiting a bright ($V = 8.42$ mag), metal-poor ($[Fe/H] = -0.3720 \pm 0.1$) star; one short-period Neptune-like planet (TOI-5704) in the Hot Neptune Desert. In total, we validated 1 super-Earth, 7 sub-Neptunes, 1 Neptune-like, and 2 sub-Saturn or super-Neptune-like exoplanets. Additionally, we identify five likely planet candidates (TOI-323, TOI-1180, TOI-2200, TOI-2408 and TOI-3913) which can be further studied to establish their planetary nature.

Page, Emma. et al. *TOI-1994b: A Low Mass Eccentric Brown Dwarf Transiting A Subgiant Star*. ArXiv:2305.08836

Abstract

We present the discovery of TOI-1994b, a low-mass brown dwarf transiting a hot subgiant star on a moderately eccentric orbit. TOI-1994 has an effective temperature of 7700^{+720}_{-410} K, V magnitude of 10.51 mag and $\log(g)$ of $3.982^{+0.067}_{-0.065}$. The brown dwarf has a mass of $22.1^{+2.6}_{-2.5}$ MJ, a period of 4.034 days, an eccentricity of $0.341^{+0.054}_{-0.059}$, and a radius of $1.220^{+0.082}_{-0.071}$ R_J . TOI-1994b is more eccentric than other transiting brown dwarfs with similar masses and periods. The population of low mass brown dwarfs may have properties similar to planetary systems if they were formed in the same way, but the short orbital period and high eccentricity of TOI-1994b may contrast this theory. An evolved host provides a valuable opportunity to understand the influence stellar evolution has on the substellar companion's fundamental properties. With precise age, mass, and radius, the global analysis and characterization of TOI-1994b augments the small number of transiting brown dwarfs and allows the testing of substellar evolution models.

Online data catalogs:

- VizieR Online Data Catalog: *ExoClock project. III. 450 exoplanet ephemerides* (Kokori, et al, 2023) (2023-07-20)
- VizieR Online Data Catalog: *TESS Grand Unified Hot Jupiter Surveys. II.* (Yee, et al, 2023) (2023-07-20)
- VizieR Online Data Catalog: *TOI-615, TOI-622, TOI-2641 RVs + ground phot.* (Psaridi, et al, 2023) (2023-07-20)

Updated to journals:

- **Yee, S., et al.** *The TESS Grand Unified Hot Jupiter Survey. II. Twenty New Giant Planets* (2023-07-20). 2023ApJS..265....1Y
- **Psaridi, A. et al**, *Three Saturn-mass planets transiting F-type stars revealed with TESS and HARPS. TOI-615b, TOI-622b, and TOI-2641b* (2023-07-20). 2023A&A...675A..39P

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.

Who's who

Director Mark Blackford

Treasurer/Membership Bob Evans

Newsletter Editor Phil Evans

Webmaster David O'Driscoll

Visit our website to see a list of our area advisers, and to find out about our projects and how to contact their leaders

Membership

New members are welcome. There is no annual subscription but donations would be gratefully received. Find out how to join by visiting the VSS website. There you will find out how to join by post, email, or directly online. If you join by email or online and wish to make a donation you will get a link to pay by PayPal's secure online payment system, from your credit card or bank account.

After you've joined and received your membership certificate, you will be signed up to the VSS-members egroup (see above), and you will also receive a password to access the members' areas of our website.

Newsletter items

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.

Reproduction rights

To obtain permission to reproduce any content for legitimate scientific or educational purposes please contact the director, Mark Blackford, at director@variablestarssouth.org.

Citations of material in this newsletter should refer to "Newsletter of Variable Stars South, RASNZ" with year and number, and include the download URL.