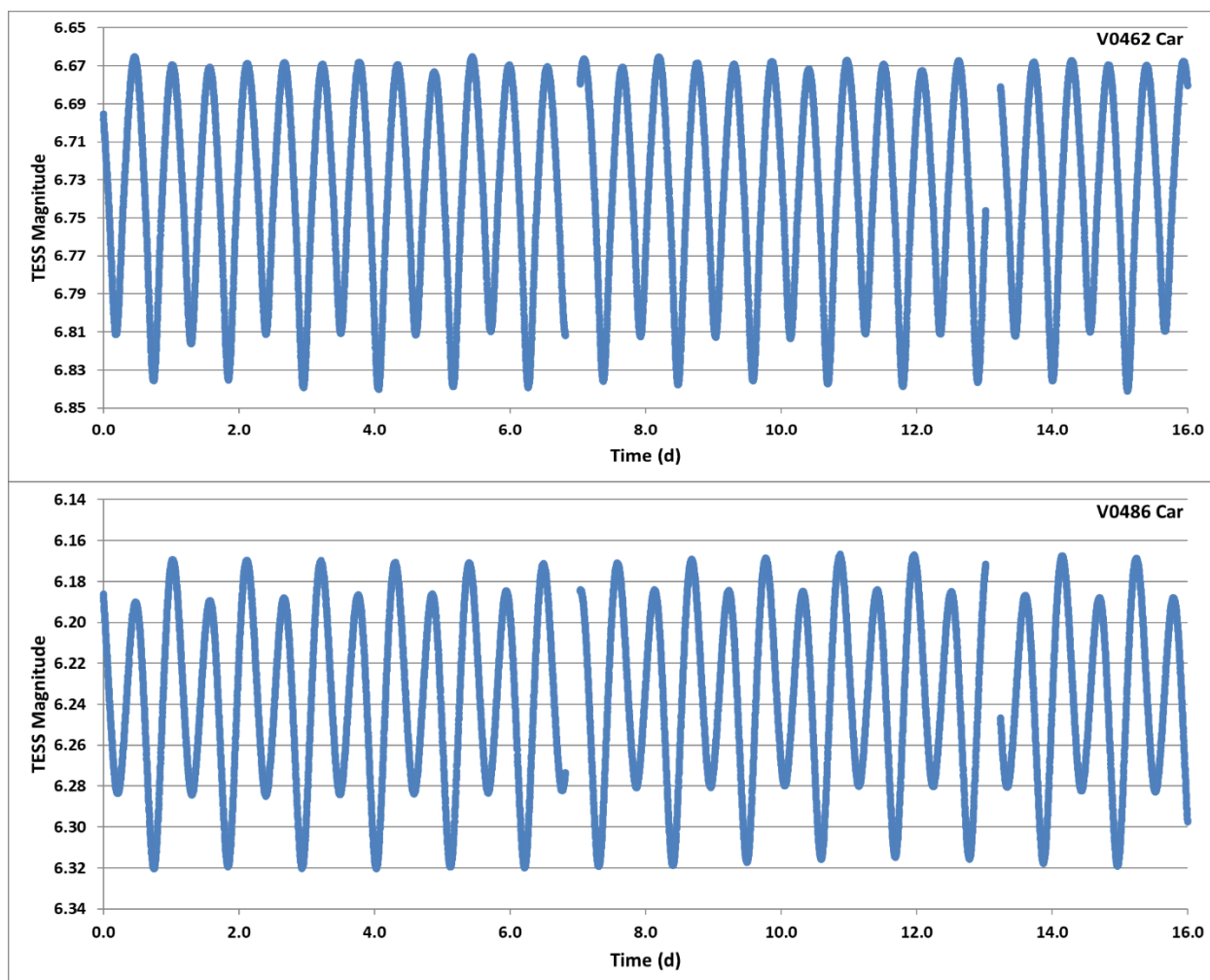




*TESS light curves of two relatively unstudied contact binaries showing variable O'Connell effects
See article by Mark Blackford on page 13.*

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From the Director – *Mark Blackford*

Welcome to our first edition of the Newsletter for 2025, the first with our new editor Ed Budding. This is a somewhat slimmer edition than usual, but we hope to build back to more substantial Newsletters in the near future. To do that we require contributions from our readership, so please put some thought to what you can provide.

In this edition, Tom Love describes his project to construct a large dataset of δ Scuti stars as a first step toward exploring the properties of a subset of these, the High Amplitude Delta Scuti Stars. David Moriarty updates us on progress of his investigations of eclipsing binaries with pulsating components, and I present details of two close binary systems with variable O'Connell Effect.

Also included is my Annual Report for 2024, on behalf of VSS, to our parent body, the Royal Astronomical Society of New Zealand. It is worth remembering that Variable Stars South was reborn from the ashes of the RASNZ Variable Star Section thanks to the mighty efforts of Tom Richards in 2009. Tom's column in the very first VSS Newsletter is recommended reading for anyone interested in the origin of our group.

It is with regret that I have made the decision to cancel the VSS symposium set for May 9th in Whakatane, NZ. There was little response to calls for presentations and, at the time this decision was made, only four people had registered to attend in-person. Several people indicated they would be interested in participating via Zoom but that doesn't pay the on-ground costs of running a meeting. We will explore the possibility of running another virtual symposium via Zoom later in the year, similar to that held in October/November 2022.

Last November Tom Love ran the inaugural VSS Journal Club Zoom meeting where he summarised a paper on AH Pictoris stars by Albert Bruch. This was followed by some discussion. About half a dozen members joined the meeting and agreed to resume in the New Year. However, due to lack of response to calls for a volunteer to summarise another paper, the planned meeting in February was cancelled. The Journal Club may be resurrected if someone is inspired by a new paper and offers to present it to the group.

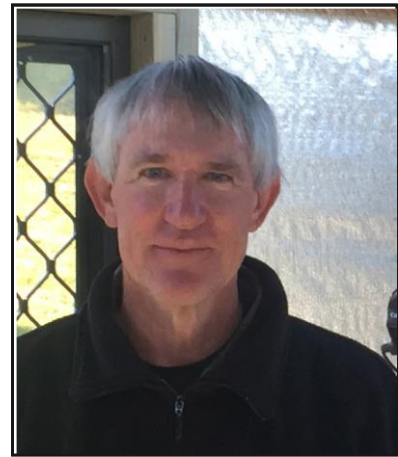
VSS members may be interested in an upcoming AAVSO webinar titled Deciphering Eclipsing Binary Systems (and how Citizen Scientists can help), presented by Dr. Pierre Maxted of Keele University. The session kicks off on Saturday, March 1 at 2:00 pm ET. A previous meeting 'Getting Ready for the Next Galactic Supernova', is now available on the AAVSO YouTube channel.

Congratulations again to Andrew Pearse on his independent discovery of V7992 SAGITTARII (NOVA SAGITTARII 2025 No. 2) in January.

I've managed only a few nights of imaging with my small refractors at Congarinni Observatory in recent months. The 14" RC telescope is still off-line due to mount problems. Weather forecasts for the remainder of summer are not too promising -- perhaps autumn will see more favourable conditions.

Wishing you all clear skies and good health,

Mark Blackford



Variable Stars South -- Annual Report

Royal Astronomical Society of New Zealand, Variable Star Section

Mark Blackford, Director

During 2024 the section continued to be active in many aspects of variable star astronomy: visual, CCD/CMOS, DSLR, spectroscopy, the analysis of measures where appropriate and the supply of these to other groups.

Newsletter

Four quarterly newsletters were published with a total of 100 pages. 22 excellent articles were published by the following authors: Mati Morel, D S Homer, Mark Blackford, Rod Stubbings, Tom Richards, Simon Sikora, Roy Axelsen, Colin Bembrick, Stan Walker, Cledison Marcos da Silva, Jeff Byron, Phil Evans, Pierre Traverse, Jean-Louis Virlichie, Hervé Roy, Tom Love, Peter Velez, Andrew Pearce, and Ed Budding.

After 54 editions, starting in May 2011, Phil Evans has stepped down as editor. On behalf of VSS I wish to thank Phil for his excellent work producing a consistently high-quality publication. Ed Budding has taken on the role in 2025 on an interim basis until someone else steps forward.

Website

Webmaster David O'Driscoll continues to maintain and improve the Variable Stars South website and Google Group. As a mainly on-line group these are essential components of VSS.

Member highlights

Below are reports contributed by several individual members on their variable star activities in 2023.

Roy Axelsen: Most photometry during 2024 comprised time series of southern eclipsing binary (EB) systems for the purpose of determining the times of mid eclipse for uploading to the EB databases of Variable Stars South (VSS). Due to cloud or rain, observations of these stars were able to be taken on only 24 nights. Images for calibration frames or for testing equipment or procedures were taken on a few other nights.

Stars observed were: V0839 Cen, V0757 Cen (no adequate minimum captured), V0758 Cen, RR Cen (ND4 filter), NT Aps (ND4 filter), V716 Cen (Canon EOS time series), V0395 Nor, OW Lup, V0954 Sco, V0398 Nor, ST Ind, BO Ind, V0343 Tel, ZZ PsA, BC Gru, DX Tuc. On two nights in September the short period delta Scuti star ZZ Mic was observed in order to update times of maximum light for the determination of the rate of change in the period.

Data on most of the above stars was derived from images captured with a ZWO ASI294MM camera imaging through a 200mm Canon lens at f/2.8. Photometry was performed in AstroimageJ, and the raw magnitude data imported in spreadsheet templates for the plotting of the light curves. The times of mid eclipse were determined by high order polynomial fits.

Observing for time series photometry ceased in October due to frequent rain and/or cloud and had not resumed on a regular basis before the end of the year.

Experimental studies were performed to test the precision and accuracy of photometry with the ASI294 camera and 200mm lens with and without calibration. The results showed that it is possible to omit calibration with darks and flats for time series photometry with this equipment. The likely reason is that images were captured with the camera's Region of Interest (ROI) feature turned on and set to ½. Images thus captured have half the width and half the height of standard images, very little vignetting, and quite small distances between the variable and comparison stars. This experiment was performed partly out of curiosity, but also because a situation had occurred in the past where images for photometry needed review, but calibration frames had been lost.

Mark Blackford: 2024 was a frustrating year for astronomy. My observatory was out of action for the first 8 months due to roof damage in a thunderstorm on Christmas night 2023. Repair work was delayed by insurance holdups and extended holidays overseas. My first observations for 2024 were made on August 28 th . In total I managed only 15 nights of observing all year. The weather at Congarinni Observatory was not conducive to photometry.

Eclipsing binary times of minima were determined for V0878 Ara, QW Tel, V0610 Ara, DX Aqr, DE Mic, MW Pav, EE Aqr, BR Ind and V0505 Sgr using my RedCat51 refractor and ASI2600 CMOS camera (purchased in 2023 using a grant from the Edward Corbould Research Fund).

My ED80 refractor and Atik One 6.0 CCD camera were used for EB times of minima of EK Tuc, DX Tuc, DY Gru, V0386 Pav, DG Mic, V Gru, and BC Gru.

Two papers were published in 2024.

Phil Evans: 2024 was a relatively unproductive year for me and my remote scope at El Sauce, Chile. Due to persistent cloud, my travels, equipment problems, and a diminishing number of available TESS targets. I began the year with seven nights' observation of an EB with delta Scuti pulsations for a VSS project and followed this with 131 nights observations of TESS exoplanet targets.

Over the year I was a co-author on six journal papers, four arXiv papers and 3 data catalog entries.

At the end of the year, I resigned my position in VSS as newsletter editor after 54 issues beginning in 2011. 2025 is already promising to be more productive and less cloudy!

Carl Knight: Continued making observations of high priority exoplanets for the EXPANSION project.

Ollie Vullings completed his Bronze STEM Academy project. He analysed spectra taken with an SA200 diffraction grating of type A, M and Wolf Rayet (WC) stars. Tom Field (RSpec SW author) was his assessor.

Conan Strachan concluded his Gold STEM Academy CV project with observations of BV Centauri and EC 21147-6438, and discussed nuclear reaction networks, compared and contrasted novae, dwarf novae, recurrent novae, nova-like. His assessor was Dr. Yael Hillman who we have had as a speaker at a previous VSS colloquium.

Piper Brooks continued her Bronze STEM Academy project learning about astroseismology and using Cepheids with Hertzsprung Progression as potential examples.

PhD student, Lia Bernabò, published, 'Evidence of apsidal motion and a possible co-moving companion star detected in the WASP-19 system'; in *Astronomy and Astrophysics*, Volume 684, April 2024, using observations I made of WASP-19b.

Cledison Marcos da Silva: In 2024 I did a total of 6,624 CCD observations and 147 visual observations. With Kilonova Seekers I did 12 transient discoveries, with 2 of these classified as supernovae. I was added as co-author in one paper: <https://ui.adsabs.harvard.edu/abs/2024MNRAS.529.1283F/abstract> and two ATels related to the discovery of the cataclysmic variable GOTO065054.49+593624.51, this CV will be the subject of a paper to be published in 2025. (see:

<https://www.astronomersteleggram.org/?read=16842> and

<https://www.astronomersteleggram.org/?read=>

David Wheeler: This was my first year doing variable star estimates. I do visual observations with a 15cm achromat with an 80mm riding piggyback. I observe from my backyard in suburban Wollongong (Bortle 5-6).

I have reported 131 estimates to AAVSO, observer code WDAH. This was done over 28 nights, I have done up to 12 in a night, but there were a few nights when I was clouded out after 1-2 observations and others where I was slow because I was learning about new stars. I was observing several nights a month until Sept, but then the weather changed, and I have observed on only one night since. There were a

couple of possible nights in late Dec but I feel too old to start work at 9.30pm. There have been 75 downloads of my data, with R Cen being the most popular.

My target list is mostly miras and semi-regulars, whose mag range and observation cadence suit my equipment. My brightest estimate was mag 4.6 and on a night of excellent seeing I saw Z Sco at mag 11.7 but most of my estimates were in the 6-10 range.

Peter Williams: During the calendar year 2024, visual observations of variable stars were obtained at Heathcote NSW on just 59 nights, possibly the lowest number of nights in many years and due to the persistent La Nina weather pattern, that continues to dominate the weather along much of the eastern coast of Australia.

Magnitude measurements obtained during 2024 totalled just 3495, but this is to be expected due to the overabundance of cloudy nights. Observations have again been concentrating mostly on bright semi-regular red variables or Mira stars whose light variations can be followed with either the 10x50mm or the 20x80mm binoculars through all, or part, of their cycle in continuation of an ongoing program to monitor poorly observed southern SR and red stars, instigated some years ago by Aline Holmes of Variable Stars South, RASNZ. As is the case for all such red variables of longer period, it takes several years at the earliest before we see some meaningful results on the behaviour of these stars, and this therefore remains a work in progress.

Other classes of variable stars also monitored include several of the brighter RCB and HdC/PVTel stars, SDOR & ACYG stars, recurrent novae and potentially recurrent old novae. Regular observation of several bright, long period southern Cepheids has continued, some now over several decades, to provide an annual mean epoch for maximum light & allowing for the study of period changes that have been shown to be taking place in these stars.

VSS Southern Eclipsing Binaries Project

Many southern eclipsing binaries have received very little attention since their discovery. The aim of the VSS SEB Project is to measure accurate times of minimum of southern hemisphere eclipsing binaries to more precisely determine their orbital periods and identify systems requiring further study.

During 2024, VSS members Roy Axelsen and Robert Jenkins submitted 31 Times of Minimum measurements of 21 different eclipsing binary targets to the SEB Project. Additional Times of Minimum were recorded by Mark Blackford, Stefan Keller, Andrew Pearce and others, but have yet to be added to the Minima database.

Ed Budding's Southern Binaries Programme

Binary stars are an important source of fundamental data on stellar properties such as their masses and luminosities. The aim of the SB programme is to study massive young close binary systems, often associated with star-forming regions, using astrometric, photometric and spectroscopic techniques. Collaborators include amateur and professional astronomers from around the world including several Variable Stars South members. Ed Budding, Tim Banks, Michael Rhodes, Tom Love, and Mark Blackford regularly meet via Zoom to discuss current and potential future projects.

In 2024 a paper on VV Orionis was published in Monthly Notices of the Royal Astronomical Society and a paper on S Antlia and epsilon Coronae Australis was published in Publications of the Astronomical Society of Australia. A paper on NO Pup is in preparation.

Publications

Our members' observations were used in numerous publications in 2023, with many being the results of Pro-Am collaborations. Below are those I am aware of.

David Moriarty and Phil Evans: Liakos, A.; Moriarty, D. J. W.; Erdem, A.; West, J. F.; Evans, P., Modelling of eclipsing binary systems with pulsating components and tertiary companions: BF Vel and RR Lep, *Astronomy & Astrophysics*, Volume 691, id.A260, 22 pp.

Phil Evans was co-author on the following publications:

Ehrhardt, Juliana; Thomas, Luis; Kellermann, Hanna, et al., Confirmation of four hot Jupiters detected by TESS using follow-up spectroscopy from MaHPS at Wendelstein together with NEID and TRES, *Astronomy & Astrophysics*, Volume 692, id.A220, 20 pp.

Mantovan, G.; Wilson, T. G.; Borsato, L., et al., The inflated, eccentric warm Jupiter TOI-4914 b orbiting a metal-poor star, and the hot Jupiters TOI-2714 b and TOI-2981 b, *Astronomy & Astrophysics*, Volume 691, id.A67, 20 pp.

Bryant, Edward M.; Bayliss, Daniel; Hartman, Joel D., et al., TOI-2379 b and TOI-2384 b: two super-Jupiter mass planets transiting low-mass host stars, *Monthly Notices of the Royal Astronomical Society*, Volume 533, Issue 4, pp.3893-3906

Schulte, Jack; Rodriguez, Joseph E.; Bieryla, Allyson, et al., Migration and Evolution of giant ExoPlanets (MEEP). I. Nine Newly Confirmed Hot Jupiters from the TESS Mission, *The Astronomical Journal*, Volume 168, Issue 1, id.32, 30 pp.

Noguer, Federico R.; Corley, Suber; Pearson, Kyle A., et al., Enhancing Exoplanet Ephemerides by Leveraging Professional and Citizen Science Data: A Test Case with WASP-77 A b, *Publications of the Astronomical Society of the Pacific*, Volume 136, Issue 6, id.064401, 20 pp.

Hord, Benjamin J.; Kempton, Eliza M. -R.; Evans-Soma, Thomas M., et al., Identification of the Top TESS Objects of Interest for Atmospheric Characterization of Transiting Exoplanets with JWST, *The Astronomical Journal*, Volume 167, Issue 5, id.233, 33 pp.

Page, Emma; Pepper, Joshua; Wright, Duncan, et al., TOI-1994b: A Low-mass Eccentric Brown Dwarf Transiting A Subgiant Star, *The Astronomical Journal*, Volume 167, Issue 3, id.109, 11 pp.

Mark Blackford was co-author on the following publications following publication:

Budding, E., Southworth, J., Pavlovski, K., et al., The enigmatic multiple star VV Ori. 2024, *Monthly Notices of the RAS*, 527, 6389, DOI: 10.1093/mnras/stad3586

Bakış, Volkan; Budding, Edwin; Erdem, Ahmet, et al., Comparative study of the W UMa type binaries S Ant and ϵ CrA, *Publications of the Astronomical Society of Australia*, Volume 41, article id. e083

Cledison Marcos da Silva was co-author on the following publication:

Froebrich, Dirk; Scholz, Aleks; Campbell-White, Justyn, A survey for variable young stars with small telescopes - VIII. Properties of 1687 Gaia selected members in 21 nearby clusters, *Monthly Notices of the Royal Astronomical Society*, Volume 529, Issue 2, pp.1283-1298

Defining a Sample of Delta Scuti Stars –

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Abstract

This brief note summarises some work in progress on a larger project on High Amplitude Delta Scuti Stars. It describes the initial step of the project, which is to construct a large sample of Delta Scuti stars from publicly available TESS light curve data. This will then provide the starting point for analysing stars with high amplitude light curves and exploring whether these high amplitude stars show distinctive properties within the overall population of Delta Scuti type stars.

Introduction

Radial velocity variability was observed in the F type star δ Scuti (also 2 Sct or HD 172748) in 1900 (Campbell & Wright, 1900), by observers using a spectrograph on the 36 inch telescope at the Lick Observatory (Campbell, 1898). Subsequent observations confirmed the impression that δ Scuti was variable, but it was not until 1935 that newer photographic emulsions allowed exposure times to be shortened to less than one hour, achieving the time resolution necessary to identify a radial velocity period of 0.19374 days (Colacevich, 1935). A study with an early photo-electric photometer measured the same period photometrically and identified characteristics of the light curve, including variable amplitude and the phasing between radial velocity and photometric cycles (Fath, 1935).

In the modern era, δ Scuti has given its name to a class of stars with specific physical and pulsation properties, although the recognition of this as a distinct classification of stars has not always been clear. They have sometimes been grouped together with other pulsating stars that have a similar position in the Hertzsprung-Russell diagram such as RR Lyrae stars (Woltjer, 1956) or AI Velorum pulsators (Epstein, 1969). While they are the dominant type of star in their region of the Hertzsprung-Russell diagram, δ Scutis have at times presented a taxonomic challenge as researchers have tried to distinguish them from other objects.

McNamara (2000) characterised High Amplitude Delta Scuti (HADS) stars as being spectral type late A or early F with an asymmetric light curve, a period of one to six hours and a peak to peak light curve amplitude of > 0.3 magnitudes. He described them as fitting within a relatively narrow temperature range of around 300K and at somewhat lower average temperatures than other δ Scuti objects. HADS therefore tend to be found in the central region of the δ Scuti instability strip, and somewhat closer to the Terminal Age Main Sequence, with the same period-luminosity relationship as other δ Scuti stars (Murphy, 2014; Petersen & Christensen-Dalsgaard, 1996). A review of A type stars notes the selection effects that exist in pre-space-based detection of δ Scutis. Selection in favour of high amplitude could be associated with slow rotation and radial pulsation modes, and with sharp-lined spectra (Murphy, 2014).

The earliest δ Scuti stars to be identified were predominantly HADS, for the self-evident reason that given the conventional definition of having an amplitude of > 0.3 magnitudes it is easier to detect such relatively large variations in brightness than smaller variations in other δ Scuti stars (Breger, M & Montgomery, M, 2000). But with the advent of comprehensive all-sky survey programmes and high precision space based photometry the number of known δ Scuti stars has increased enormously in the past two decades, from the 636 catalogued by Rodriguez & Lopez-Gonzalez (2000) to samples of many thousands (Jayasinghe et al., 2020; Murphy et al., 2019; Netzel et al., 2022). As a consequence of identifying this larger sample of δ Scuti stars, it is now clear that HADS constitute a relatively small proportion, and represent a small number of all objects in the δ Scuti instability strip, estimated at around 0.3% (Lee et al., 2008).

But the traditional definition of HADS still presents us with a group of objects that raise questions. The nature of HADS as a distinct class of object is still unclear, and the issue of whether they are plausibly post main sequence objects, or lie at some other point of stellar evolution is still uncertain.

Given the ability of space based photometric missions to support homogeneous large-scale surveys of a single type of object across the whole sky, it is increasingly possible to explore well defined large samples of δ Scuti stars while minimising, or accounting for, selection bias. This presents opportunities to explore the classical definitions of HADS, and to investigate the complex relationships and definitions between these stars and the rest of the menagerie of pulsating objects in the A-F region of the Hertzsprung-Russell diagram.

While Transiting Exoplanet Survey Satellite (TESS) (Ricker et al., 2014) data have been used to some extent to explore δ Scuti stars, they have not yet been used to address questions about the properties of HADS. Moreover, TESS has recently achieved close to all sky coverage and is generating higher cadence data for a large number of targets. This means that there is an opportunity to undertake exploratory data analysis of HADS properties with a combination of TESS and Gaia data, on the basis of a close to all-sky homogeneous survey of δ Scuti stars.

Data sources and approach

This study uses data from TESS to explore HADS within the overall population of δ Scuti stars. The approach begins with establishing a well-defined sample frame of δ Scuti stars from across the whole sky, and then explores the HADS within that dataset, using statistical techniques to test for differences in HADS properties from the wider δ Scuti population. This note describes progress to date in constructing the sample of δ Scuti stars.

The main steps in constructing the dataset are:

- Identifying stars from the TESS Input Catalog Version 8 (Stassun et al., 2019) that lie between an estimated temperature of 6500 K to 9500 K, and between 4 to 100 solar luminosities;
- Downloading the light curve from one sector of the highest cadence available of TESS data, considering 200s, 600s and 1800s cadences;
- Calculating a Lomb-Scargle frequency spectrum for each downloaded light curve;
- Finding the frequency amplitude and signal to noise ratio of the highest peak in the frequency spectrum;
- Using the calculated parameters of each light curve to narrow the sample down to likely δ Scuti stars.

Once a clean population sample of δ Scuti stars has been constructed, then the HADS within that population can be identified, and their properties compared with overall δ Scuti properties.

Results

Selecting stars from the TESS input catalog with temperature between of 6500 K and 9500 K, and between 4 to 100 solar luminosities, identified 244,692 objects. These are stars that are generally in the area around the δ Scuti instability strip. Light curves were successfully downloaded for 210,178 of these stars, with the distribution across cadences shown in Table 1. Stars where no light curve was available were largely from the dead area of TESS coverage around the galactic centre. The vast majority of light curves have cadences of 200 s or 600s.

Lomb-Scargle frequency spectra were calculated for each light curve using the Python (Van Rossum & Drake, 1995) module for Lomb-Scargle periodograms (VanderPlas, 2018). The frequency of the greatest amplitude maximum in each periodogram was extracted, and the signal-to-noise ratio was found by comparing that maximum amplitude (in parts per thousand) to the mean amplitude of the very

highest parts of the periodogram, from the 95th to 98th centiles of frequency that represents the continuum frequency level.

Table 1: Cadences of Delta Scuti light curves from TESS

Cadence	Light curves
200	100,989
600	93,087
1800	15,728
3600	305
Other	69
Total	210,178

Removing light curves that had:

- A maximum frequency amplitude with signal to noise ratio of < 5 ;
- A maximum frequency amplitude with a frequency of < 5 cycles/day.

left a sample of 48,148 stars.

The current stage of work is assessing how purely this remaining sample represents δ Scuti stars. In particular, there is a risk of contamination from contact binaries with very short periods and from high frequency ellipsoidal variables (non-eclipsing binaries that show subtle variation due to the changing aspect ratio of the system as seen from Earth). One way that previous researchers have used, in order to eliminate contact binaries, is to calculate a ratio of the median power of a periodogram in the range < 10 cycles/day (a parameter referred to as μ), to the median power of the periodogram > 10 cycles/day, and to plot this against the skewness of the periodogram. Light curves with values outside a maximum μ or a minimum skewness are likely not to be δ Scutis (Dholakia et al., 2024).

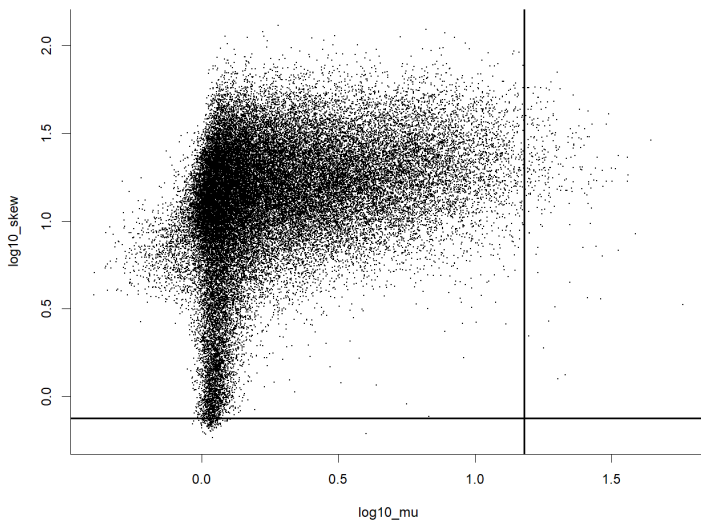


Figure 1: Skewness and mu parameters for 48,148 light curves. The vertical and horizontal lines indicate the limits beyond which stars are less likely to be δ Scut from Dholakia et al. (2024).

Very few stars in the present dataset have periodogram parameters that lie outside the limits for δ Scuti properties indicated by Dholakia et al. (2024). Visual inspection of the light curves and periodograms of stars that lie outside those limits in Figure 1 has so far not revealed any contact binaries. They have, however, revealed at least one example of an ellipsoidal variable. It appears that the preliminary steps of removing stars where the main frequency has signal to noise ratio < 5 , and frequency < 5 cycles/day may have removed the majority of non δ Scuti stars from the sample.

Discussion

The steps taken so far have been able to generate a catalogue of nearly 50,000 stars that are very likely to be δ Scutis. The next steps in further refining this list of stars, to remove any remaining contaminants from contact binaries or ellipsoidal variables, will be to look at patterns for each star among the five largest amplitude frequencies detected from the Lomb-Scargle periodograms, which may be able to discriminate any remaining contact binaries or ellipsoidal variables. To this end, pre-whitened frequencies have been extracted in an automated manner from all 48,148 periodograms using Python code developed by Gautam (Murphy et al., 2024).

The aim of this project is to define HADS, and to compare their properties to those of the overall δ Scuti population. For this purpose, it is preferable to have an overall sample of stars that are well defined as δ Scuti, with minimum contamination from other types of stars, so that the cleanest comparison of properties can be made with the subset of these stars that are HADS. Using screening terminology, we are more interested in the specificity of the sample (i.e. are they genuinely δ Scuti?) than the sensitivity (i.e. have we detected all δ Scutis?). Notwithstanding this preference for specificity, a side effect of this analysis is likely to be a new catalogue of more than 45,000 δ Scuti stars and the main properties of their light curves, which is significantly larger than any existing δ Scuti catalogue.

Once this phase of the project is complete and a satisfactorily clean δ Scuti dataset has been achieved, then work will proceed to explore natural thresholds at which HADS might be defined, and the basic astrophysical properties of those HADS.

Acknowledgements

This work is undertaken with the supervision of Associate Professor Simon Murphy of the University of Southern Queensland.

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Spectroscopy

Together with Mark Blackford and Julian West, I was awarded an ECRF grant in 2020 to pay for time on the Australian National University's 2.3 m telescope at Siding Spring Observatory. Spectra of eclipsing binary systems with pulsating primary components were observed with the aim of determining spectral types; and to calculate radial velocities of both components. Progress was complicated by the discovery of tertiary components in several of the binary systems; these cause blending of the lines of the primary and tertiary components in close systems (see the AAQ Annual Proceedings 2022 and 2023).

A paper on BF Velorum and RR Leporis has been published in *Astronomy and Astrophysics*, vol. 691, 2024. This is the link with free access to read or download the paper:

https://www.aanda.org/articles/aa/full_html/2024/11/aa50560-24/aa50560-24.html#S19.

Abstract:

This research paper presents a comprehensive analysis of RR Lep and BF Vel, two southern short-period, semi-detached, oscillating Algols (oEA stars) that have been shown to be triple systems. We determined the spectral types of the primary components and calculated the radial velocities from spectra observed with the Australian National University's 2.3 m telescope and Wide Field Spectrograph. The spectra of the Na I D doublet confirmed the presence of tertiary components that were apparent in the broadening function analyses. During primary eclipses chromospheric activity in their secondary components was apparent in their H α spectra; it was also apparent in the Na I D spectra of BF Vel with its almost complete annular eclipse. Ground-based telescopes were used for observations in several pass bands for photometric analyses. These observations were complemented by data from the Transiting Exoplanet Survey Satellite (TESS) mission, allowing us to model the light curves, followed by a detailed analysis of pulsations. Eclipse-timing variation (ETV) analyses of both systems were used to determine the most likely mechanisms modulating the orbital period.

We found mass values of $M_1 = 2.9 M_{\odot}$ and $M_2 = 0.75 M_{\odot}$ for the components of RR Lep, along with $M_1 = 1.93 M_{\odot}$ and $M_2 = 0.97 M_{\odot}$ for those of BF Vel. By integrating information from photometry, spectroscopy, and ETV analysis, we found that tertiary components revolve around both systems. The primary star of RR Lep pulsates in 36 frequencies; of these, five were identified as independent modes, with the dominant one being 32.28 d^{-1} . The pulsating component of BF Vel oscillates in 37 frequencies, with the frequency 46.73 d^{-1} revealed as the only independent mode. For both systems, a number of frequencies were found to be related to the orbital frequency. Their physical properties were compared with other oEA stars in mass-radius and Hertzsprung-Russell diagrams, while the pulsation properties of their δ Sct components were compared with currently known systems of this type within the orbital-pulsation period and log g -pulsation period diagrams.

Julian and I have started working on the next paper; the systems are IZ Telescopii, BD Virginis and UW Virginis.

Observatory report

Cloudy skies and other issues prevented observing at Glen Aplin in 2024.

Preliminary Study of Two Eclipsing Binaries in Carina

Mark Blackford

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Abstract

V0462 Carinae and V0486 Carinae are bright β Lyrae-type eclipsing binary (EB) systems with periods of ~ 1.1 days. These systems were chosen for an upcoming in-depth study by Ed Budding's Southern Eclipsing Binaries Project team. It appears neither system has been studied in detail previously, despite being on the border of naked eye visibility. High resolution spectra had been recorded by Ed some years ago but have not yet been analysed. This study was initiated to determine what information could be gleaned from publicly available light curves and eclipse minima timings. Preliminary results are presented below.

Transiting Exoplanet Survey Satellite (TESS) Data

I was unable to find any light curves for either system in journal publications, however, they have both been observed by the Transiting Exoplanet Survey Satellite (Ricker et al., 2014) These observations are available from the Mikulski Archive for Space Telescopes (MAST) website:

<https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html>

Table 1 lists the currently available data for V0462 and V0486 Carinae.

Table 1: TESS photometry of V0462 and V0486 Carinae.

TESS Sector	Start Date	2-Minute Cadence	10-Minute Cadence
7	2019-01-08	V0462 Car	
8	2019-02-02	V0462 Car	
9	2019-02-28	V0462 Car, V0486 Car	
10	2019-03-26	V0486 Car	
34	2021-01-14	V0462 Car	
35	2021-02-09	V0462 Car	
36	2021-03-07	V0462 Car	V0486 Car
37	2021-04-02		V0486 Car
38	2021-04-29		V0486 Car
61	2023-01-18	V0462 Car	
62	2023-02-12	V0462 Car	
63	2023-03-10	V0462 Car, V0486 Car	
64	2023-04-06	V0486 Car	
65	2023-05-04	V0486 Car	

O'Connell Effect

On visually inspecting the TESS light curves it was apparent that both V0462 and V0486 Car exhibit small differences in brightness of the out-of-eclipse maxima either side of primary eclipses (Figure 1). This phenomenon is reasonably common in close eclipsing binaries and is referred to as an O'Connell Effect (O'Connell, 1951). The mechanism not fully understood but has been variously ascribed to hot or cold star spots on one or both stars, impacts of gas streams between the components of the binary system, or the flow of circumstellar matter, asymmetrically deflected due to Coriolis forces.

For V0486 Car the maximum following primary eclipses is always brighter than the preceding one, this is referred to as a positive O'Connell Effect (Figure 2). V0462 Car, however, oscillates between positive and negative O'Connell Effect. The exquisite precision of TESS data reveal that the magnitude of the

O'Connell Effect for both systems vary on time scales of several days, as does the magnitude difference between primary and secondary eclipses.

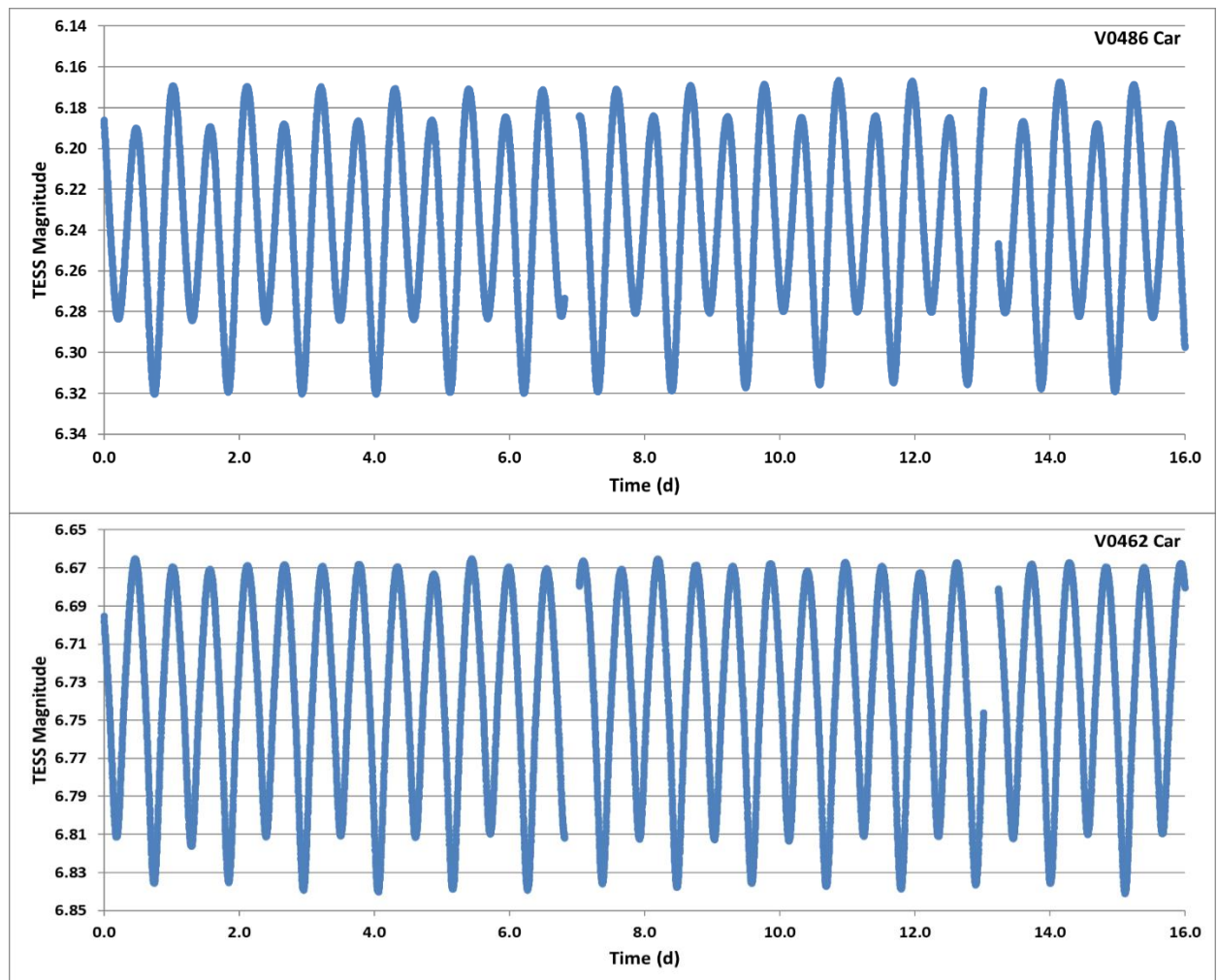


Figure 1: First 16 days of Sector 63 TESS light curves for V0462 Car (top) and V0486 Car (bottom) showing small variations in the brightness of maxima and minima from cycle to cycle.

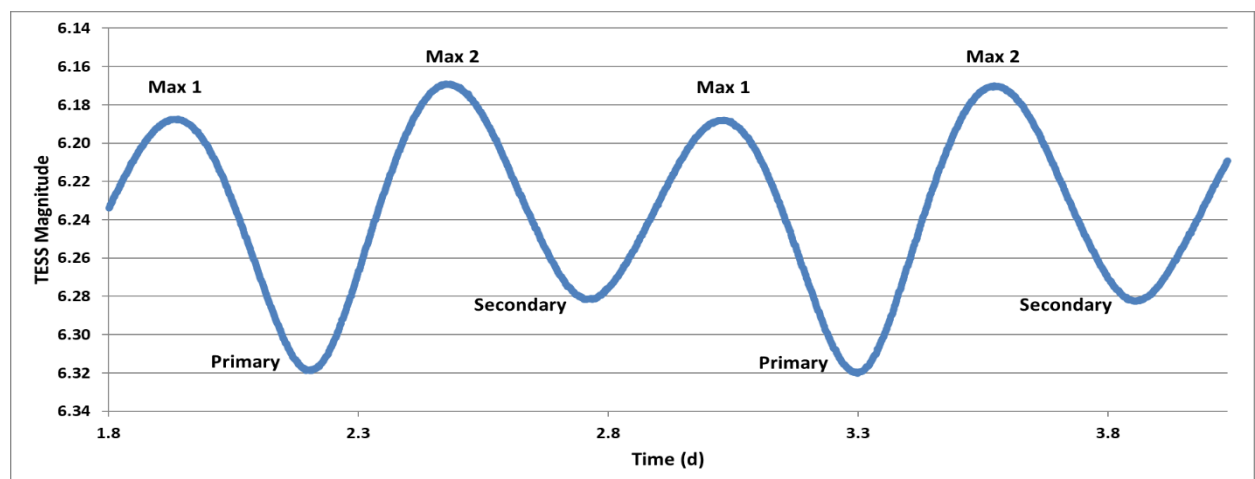


Figure 2: Two cycles of Sector 63 TESS light curve for V0486 Car showing positive O'Connell Effect (i.e. Max2 brighter than Max1).

Measurements from TESS Light Curves

For the current study, measurements of the time of minimum and magnitudes of primary and secondary eclipses, and magnitudes of out of eclipse maxima were required for every orbit recorded in each sector of data for both systems. This proved to be extremely time consuming using conventional software tools such as Peranso. Instead, I constructed an Excel spreadsheet to perform least squares fitting of a polynomial curve to sections of the TESS light curves and calculate the time of minimum (for eclipses) or maximum (for out of eclipse) and the corresponding magnitude at those times. Macros were employed to semi-automate the process.

After some experimentation, a 6th order polynomial was chosen as it accurately described the shape of eclipses and maxima without over fitting the data. Figure 3 shows a typical primary eclipse of V0462 Car with the fitted polynomial curve and the fit residuals.

For the 2-minute cadence datasets there were approximately 200 TESS observations in each fitted section of light curve. Occasionally there were obviously discrepant observations which were omitted before performing the least squares fit. Only about 40 observations were included in the fitted sections for the 10-minute cadence datasets of V0486 Car. No discrepant observations were identified in these.

The uncertainty of measured eclipse minima times was less than 0.0001 days (about 8 seconds), and the uncertainty of minima and maxima magnitudes was less than 0.1 millimag.

A total of 190 primary and 192 secondary eclipses were measured from the V0462 Car TESS light curves. For V0486 Car 176 primary and 175 secondary eclipses were measured. Barycentric Julian Date (BJD) is the time system used with TESS data.

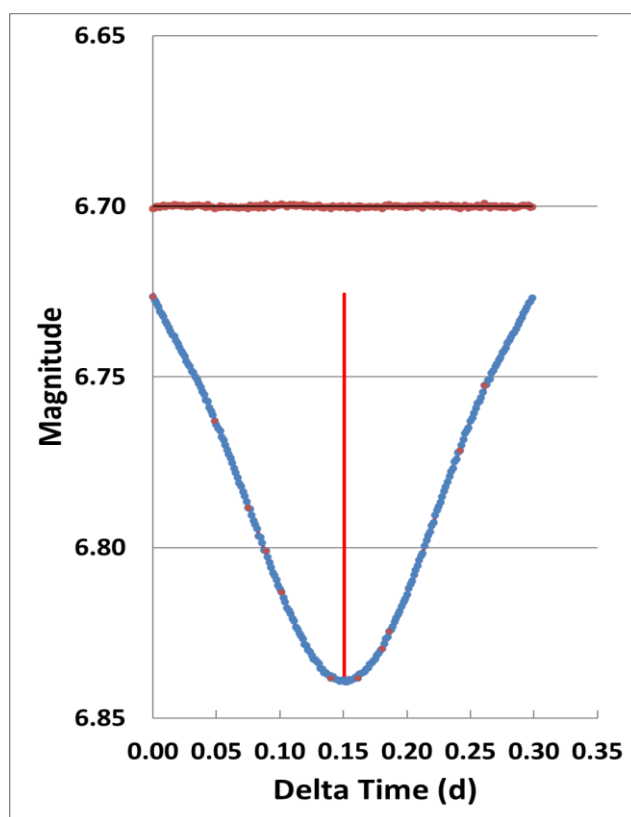


Figure 3: Typical primary minimum of V0462 Car showing TESS data (blue circles) with 6th order polynomial fit (red curve behind TESS data). The fit residuals (red dots) are offset by 6.70 magnitude units. The time of minimum is indicated by the vertical red line.

Variation of O'Connell Effect and Eclipse Minima Depths

Figure 4 shows the magnitude of the O'Connell Effect ($\text{Max2} - \text{Max1}$) was not constant for either binary system. The same is true for the difference in eclipse depths ($\text{Pri} - \text{Sec}$). It should be noted that uncertainties in the measured magnitudes are much smaller than the amount of variation shown in these plots.

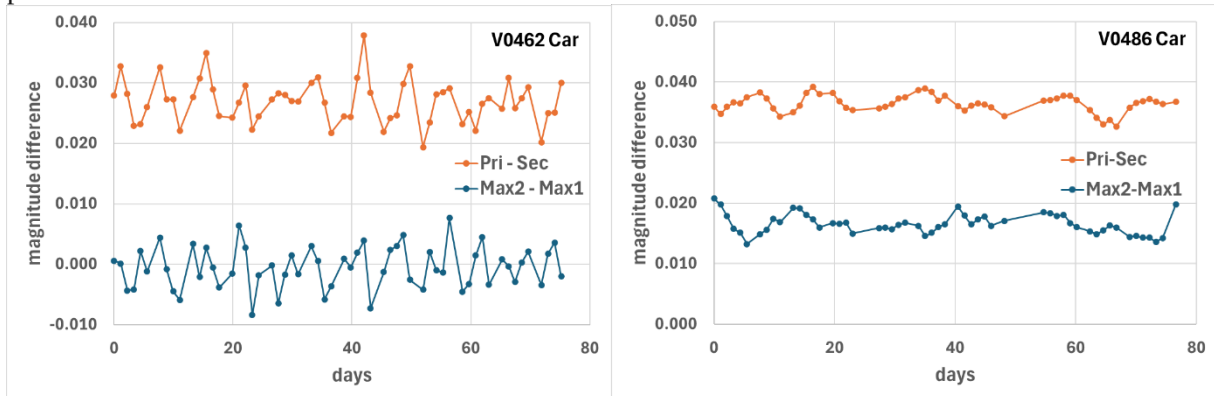


Figure 4: Variation of O'Connell Effect ($\text{Max2} - \text{Max1}$) and difference in eclipse depth ($\text{Pri} - \text{Sec}$) for V0462 and V0486 Carinae in TESS data from 2023.

For V0462 Car the O'Connell Effect varied between -8 and +8 mmag in a semi-periodic manner. The eclipse depth difference varied in a similar manner between 19 and 38 mmag.

For V0486 Car the range of variation is smaller. The O'Connell Effect varied between +13 and +21 mmag in a semi-periodic manner. The eclipse depth difference varied between 33 and 39 mmag.

Minima timing variations

Figure 5 shows Observed – Calculated diagrams for the two systems over the 4-year period covered by TESS observations (2019-2023). For each system the epoch and period used to calculate predicted times were derived by linear regression of all measured TESS eclipse minima times using the first primary eclipse as the initial epoch. The regressed values are listed in Table 2.

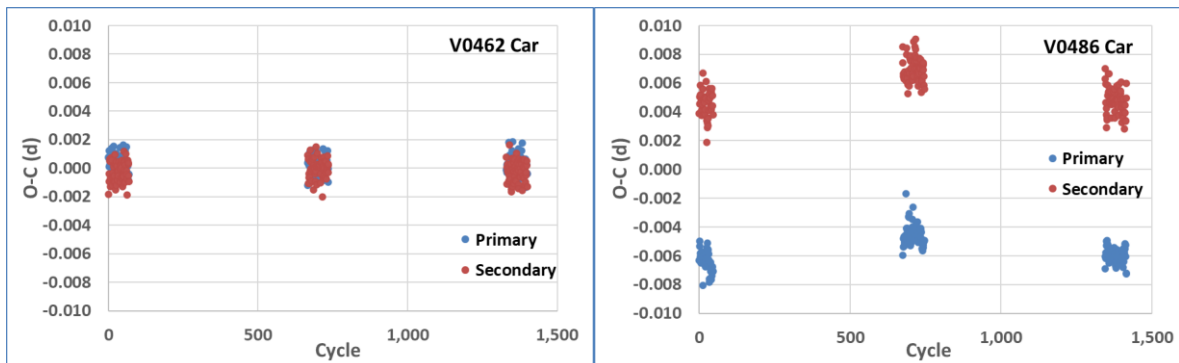


Figure 5: Observed – Calculated ($O - C$) diagrams of TESS eclipse minima timings from 2019 to 2023. Blue dots are primary eclipses, and red dots are secondary eclipses.

The two systems are markedly different. V0462 Car shows no evidence of orbital ellipticity nor period change over the 4-year period, whereas V0486 shows clear evidence of both orbital ellipticity (secondary eclipses are offset from primary eclipses) and period change (downward curve of data).

Table 2: Regressed epoch and period derived for V0462 and V0486 Carinae from TESS photometry.

System	Epoch (BJD)	Epoch error (d)	Period (d)	Period error (d)
V0462 Car	2458492.58611	0.00006	1.10568295	0.00000007
V0486 Car	2458543.85016	0.00054	1.0938831	0.0000006

The vertical scatter of data points (~ 0.004 d) in Figure 5 is much greater than the measurement error of individual eclipse minima times (< 0.0001 d). I believe the scatter results from distortions of the light curve shape caused by O’Connell Effect variations. Fitting a polynomial to eclipse light curves yields the time of minimum light, not necessarily the time of mid-eclipse. Time of mid-eclipse (i.e. when the two stars are in perfect alignment with the observer) is the parameter we would ideally like to determine. However, none of the techniques I am aware of for measuring photometric light curves, including the method of Kwee and van Woerden (1956), can directly measure time of mid-eclipse.

Future Studies

TESS is scheduled to observe V0462 Car in sectors 88, 89 and 90 (January to March 2025), and V0486 Car in sector 90 (March 2025). I will measure magnitudes and times of eclipse minima and magnitudes of out-of-eclipse maxima when these observations are released to the public. Sources of other eclipse minima times will be sought to extend the O-C diagrams.

I am attempting to record BVI filter time series of the two targets to measure minima times and for light curve modelling by other members of Ed Buddings team. However, current weather patterns at Congarinni Observatory are hampering this work.

The ultimate aim is to eventually produce a peer review journal paper combining photometric and spectroscopic analysis of these two interesting eclipsing binaries.

Acknowledgements

This research made use of the AAVSO VSX database and the NASA Astrophysics Data System Bibliographic Services. This paper includes data collected by the TESS mission, which are publicly available from the Mikulski Archive for Space Telescopes (MAST).

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Modelling of eclipsing binary systems with pulsating components and tertiary companions: BF Vel and RR Lep, A. Liakos, D. J. W. Moriarty, A. Erdem, J. F. West, P. Evans

Abstract

This research paper presents a comprehensive analysis of RR Lep and BF Vel, two southern short-period, semi-detached, oscillating Algols (oEA stars) that have been shown to be triple systems. We determined the spectral types of the primary components and calculated the radial velocities from spectra observed with the Australian National University's 2.3 m telescope and Wide Field Spectrograph. The spectra of the Na I D doublet confirmed the presence of tertiary components that were apparent in the broadening function analyses. During primary eclipses chromospheric activity in their secondary components was apparent in their H_α spectra; it was also apparent in the Na I D spectra of BF Vel with its almost complete annular eclipse. Ground-based telescopes were used for observations in several pass bands for photometric analyses. These observations were complemented by data from the Transiting Exoplanet Survey Satellite (TESS) mission, allowing us to model the light curves, followed by a detailed analysis of pulsations. Eclipse-timing variation (ETV) analyses of both systems were used to determine the most likely mechanisms modulating the orbital period. We found mass values of $M_1 = 2.9 M_\odot$ and $M_2 = 0.75 M_\odot$ for the components of RR Lep, along with $M_1 = 1.93 M_\odot$ and $M_2 = 0.97 M_\odot$ for those of BF Vel. By integrating information from photometry, spectroscopy, and ETV analysis, we found that tertiary components revolve around both systems. The primary star of RR Lep pulsates in 36 frequencies; of these, five were identified as independent modes, with the dominant one being 32.28 d^{-1} . The pulsating component of BF Vel oscillates in 37 frequencies, with the frequency 46.73 d^{-1} revealed as the only independent mode. For both systems, a number of frequencies were found to be related to the orbital frequency. Their physical properties were compared with other oEA stars in mass-radius and Hertzsprung-Russell diagrams, while the pulsational properties of their δ Sct components were compared with currently known systems of this type within the orbital-pulsation period and log g -pulsation period diagrams.

Astronomy & Astrophysics 691 A260 (2024)

DOI: 10.1051/0004-6361/202450560

Comparative study of the W UMa type binaries S Ant and ϵ CrA, Bakış, Volkan; Budding, Edwin; Erdem, Ahmet; Love, Tom; Blackford, Mark G. ; Wu, Zihao ; Tang, Adam ; Rhodes, Michael ; Banks, Timothy S.

Abstract

Contact binaries challenge contemporary stellar astrophysics with respect to their incidence, structure, and evolution. We explore these issues through a detailed study of two bright examples: S Ant and ϵ CrA, that permit high-resolution spectroscopy at a relatively good S/N ratio. The availability of high-quality photometry, including data from the TESS satellite as well as Gaia parallaxes, allows us to apply the Russell paradigm to produce reliable up-to-date information on the physical properties of these binaries. As a result, models of their interactive evolution, such as the thermal relaxation oscillator scenario, can be examined. Mass transfer between the components is clearly evidenced, but the variability of the O'Connell effect over relatively short-time scales points to irregularities in the mass transfer or accretion processes. Our findings indicate that S Ant may evolve into an R CMa type Algol, while the low mass ratio of ϵ CrA suggests a likely merger of its components in the not-too-distant future.

Publications of the Astronomical Society of Australia, Volume 41, article id. e083

10.1017/pasa.2024.92

10.48550/arXiv.2409.17303

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.VariableStarsSouth.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.

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

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