Draft version August 23, 2025
Typeset using LaTeX **twocolumn** style in AASTeX631

Observing Variable Stars: Best Birds (but we're angry)

Liam Becker,[1] Tristen Arias,[1] Sydney Pemble,[1] and Ishaani Purang[1]

[1] *University of Washington - ASTR 481*

ABSTRACT

AT Andromedae, an asymmetric RR Lyrae-variable in the constellation Andromeda, has not had data on it submitted to the AAVSO database since January, 2025. In this work, I detail my process of observing, processing, and analyzing data of AT And that I collected using the 30-inch telescope at the Manastash Ridge Observatory on the nights of July 25th through July 27th. The purpose of this work is to update the AAVSO database with new observations of AT And, to ensure consistency and validity of the understanding of the star. I find V magnitudes ranging from 10.06 to 10.55—roughly half of a magnitude too bright, likely due to flaws in color standardization–and a period of 0.5964 days, merely 3.33% different from the accepted period of 0.6169 days. With this period I am able to successfully fit an RR Lyrae-type lightcurve using `gatspy`.

1. INTRODUCTION

The RR Lyrae-variable AT Andromedae varies by roughly 0.5 magnitudes between 10.92 and 10.42 in the Johnson V filter over the course of its $\sim$ 0.6-day period (AAVSO 2025a). It exhibits an asymmetric light curve, with a steep increase in brightness followed by a shallower decline. Data on AT And has not been submitted to the AAVSO database since January 2025; in order to update and confirm the validity of the data, I chose to observe AT And during the four nights Team Best Birds (Tristen Arias, Sydney Pemble, Ishaani Purang, and myself) spent at the Manastash Ridge Observatory in central Washington between Thursday, July 24, 2025, to Sunday, July 27, 2025.

In Sec. 2.1 I discuss the details of my observations of AT Andromedae; I walk through photometry of those observations in Sec. 2.2, with analysis and results of my methods described in Sec. 3.

2. METHODS

Manastash Ridge Observatory is located in central Washington state (latitude: 46 57 03.95, longitude: -120 43 28.33, altitude: 1198 m). The 30" telescope at MRO has a field of view (FOV) of 8 arcminutes by 8 arcminutes and its charge-coupled device (CCD), Evora, has a plate scale of 0.98 arcseconds per pixel (Fraser 2025). During a previous trip to the observatory, I found Evora to have negligible dark current (7.47×10^{-3} Analog-to-Digital Units (ADUs) per second), gain of 1.59 e^- per ADU, and read-noise of be 9.44 ADUs (Becker 2025).

My collaborators and I observed several different objects during our four-night run from Thursday, July 24, 2025, to Sunday, July 27, 2025—in Sec. 2.1 I detail my observations of the RR Lyra-variable, AT Andromedae in the Johnson V filter.

2.1. *Observations*

As we cycled through our observing targets, there were gaps from 10 to 60 minutes between exposures of my target, AT And, depending on which of my collaborators' targets were visible. Additionally, two of my collaborators were observing transits on night one, meaning I was unable to collect any data for AT And on the first night of our run.

Table 1 details the observing conditions at the observatory during our four-night run; although there were clouds on Night 2, they were during Sydney's transit and only affected a few of my images. The moon was almost entirely un-illuminated during the our run and set before most of our observations, so there were no concerns of sky brightness due to the moon.

The AAVSO Chart, X40648QC, for AT And in V is shown in Fig. 1 along with information regarding the literature values for the minimum magnitude, maximum magnitude, period, variable type, spectral type, and J2000 coordinates. The star is an RRAB-type variable (RR Lyrae-variable with asymmetric lightcurve) which

Corresponding author: Liam Becker
liamb27@uw.edu

Night	Date	Weather	Seeing	Illum %	Moonset
1	07/24/25	clear	5.7	0	21:29
2	07/25/25	cloudy	8.1	3	21:53
3	07/26/25	clear	6.1	7	22:11
4	07/27/25	clear	5.7	13	22:24

Table 1: Table of information regarding the weather, seeing, illumination percentage of the moon, and the time of moonset at MRO during the nights of our observations. The seeing was determined via the full width at half-maximum (FWHM) of RR Lyra in the V-band fields we took each night—found with the Star tool on the Astroart application (Cavicchio & Nicolini 2025).

varies by roughly 0.5 magnitudes in V over its ~ 0.62-day (~ 14.81-hour) period. The details for AT And and the AAVSO comparison star, 000-BCR-873 (labeled in Fig. 1, and hereafter referred to as 112), are listed in the top two rows of Tab. 2.

In order to determine the transformation coefficients for color standardization, we also observed a portion of the AAVSO standard field SA38 SF3 (Chart ID: X40648AGN) from Fig. 76 of Landolt (2013) (hereafter referred to as SF3), listed in the bottom three rows of Tab. 2.

The pointing and tracking at MRO are imperfect, so in order to keep AT And and the comparison star in the same field, we had to manually pan the scope for each exposure. Errors in the panning of the telescope caused several exposures to omit the comparison star (including those taken two weeks after our run to make up for our failure to capture any exposures in the Johnson B filter), which had to be thrown out during construction of the lightcurve.

To reduce my data I follow the reduction process outlined in Becker (2025), creating a median bias, normalized median skyflat, and illumination correction for each night, ultimately deciding to forgo the use of the illumination correction, due to the high signal-to-noise ratio (SNR) in the skyflats (on the order of 10^4), shown by the "dust donuts" in Fig. 2. When processing my science images, I subtract the median bias and divide by the median skyflat from the night of observation, before applying `astroscrappy.detect_cosmics` to remove any cosmic rays (Astropy Collaboration et al. 2022).

2.2. *Photometry*

With my images reduced, I used `photutils` to do the photometry, using the `DAOStarFinder` function to determine the centroids of AT And, 112, and the stars of SF3 (Bradley et al. 2024). To find the optimal aper-

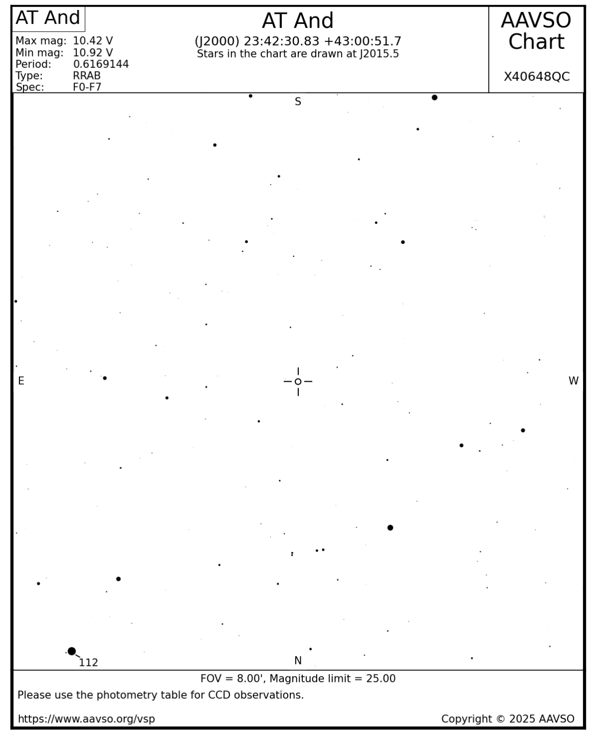


Figure 1: Star chart for AT And (center of chart) alongside the AAVSO comparison star in the lower left, labeled 112 (AAVSO 2025b). Shown in the header of the chart are the minimum and maximum magnitudes, period in days, variable type, and spectral type on the left, with the J2000 coordinates in the center.

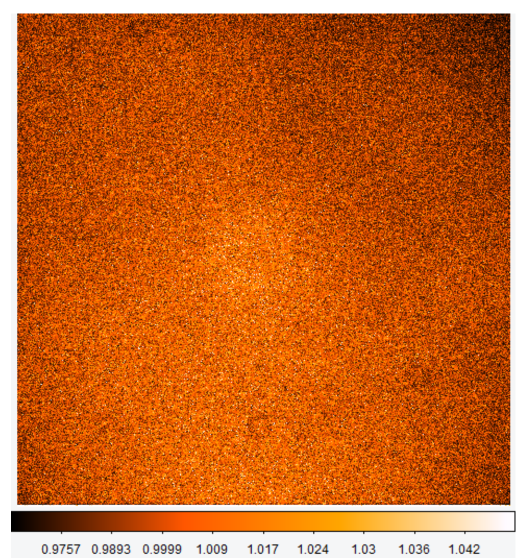


Figure 2: Normalized skyflat from night two in the V filter. The high SNR is evidenced in the flat by the "dust donuts" in the image.

AUID	Label	Dec	RA	V	B-V
000-BCR-863	AT And	43 00 51.7	23 42 30.83	10.42–10.92	0.42–0.56
000-BCR-873	112	43:04:34.6	23:42:48.09	11.169	1.176
000-BMM-293	86	45:19:16.8	18:49:07.11	8.575	1.266
000-BMM-290	105	45:20:23.4	18:48:47.75	10.451	0.967
000-BMM-292	108	45:14:13.7	18:49:04.39	10.774	0.357

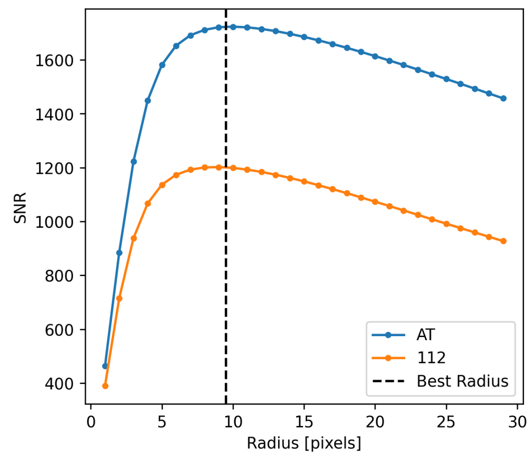
Table 2: Details of my observing targets. The table is split between the target (top) and standard (bottom) fields.

ture radius for aperture photometry, I find the aperture which maximizes the SNR.

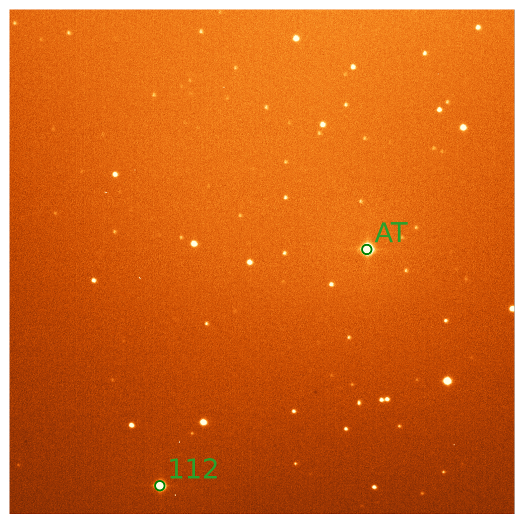
$$S/N = \frac{gN_*}{\sqrt{gN_* + n_{\rm pix} g N_{\rm sky} + n_{\rm pix}\sigma_{\rm RN}^2}} \tag{1}$$

The CCD Equation (Eq. (1)) calculates the SNR of an aperture with the gain (g), number of counts collected by the aperture in ADUs (N_*), number of pixels in the circular annulus used for the photometry ($n_{\rm pix}$), number of counts collected by the annulus in ADUs ($N_{\rm sky}$), and the read-noise ($\sigma_{\rm RN}$).

Using aperture photometry and Eq. (1), I calculate the SNR for multiple aperture radii, determining the "Best Radius" (BR) for each image to be that which maximizes the SNR for each star in the field. An example of this is shown in Fig. 3a, with an 180-second exposure of AT And and 112 from night four where the BR was 9.5 pixels; the apertures are plotted over the stars in Fig. 3b. The BR for each star excludes some of the star's light (typically less than 0.1 magnitudes), so I correct the photometry by adding the difference between the magnitude at the largest radius to that at the BR.



(a) SNR vs. aperture radius



(b) Apertures plotted over AT And and 112

Figure 3: Shown here are (a) SNR vs. aperture radius for a 180-second exposure of AT And and 112, and (b) apertures plotted over the stars, with BR = 9.5 pixels.

3. RESULTS

To standardize my observations of AT And, I use Eq. (2) with photometry of SF3, plotting the difference between literature- and instrumental-V magnitudes for my stars, $(V - v)$, vs. the instrumental $B - V$, $(b - v)$, fitting a first degree polynomial in Fig. 4 to determine $\mu_{\rm V} = 1.36$.

$$(V - v) = \mu_{\rm V}(b - v) + C_{\rm V} \tag{2}$$

I intended to use Eq. (3), but initially failed to take any exposures of AT And in the B filter.

$$\begin{aligned} V = {} & v - v_{\rm comp} + V_{\rm comp} \\ & + \mu_{\rm V}[(b - v) - (b - v)_{\rm comp}] \end{aligned} \tag{3}$$

The group observing two weeks later was kind enough to take exposures in B and V, but 112 wasn't captured in the field and I ultimately chose to use Eq. (4), where $(b_1 - v_1)$ is the instrumental $B - V$ for the single set of B and V images taken later (rather than $(b - v)$ for every exposure), and $(B - V)_{\rm comp}$ is the literature $B - V$ value for the comparison star, 112.

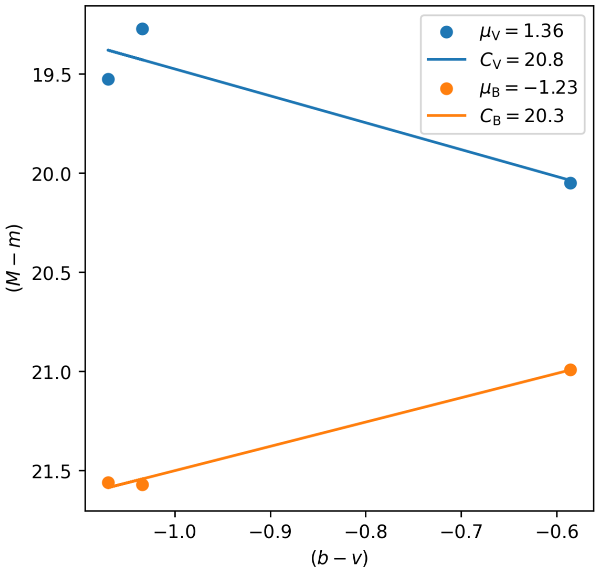


Figure 4: The difference between literature and instrumental magnitudes for my stars vs. the instrumental $B-V$. Data for V is plotted in blue (*top*) and for B in orange (*bottom*). Transformation coefficients for each filter are listed in the legend.

$$V = v - v_{\mathrm{comp}} + V_{\mathrm{comp}} + \mu_{\mathrm{V}}[(b_1 - v_1) - (B-V)_{\mathrm{comp}}] \quad (4)$$

Figure 5 shows the transformation-corrected timeseries photometry data of AT And I collected during nights two, three, and four of our observing run. I find $V_{\mathrm{min}} = 10.06$ and $V_{\mathrm{max}} = 10.55$, a difference of ~ 0.49 magnitudes. Despite differing from the literature values for V_{min} and V_{max} of 10.42 and 10.92 (AAVSO 2025a), they share nearly exactly the same amount of variability.

This discrepancy indicates an error in the transformation correction; a possible cause of the error is the fact that I use different values in Eq. (4) than were called for, resulting in a flawed correction. Another possibility is that the stars in SF3 are too few and cover too small of a range of $B-V$ values to fit an accurate value for μ_{V}. The magnitudes I calculate without the μ_{V} color-correction term are 10.37 and 10.85—closer to the literature values. A smaller negative value of μ_{V} would bring my magnitudes closer to the literature values, lending credence to this second theory.

Interestingly, the data entries I looked at on the AAVSO website indicate “No” under the “Transformed” field—although I am not exactly sure if the table is referring to the same transformation as I am, it could be evidence that my values should be compared to the AAVSO ones without the transformation-coefficient correction. This idea makes little sense to me, so I proceed through my analysis assuming it not to be true.

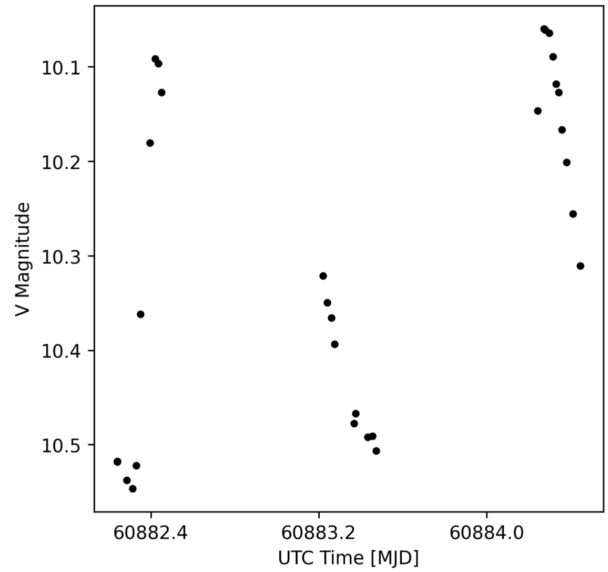


Figure 5: The transformation-corrected timeseries photometry data of AT And during nights two, three, and four of our observing run.

In order to determine the period of these data, I use `LombScargle` from `astropy.timeseries` to create the periodogram in Fig. 6, finding the best period to be 0.5964 days, or 14.313 hours. Compared to the accepted value of 0.6169 days, the period I find differs by only 3.33% (AAVSO 2025a). I interpret this result as mostly accurate, seeing as phase-folding the data in Fig. 7 creates a very recognizable asymmetric RR Lyra-like lightcurve. The data almost entirely cover the period of AT And, yet I would guess that observations on night one might fill any remaining gaps, bring the period closer to the accepted value, and possibly even lower some of the other peaks in Fig. 6.

To plot the lightcurve fit in Fig. 7 I use the (heavily outdated) Python package `gatspy` from `AstroML` (VanderPlas & Ivezić 2015). Since `gatspy` only models RR Lyrae in the SDSS *ugriz* filter system, I chose r as a proxy for my V-band observations.

4. CONCLUSIONS

Data on the asymmetric RR Lyrae-variable, AT Andromedae, have not been submitted to the AAVSO database since January of 2025. With my observations from July 25th to July 27th, I am able to reproduce characteristics of the star’s lightcurve that agree with or are similar to those from the AAVSO.

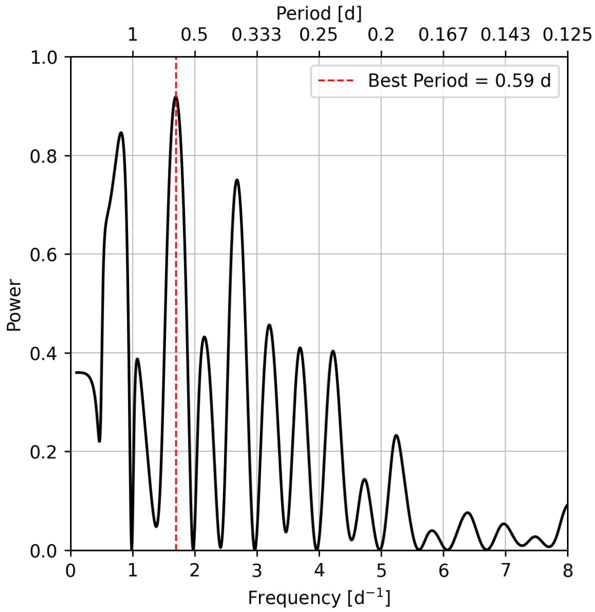


Figure 6: Lomb-Scargle periodogram power spectrum of frequencies in my data. Periods for each frequency are labeled on the upper x-axis, with the best period (0.5964 days) shown by the vertical dashed line in red.

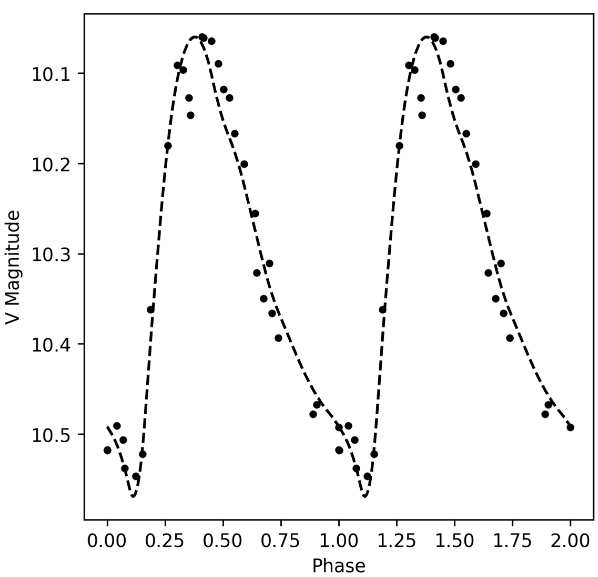


Figure 7: Two phases of the phase-folded lightcurve of AT And, with period 0.5964 days. The dashed line shows an RR Lyrae lightcurve model fit to the data with `gatspy` from `AstroML` (VanderPlas & Ivezić 2015).

Using the slightly-modified magnitude standardization in Eq. (4), I correct my photometry to find $V_{\mathrm{min}} = 10.06$ and $V_{\mathrm{max}} = 10.55$—a nearly identical change in magnitude to the AAVSO values, yet ~ 0.36 magnitudes too bright, likely due to errors in the standardization. I determine the period of AT And to be 0.5964 days, only 3.33% different from the AAVSO value of 0.6169 days. With my corrected magnitudes and derived period, I reconstruct the lightcurve of AT And, fitting a model from `gatspy` in Fig. 7 that appears remarkably similar to those on the AAVSO database (AAVSO 2025a).

These results are imperfect and could be improved through more careful attention to the elements required for photometric standardization. Additionally, data observed during a fourth or fifth night could help increase the precision and accuracy of the results.

My data do not show with sufficient certainty that anything outside of the norm is occurring with the variability of AT Andromedae.

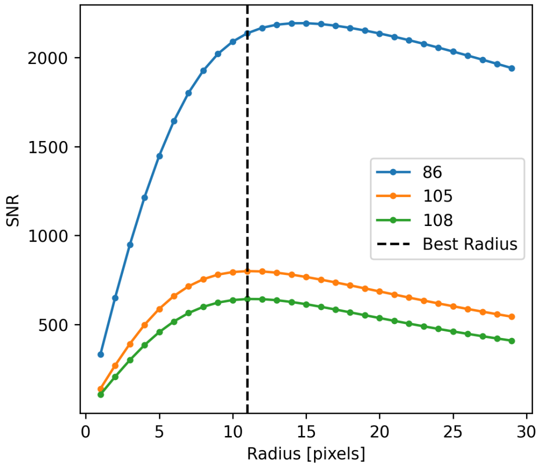
ACKNOWLEDGMENTS

I acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.

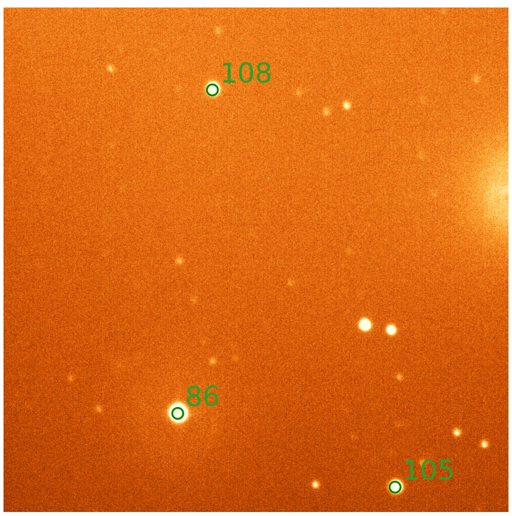
Special thanks to Team Best Birds for making our this summer so enjoyable! Thank you to Professor Oliver Fraser for your understanding and patience as I worked through difficulties I had with this project (including the concussion lol). Lastly, thanks to Ishaani Purang, Devanshi Singh, and Taeo Kim for their support through this class and for proofreading this paper!

APPENDIX

A. ADDITIONAL FIGURES



(a) SNR vs. aperture radius



(b) Apertures plotted over SF3 for stars 86, 105, and 108

Figure A1: Shown here are (a) SNR vs. aperture radius for a 60-second exposure of SF3, and (b) apertures plotted over the stars, with BR = 11 pixels.

REFERENCES

AAVSO. 2025a, Details for AT And, The American Association of Variable Star Observers (AAVSO). https://vsx.aavso.org/index.php?view=detail.top&oid=73

—. 2025b, AAVSO Variable Star Plotter, The American Association of Variable Star Observers (AAVSO). https://apps.aavso.org/vsp/

Astropy Collaboration, Price-Whelan, A. M., Lim, P. L., et al. 2022, ApJ, 935, 167, doi: 10.3847/1538-4357/ac7c74

Becker, L. 2025, The Instrument and Sky: Best Birds. https://liamb27.github.io/papers/ASTR_481_A.pdf

Bradley, L., Sipőcz, B., Robitaille, T., et al. 2024, astropy/photutils: 2.0.2, 2.0.2, Zenodo, doi: 10.5281/zenodo.13989456

Cavicchio, F., & Nicolini, M. 2025, Astroart, MSB Software. https://msb-astroart.com/default.htm

Fraser, O. 2025, University of Washington. https://uwmro.github.io/

Landolt, A. U. 2013, AJ, 146, 131, doi: 10.1088/0004-6256/146/5/131

VanderPlas, J. T., & Ivezić, Ž. 2015, ApJ, 812, 18, doi: 10.1088/0004-637X/812/1/18

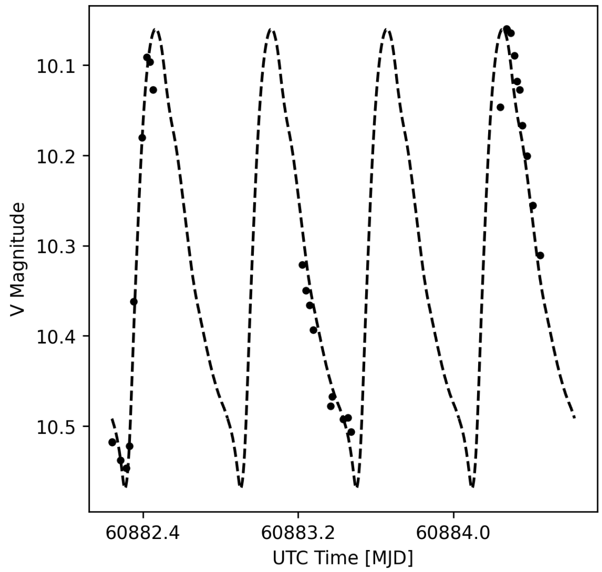


Figure A2: The non-phase-folded photometry data with the lightcurve fit plotted over it.