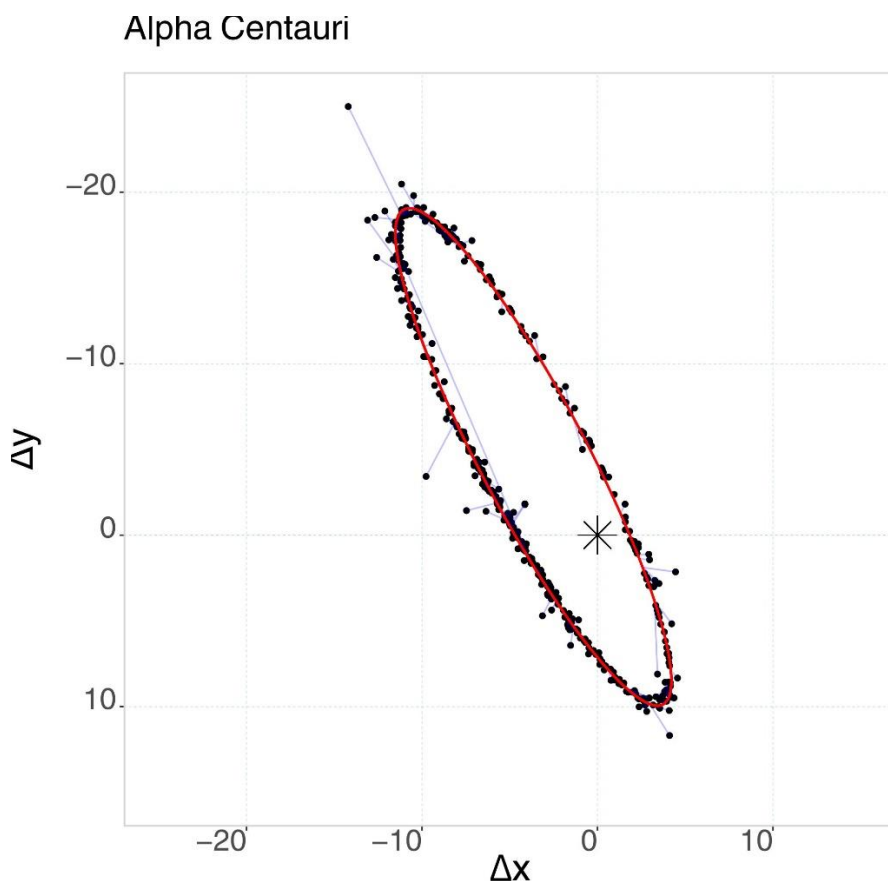




Relative orbit of the double star α Centauri AB. See article by A.Vanukuri & M Ersteniuk on page 5.

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From the Director – *Mark Blackford*

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Welcome to our second edition of the Newsletter for 2025. We have an interesting article by Tim Banks describing ongoing studies of a triple system in which the wide component is much older than the inner pair. Also, two students supervised by Tim have contributed an excellent article describing their analysis of double star orbits using advanced statistical methods.

My contribution, by comparison, is more mundane. However, it may be useful for others doing differential photometry of relatively bright stars.

As always, we encourage contributions to the Newsletter from VSS members and other interested people. Please contact me or the editor Ed Budding.

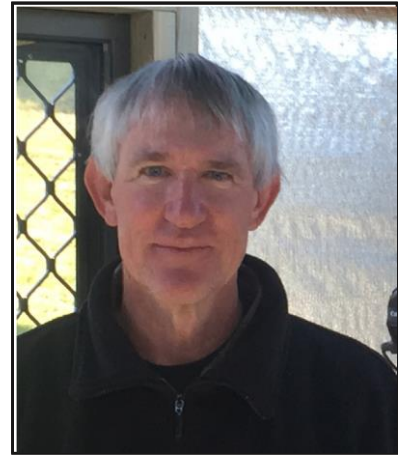
The 2025 RASNZ Conference starts May 9th in Whakatane, NZ. I wish the organisers and participants a successful and enjoyable meeting. Unfortunately, VSS won't be running a symposium, but several members will be attending the conference. I hope someone can write a summary of the weekend's events for a future VSS Newsletter.

Congratulations to Steve Kerr on his discovery of a satellite of minor planet 127418. Steve recorded two dimming events during the occultation of star UCAC4 355-159264 in August last year. This was announced on March 13, 2025, in Electronic Telegram No. 5521 from the Central Bureau for Astronomical Telegrams.

Congarinni Observatory enjoyed somewhat improved weather since the last Newsletter, despite Cyclone Alfred affecting large swathes of the east coast for several weeks. I was able to observe on about 15 nights over the last two and a half months – not great, but better than it has been.

Wishing you all clear skies and good health,

Mark Blackford



CN Lyncis – An Unusual Triple System

Tim Banks, Dept. Physical Science & Engineering, Harper College, USA

Abstract

Work in progress on the enigmatic triple star CN Lyn AB is summarized. The B component appears not coeval with the close eclipsing binary Aab. A possible explanation is sketched.

Introduction

A recent international study led by Turkish astronomer Gökhan Yücel, and involving VSS member Timothy Banks, investigated the unusual triple system CN Lyn.

Triple star systems hold significant astrophysical importance, offering insights into stellar evolution, dynamical interactions, and mass transfer processes. Due to their complexity compared to single or binary star systems, triple systems introduce a more comprehensive understanding of stellar processes from formation to final stages. Events such as mass transfer and mergers within such systems can trigger high-energy astrophysical phenomena, including supernova explosions and the formation of compact objects like neutron stars and black holes.

CN Lyn system

CN Lyn was detected by the HIgh Precision PARallax Collecting Satellite (Hipparcos) as a detached eclipsing binary system with an orbital period of 1.9554 days. The binary is notable for the inconsistency between its luminosity class as determined from photometry, and the classification derived from Hipparcos parallax data. The first ground-based observation of CN Lyn was made by Marrese et al. (2004) after obtaining high-resolution spectra for the purpose of evaluating Gaia performance. Light from a third star was detected in the system, contributing around 30% of the combined system light in the Hipparcos observations. Eclipse timing by Liao et al. (2021) determined the orbital period for the third star to be around 17 years.

A variety of data sources were analysed in the Yücel study, including photometry from TESS, spectroscopy, and Gaia data. This led to the surprising discovery that the outer member (star B) of the system was substantially metal poor compared to the inner pair (Aa, Ab). The mass, radius, and $[\text{Fe}/\text{H}]$ metallicity of the inner eclipsing binary stars were 1.17 ± 0.01 solar masses, 1.79 ± 0.01 solar radii and -0.78 ± 0.02 for component Aa; and 1.14 ± 0.01 , 1.65 ± 0.01 , and -0.55 ± 0.03 for Ab. B's values, however, were found to be 0.85 ± 0.23 , 1.44 ± 0.03 , and -1.83 ± 0.11 .

Further analysis

The tool “Modules for Experiments in Stellar Astrophysics” (MESA) was employed for evolution calculations. The evolution of multiple systems is tricky, since orbital elements, period, and eccentricity (if present) are also changing during evolution because of angular momentum exchange and losses within the systems, besides the evolution of the individual stars. One may consider both in terms of the calculation of evolutionary scenarios of binary systems. The binary module of MESA considers both orbital parameter changes and the natural evolution of stars in binary systems, simultaneously.

Evolutionary scenarios of the close binary (Aab) and the distant star (B) were investigated. The analysis indicated that the age of the A system is 3.89 ± 0.10 Gyr and that mass transfer between the components will start in about 460 Myr. On the other hand, it also indicated that the B component is in the main-sequence band, very close to reaching terminal age main sequence (TAMS), with an age of 12.5 ± 2.5 Gyr.

Analysis of the kinematic data from Gaia indicated that the orbit of CN Lyn AB has an eccentricity that does not exceed 0.30, with a maximum distance from the Galactic plane of 330 ± 11 pc. These findings suggest that CN Lyn A is a member of the old thin disk of the Milky Way. The binary system's birthplace was deduced by tracing the binary system's age as given above and using the package *galpy* (Yontan & Canbay, 2023). This analysis determined the birth radius of the binary system was at a

distance of 14.59 ± 0.86 kpc from the Galactic centre, which indicates that CN Lyn was formed in the metal-poor edge of the Milky Way's thin disk. The system also has a flattened orbit.

Conclusion

The key question is how such a triple system could have formed. One hypothesis is that the A system might have captured the third component in a region of weak gravitational interactions far beyond the Galactic centre. In conclusion, the fact that the tertiary star (B) of the CN Lyn is older and metal-poor (rather similar to Halo objects) compared to the inner pair (A) suggests that the B component was captured by a gravitational effect sometime after the formation of the Aab-system. Work is on-going to better understand the dynamics of this unusual and interesting system. The full paper may be found at: <https://iopscience.iop.org/article/10.3847/1538-3881/ad9d46>

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Yontan T. and Canbay R., 2023, PAREP, 1, 65

Dancing with the Stars

Anvith Vanukuri, William Fremd High School & Maksym Ersteniuk, Harper College, USA

Imagine the vast expanse of the night sky, a canvas adorned with countless twinkling stars. Among these stellar jewels, some stars are not solitary wanderers but rather exist in pairs, bound together by gravity, engaged in an intricate cosmic dance. These are the binary star systems, and understanding their orbital dynamics is a fascinating pursuit in astronomy.

In their recent paper *Estimating Orbital Parameters for Visual Double Stars*, two young astronomers embarked on a journey to unravel the mysteries of such stellar pairs. Their focus was on determining the orbital parameters of nine visual binary star systems, using a sophisticated tool known as Hamiltonian Markov Chain Monte Carlo (sometimes abbreviated as HMC). Maksym was a student at Harper College during the study, and Anvith was a Junior at William Fremd High School.

Now, let us delve into the fascinating world of MCMC methods, starting with the foundational Metropolis algorithm. Imagine you are exploring a vast, uncharted territory, and you want to map out its features. You might start by taking a random step in any direction. If the new location seems promising, you will stay on that track; otherwise, you might return to your previous spot. By repeating this process countless times, you will gradually create a useful and comprehensive map of the terrain.

The Metropolis algorithm, in essence, is like this exploration process. It is a way to sample from a probability distribution, even if we don't know its exact shape. We start with an initial guess for the parameters we are interested in and then propose a new set of parameters. If these new parameters seem more likely, based on the data we have, we accept them; otherwise, we stick with our old guess. Again, by repeating this process many times, we create a chain of parameter values that eventually converge to the optimal distribution and the best fitting estimates for the orbital parameters, for the case in question. However, the Metropolis algorithm can sometimes be slow and inefficient, especially when dealing with complex distributions. That is where the HMC method comes in, like a turbocharged version of the Metropolis algorithm.

Imagine now that instead of taking random steps, you have a guide who can suggest more informed directions, leading you to the most interesting areas more quickly. The HMC method is like having this guide. It uses gradient information from the probability distribution to propose new parameter values that are more likely to be accepted. This allows exploration of the parameter space more efficiently, leading to faster convergence and more accurate results. In their study, the researchers applied the HMC method to estimate the orbital parameters of the nine binary star systems. The studied systems are identified as Sirius, α Cen, AGC 11AB, BU 151 AB, BU 513 AB, BU 648, BU 883 AB, STT 38BC, and TF 1196AB. The authors compared their results to those in the Washington Double Star (WDS) catalogue, a comprehensive database of double star information.

The agreement between their estimates and the WDS values was impressive, demonstrating the reliability of the HMC technique. The authors are now keen to try their method on 'new' systems without orbital solutions, given the good performance of their program for the foregoing systems. This research not only sheds light on the orbital dynamics of the selected binary star systems but also showcases the power of advanced statistical methods in astronomy. The HMC method, with its ability to efficiently explore complex probability distributions, holds great promise for future studies in this field.

Both students immensely enjoyed the project, which involved learning to program in R, details of visual double stars, and various optimization techniques. They are thrilled that their work was considered good enough to publish in a research journal, with the peer reviewer (a professional astronomer) commenting that the research was meaningful. They appreciated that the work was carried out by young students. The authors are now thinking about how to include radial velocity data into their models. Readers interested in learning more about this can find it at: https://oejv.physics.muni.cz/issues/oejv_0248.pdf

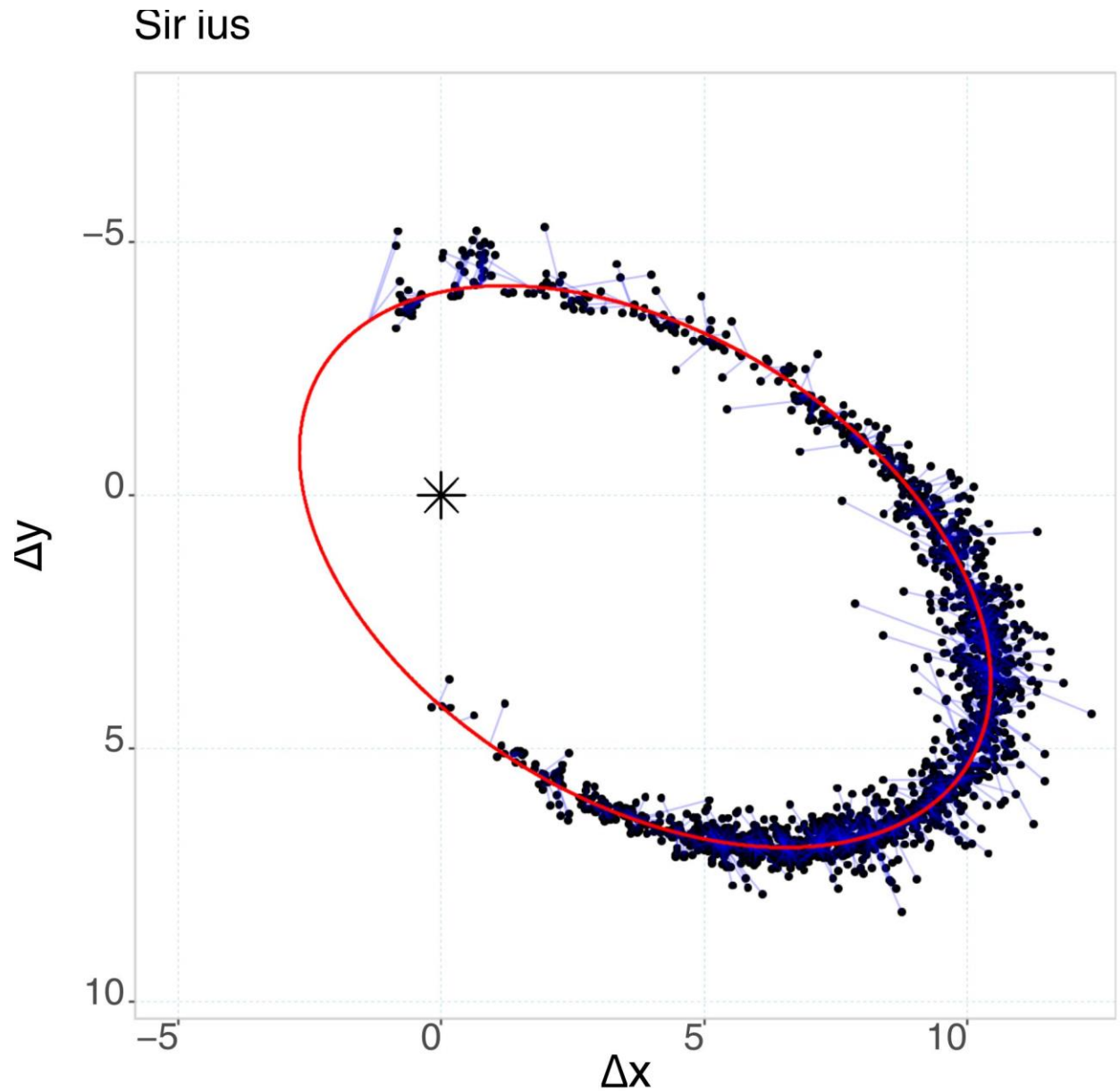


Figure 1: Model apparent orbits were fitted to positional data for Sirius and Alpha Centauri (see front cover). The model orbits are the red curves, the primary star is indicated with an asterisk symbol (at the origin), the data points with dots and the short blue lines connect the observations with their expected position on the model orbit. North is upwards and east increases to the right. Sirius completes an orbit in around 50 years, and Alpha Centauri in 80 years.

Estimating V, B – V, V – R and V – I values from Tycho-2 B_T and V_T magnitudes

Mark Blackford, Congarinni Observatory

Introduction

In differential photometry the magnitude of a target star is computed from the known magnitude of a non-variable comparison star of similar brightness recorded in the same image. For accurate results we need accurate comparison star magnitudes in each filter used for imaging; in my case Johnson-Cousins BVRI photometric filters. There are many ‘standard stars’ that have very accurately measured magnitudes in multiple filters (e.g. Cousins E and F regions, Landolt Equatorial Standards). These are clumped into many small regions distributed around the sky, but rarely are they in the field of view of the variables we wish to monitor. Therefore, a large number of more generally dispersed comparison stars is needed.

The AAVSO Sequence Team have provided comparison star sequences for many variables, but not yet for the majority of southern hemisphere eclipsing binaries that I observe. The Sequence Team respond to requests for new sequences promptly, however I wanted to explore the possibility of selecting potential comparison stars myself. Most of my targets are brighter than ~11th mag and the Tycho-2 catalogue provides adequate numbers of potential comparison stars in the field of view of my telescopes. In this article I will look at how to transform Tycho-2 magnitudes to the Johnson-Cousins photometric system.

Tycho-2 Catalogue

Tycho-2 is an astrometric reference catalogue (ESO, 1997), (Høg, et al., 2000) containing positions and proper motions as well as two-colour photometric data for the 2.5 million brightest stars in the sky. It is a product of the European Space Agency’s astrometric mission, Hipparcos, which operated from November 1989 to March 1993. However, the Tycho-2 V_T and B_T filters are not precisely matched to the corresponding V and B filters in the standard Johnson-Cousins (JC) system, and there were no filters covering the R and I passbands. Several Tycho-2 to JC conversion algorithms have been published. I will look at one method of transforming from Tycho-2 V_T and B_T to Johnson B and V, followed by two methods of calculating Johnson-Cousins V-R and V-I.

Tycho-2 V_T and B_T to Johnson B and B - V

In Appendix C of their paper, Mamajek, et al. (2002) presented polynomial equations for transforming Tycho-2 B_T and V_T magnitudes to Johnson V and B-V. There were a couple of errors in the original paper that were later corrected in Mamajek, et al. (2006). The correct equations are listed below.

$$V = V_T + 0.00097 - 0.1334 * (B_T - V_T) + 0.05486 * (B_T - V_T)^2 - 0.01998 * (B_T - V_T)^3 \quad (1)$$

$$B - V = (B_T - V_T) - 0.007813 * (B_T - V_T) - 0.1489 * (B_T - V_T)^2 + 0.03384 * (B_T - V_T)^3 \quad (2)$$

$$B - V = (B_T - V_T) - 0.006 - 0.1069 * (B_T - V_T) + 0.1459 * (B_T - V_T)^2 \quad (3)$$

Equation 1 is valid for $-0.25 < B_T - V_T < 2.0$

Equation 2 is valid for $0.4 < B_T - V_T < 2.0$

Equation 3 is valid for $-0.25 < B_T - V_T < 0.4$

These equations are used by the AAVSO Sequence Team when preparing photometric sequences for comparison stars.

Tycho-2 B_T and V_T to Johnson-Cousins $V - R$ and $V - I$

Michael Poxon provided the following equations the AAVSO Sequence Team use for transforming Tycho-2 B_T and V_T magnitudes to Johnson-Cousins $V - R$ and $V - I$ colour indices.

$$R = (V_T - 0.014) - 0.5405*(B_T - V_T) \quad (4)$$

$$I = (V_T - 0.039) - 0.9376*(B_T - V_T) \quad (5)$$

I have not been able to find a paper describing how these simple linear equations were derived.

Johnson $B - V$ to Johnson-Cousins $V - R$ and $V - I$

Caldwell et al. (1993) presented several dozen polynomial relationships for transforming between 11 different colour indices. The relationships are of the form:

$$Y = C1 + C2*X + C3*X^2 + C3*X^3 \dots \quad (6)$$

Where X = the input colour index, Y = output colour index and $C1$, $C2$, $C3$ etc are polynomial coefficients.

Only the $B - V$ to $V - R$ and $B - V$ to $V - I$ relationships will be considered here. In each case there are different relationships depending on whether the star is classified as a giant or dwarf. Table 1 lists the polynomial coefficients and other parameters for the $B - V$ to $V - R$ transform equation. Table 2 lists the same for the $B - V$ to $V - I$ transform equation.

E Region standard stars

Menzies, et al. (1989) present a catalogue of standard stars with V magnitudes and colour indices in the Johnson UB V and Cousins RI system located in the E Regions (nine areas a few degrees across distributed around the sky at ~ 45 deg S declination) and F Regions (three areas a few degrees across distributed around the sky at ~ 75 deg S declination) and in the Magellanic Clouds. These provide an excellent sample to test how well the various transformation equations perform. Only the E Region standards have been used in this study.

The E Region catalogue contains a total of nearly 600 stars. Several known or suspected variables are included and some stars do not have $V - R$ or $V - I$ values. These have been rejected from the test sample, as were several stars noted as having close companions that could contaminate photometry. Also rejected were stars fainter than 11th or brighter than 3rd magnitude in V . The final test sample contains 473 stars.

Cross referencing with Tycho-2 catalogue

The Tycho-2 catalogue (I/259/tyc2) is accessible via the VizieR website at the Strasbourg Astronomical Data Center (<https://cds.unistra.fr/>). The B_T and V_T magnitudes, and their statistical error values were extracted from the catalogue for each of the 473 stars in the test sample.

This data, along with the corresponding E Region catalogue magnitudes and colour indices for each star, were imported into an Excel spreadsheet for analysis and plotting.

B_T and V_T magnitudes compared with E Region catalogue B and V magnitudes

In the following a subscript “T” denotes Tycho-2 catalogue values. Transformed values are denoted by subscript “X”, where X = the number of the transformation equation used. E Region catalogue values have no subscript.

The top panels of Figure 1 show the difference between V_T magnitudes and the corresponding Johnson V magnitudes from the E Region catalogue. When plotted against V magnitudes the scatter is quite large. However, when plotted against $B - V$ the data is more tightly constrained. For stars with $B - V = 0$ the V_T and V magnitudes are essentially the same, but the difference increases as $B - V$ increases. If the B_T and V_T filters were a perfect match with the Johnson B and V filters the data points would lie on a horizontal line passing through zero on the y-axis.

Table 1: *Caldwell et al. (1993) relationship 2 for transforming $B - V$ to $V - R$.*

relation	2	2	specific relation in Table 2 of Caldwell et al. (1993)
case	giants	dwarfs	applicable star type
in	B-V	B-V	input colour
fm	-0.25	-0.23	bluest input B-V well represented by the fit
to	1.70	1.95	reddest input B-V well represented by the fit
shfx	1	1	numerical shift to input colour
out	V-R	V-R	output colour
shfy	1	1	numerical shift to output colour
ord	7	11	order of fitting polynomial
c1	-0.4832140	-0.4140951	
c2	0.4218768	0.7357165	
c3	0.2061298	-0.0524298	
c4	0.4930307	-0.6293304	
c5	-0.3562433	2.3328710	
c6	-0.5103325	3.8123650	
c7	0.4183262	-5.0829410	
c8	0.3679392	-6.5203250	
c9		4.8177970	
c10		5.0655050	
c11		-1.7060110	
c12		-1.5682430	

Table 2: *Caldwell et al. (1993) relationship 4 for transforming $B - V$ to $V - I$.*

relation	4	4	specific relation in Table 2 of Caldwell et al. (1993)
case	giants	dwarfs	applicable star type
in	B-V	B-V	input colour
fm	-0.25	-0.23	bluest input B-V well represented by the fit
to	1.75	1.40	reddest input B-V well represented by the fit
shfx	1	1	numerical shift to input colour
out	V-I	V-I	output colour
shfy	1	1	numerical shift to output colour
ord	7	7	order of fitting polynomial
c1	-0.0088796	-0.0890659	
c2	0.7390707	1.3196750	
c3	0.3271480	0.4461807	
c4	1.1401690	-1.1881270	
c5	-0.1908637	0.2465572	
c6	-0.7898824	8.4786270	
c7	0.5190744	10.4659900	
c8	0.5358868	3.6412260	

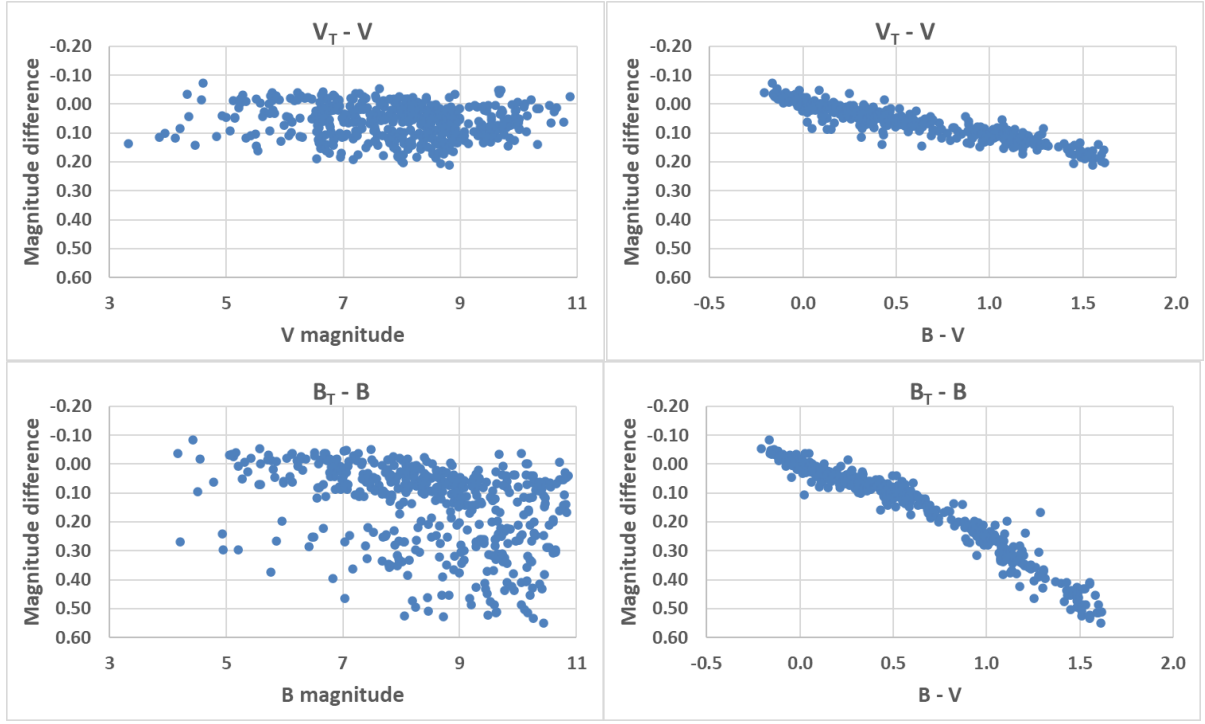


Figure 1: Difference between Tycho-2 magnitudes and E Region catalogue values as a function of V or B magnitude (left) and B – V colour index (right). Note: all plots have the same vertical scale range.

Figure 1 bottom panels show similar plots for B_T and B magnitudes. The relationship between $B_T - B$ and $B - V$ is less linear and more extreme. We can conclude that the V_T filter passband is better match to the Johnson V filter passband than the B_T filter passband is to the Johnson B passband. These plots illustrate why transforming the Tycho-2 magnitudes to the Johnson-Cousins system is necessary.

Equations 1, 2 and 3 transformations

Transforming the Tycho-2 magnitudes using equations 1 to 3 results in much better correspondence with the E Region catalogue magnitudes (Figure 2). Note that scatter is greater at the fainter end of the left panel plots, as one would expect.

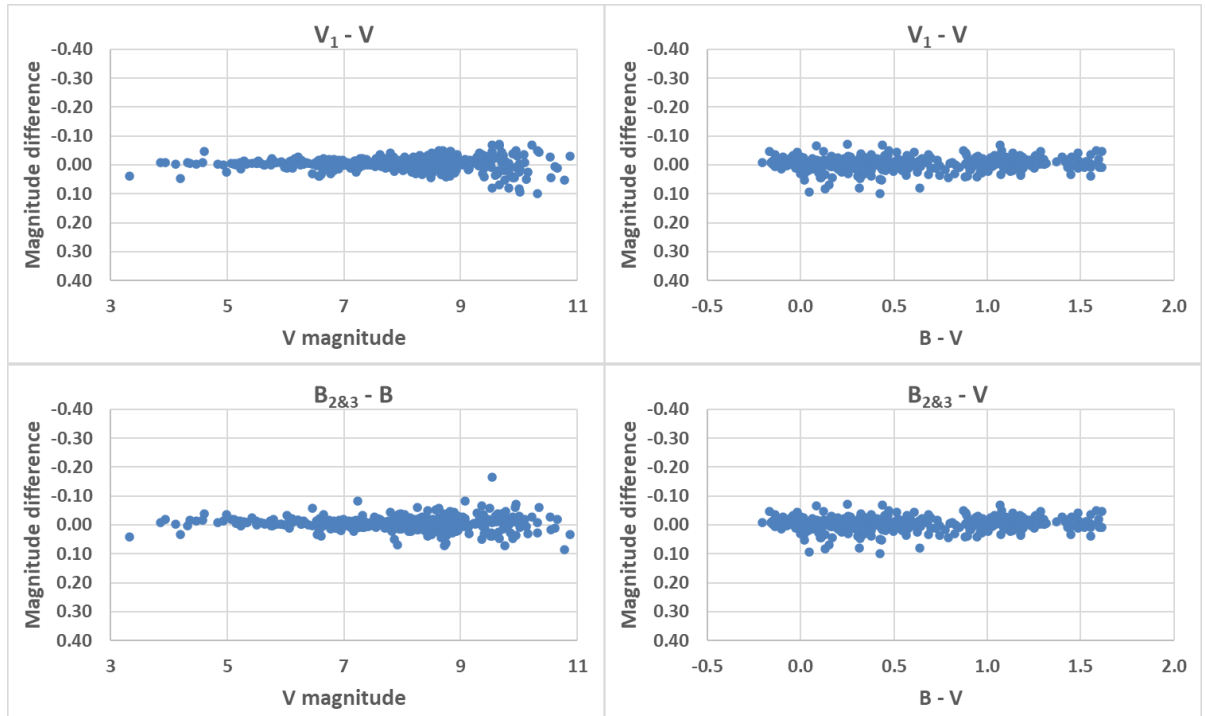


Figure 2: Same plots as Figure 1 after transforming Tycho-2 magnitudes using equations 1 to 3.

Equations 4 and 5 transformations

R and I magnitudes were calculated from the Tycho-2 B_T and V_T magnitudes by applying transformation equations 4 and 5, respectively. Figure 3 shows that these simple linear equations result in poorly transformed magnitudes.

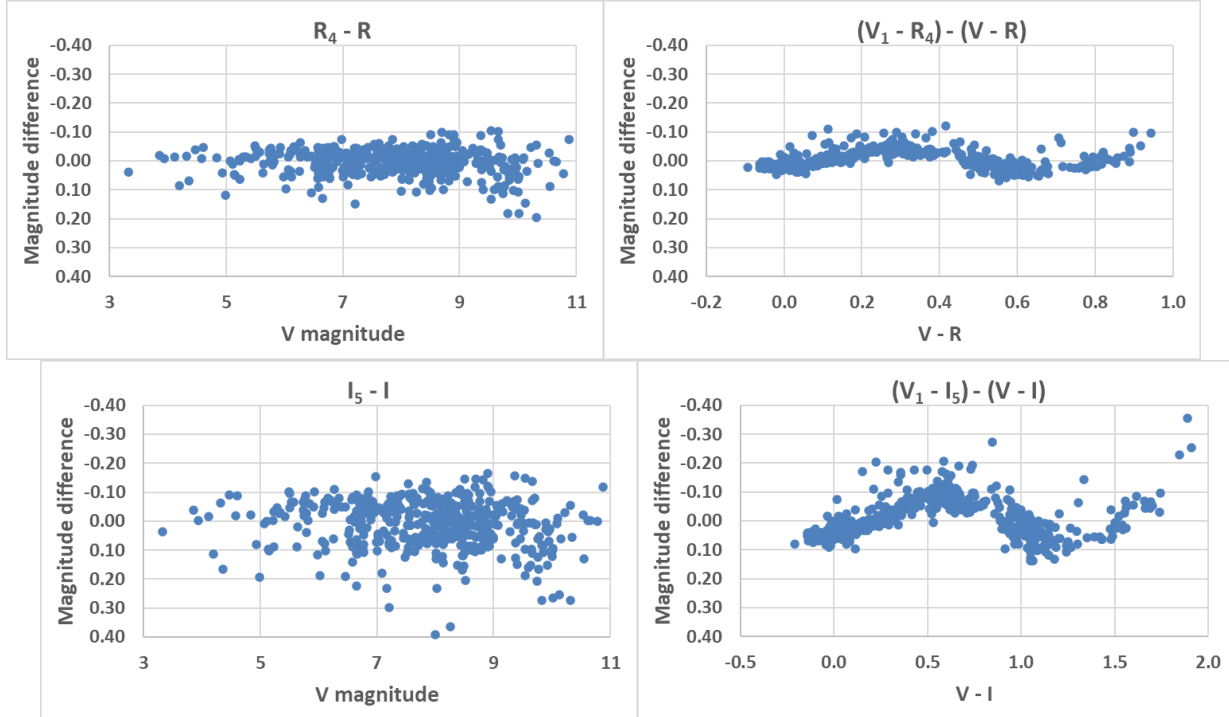


Figure 3: Same plots as Figure 1 after transforming Tycho-2 magnitudes using equations 4 and 5.

Equation 6 transformations

Equation 6 uses Johnson $B - V$ as input values because the Caldwell et al. (1993) paper predates the Tycho-2 catalogue. Therefore, transformed $B_{2\&3}$ and V_1 magnitudes (used for Figure 2) were used as input for equation 6 to calculate transformed R and I magnitudes using the parameters in Tables 1 and 2. It was also necessary to know the luminosity class of each star to determine if they are classified as dwarf or giant, and therefore which set of polynomial coefficients to use. Thankfully the spreadsheet supplied by Stan Walker already included spectral type and luminosity class for all but 45 of the test sample of E Region standard stars.

Equation 6 works well when transforming to R magnitudes (Figure 4 top panels). The bottom panels, however, have three distinct horizontal bands of datapoints indicating a problem when transforming to I magnitudes.

The cause of the transformation problem is apparent when giant and dwarf stars are plotted separately, as shown in the top panels of Figure 5. Giant stars are indicated by red dots, dwarf stars by light green dots. Dark green dots represent the 45 stars that did not have luminosity class data. These were transformed as if they were giants. The blue dots are subgiants for which the transformed I magnitudes was taken as the average of the values calculated by the giant and dwarf coefficients. The band of dwarf star datapoints are displaced vertically from the giant star datapoints by a median value of 0.175 magnitude.

This offset can be corrected by adjusting either the “shfy” or C1 parameters for dwarfs in table 2. I chose to set “shfy” to 1.175, the results are plotted in the bottom panels of Figure 5. With this slight correction the Caldwell et al. transformation relationships produce significantly better transformed I magnitudes than the Table 2 parameters (Figure 5 bottom panels).

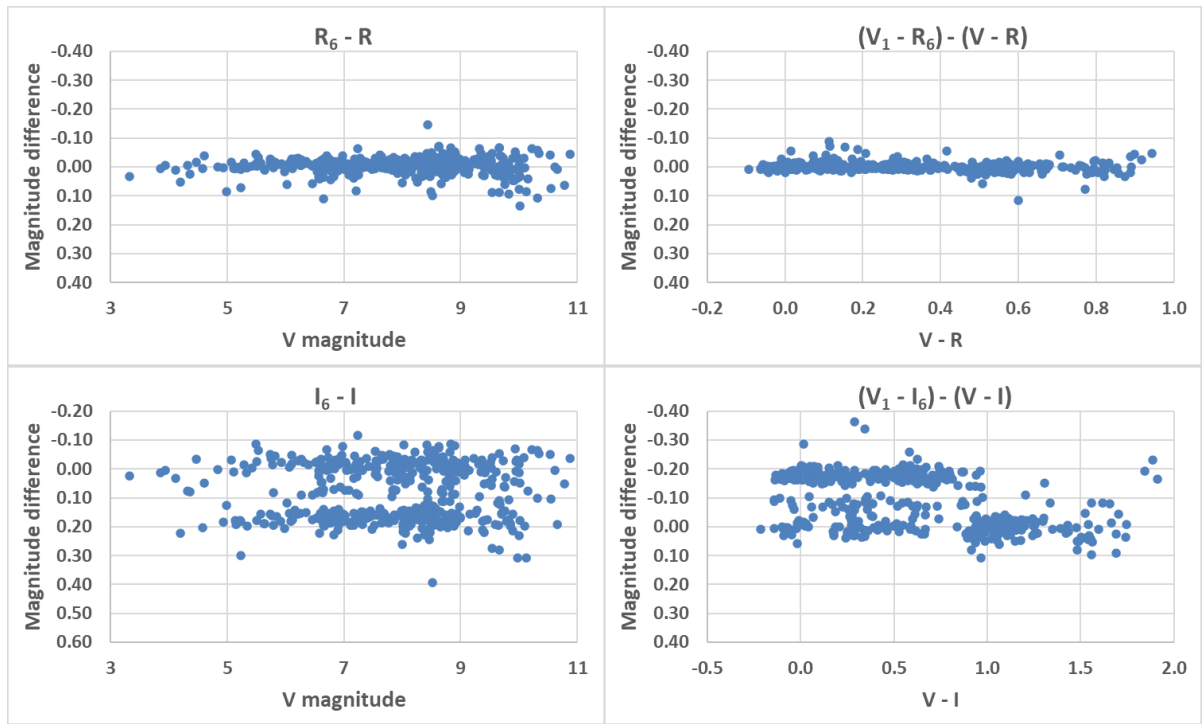


Figure 4: Same plots as Figure 1 after transforming Tycho-2 magnitudes using equation 6.

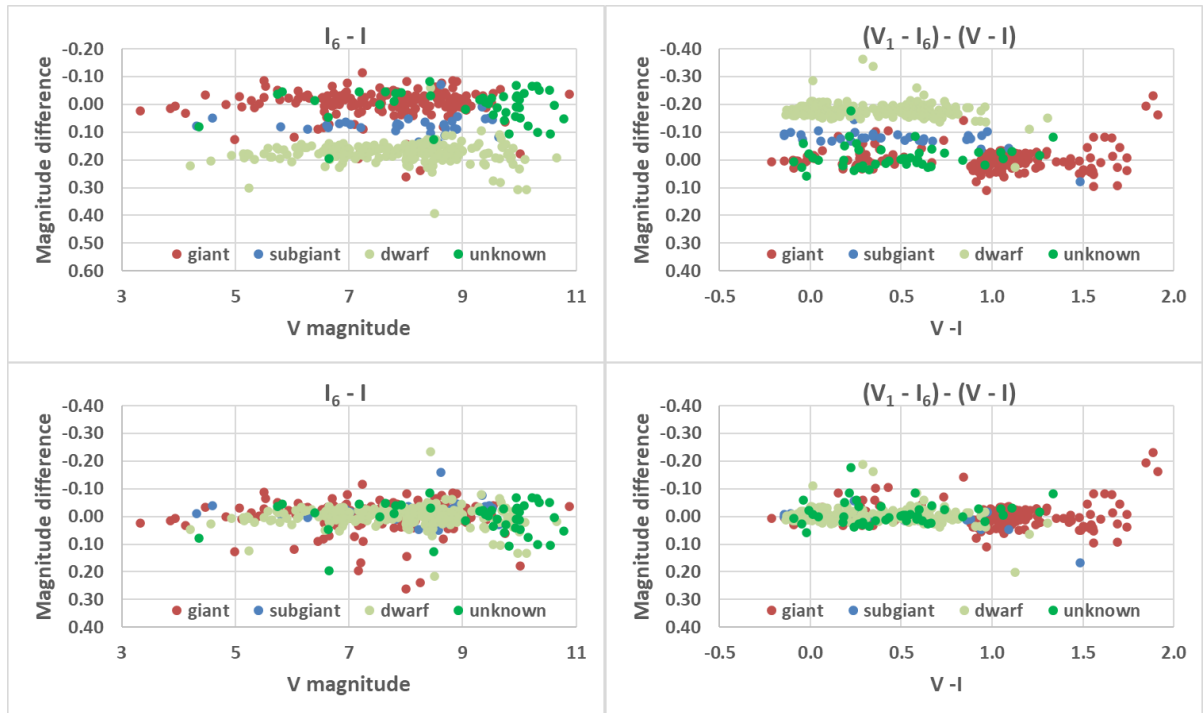


Figure 5: Same plots as Figure 1 after transforming Tycho-2 magnitudes using equation 6.

Conclusions

The Tycho-2 catalogue includes B_T and V_T magnitudes of the 2.5 million brightest stars in the sky, providing a rich source of potential comparison stars for differential photometry. To be useful, the B_T and V_T magnitudes need to be transformed to the Johnson-Cousins BVRI photometric system.

Mamajek, Meyer & Leibert (2002, 2006) equations produce transformed V and $B - V$ values in excellent agreement with the E Region standard star catalogue.

The linear equations used by the AAVSO Sequence team for transforming B_T and V_T to Johnson-Cousins $V - R$ and $V - I$ do not produce reasonable results and is not recommended.

On the other hand, polynomial relationships 2 and 4 of Caldwell et al. (1993) produce significantly better transformed $V - R$ and $V - I$ values, respectively. However, for dwarf stars the “shfy” parameter for relationship 4 must be set to 1.175 instead of 1, as listed in their paper. The downside of this method is that we need to know whether a potential comparison star is classified as a giant or dwarf, so the correct transformation coefficients are used.

In a future article I will explore using a polynomial relationship to transform directly from $B_T - V_T$ to Johnson-Cousins $V - R$ and $V - I$, without needing to know the dwarf/giant status of the star.

Acknowledgements

This research made use of the NASA Astrophysics Data System Bibliographic Services and the VizieR catalogue access tool, CDS, Strasbourg, France (DOI : 10.26093/cds/vizieR). The original description of the VizieR service was published in 2000, A&AS 143, 23. I thank Stan Walker for providing the E Region standard star data, and Michael Poxon for equations 4 and 5.

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New Journal Seeking Authors

Physics and Astronomy Reports is a new open-access, peer-reviewed and international research journal, published semi-annually in June and December. It aims to contribute to scientific knowledge in the fields of physics and astronomy. The first issue was in 2023.

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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 with major international organisations such as the British Astronomical Association, the Center for Backyard Astrophysics, and the American Association for Variable Star Observers.

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

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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 (ed.budding@gmail.com). I'd prefer Microsoft Word (or compatible) files with graphics sent separately. Don't use elaborate formatting or fancy fonts and please do not send your contribution as a fully formatted PDF file.

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

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