Title

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I. INTRODUCTION

II. DATA ACQUISITION AND SETUP

Observations were made on and at the Zaffarano Hall observation deck in Ames, Iowa ($-93.647\,34°$, $42.029\,96°$, 342 m). Both nights had clear viewing and the ambient temperature was around 13 °C for the first viewing and 16 °C to 4 °C. The moon had little to no effect on our sight either night due to the target position being 107° away. Observations were made using a Meade 8" reflector telescope with a 2x focal length extender and an SBIG ST-402ME CCD camera with internal V, B, and I filters.

Setting up the telescope was the same as previous observations made with the 8" Meade telescope at Zaffarano Hall. was the trial night to determine whether DQ Cep would be visible and if the difference in magnitude could be seen.

A lot of time was spent locating the star of interest and orienting the camera. The method we found best for use with our specific Meade telescope was to slew to SAO 33047 and refernce a star chart to see where it sits in relation to DQ Cep and also SAO 33050. Now, slew to SAO 33050 and notice which direction the telescope slews. This will define polar axis in relation to the star chart. Then, we found similar triangle and were able to orient ourselves correctly on both axes compared to the star chart and then slewed to DQ Cep. Using the focal length extender was necessary to get both of our reference stars in the frame. This also depends on the orientation of the CCD, so we made sure to rotate the CCD on the mount so that all stars are in the image.

After focusing and determining our exposure time, we took 100 frames with 15 s exposures and a 10 s pause in between each frame. This pause is vital to allow re-aligning as the stars and mount fall out of alignment as the Earth rotates. In general we noticed about every 10 frames a small movement was necessary to keep all sources fully in frame.

The observations on were meant to gather as much data as possible. With a previously stated period of 0.0789 d (1.89 h)[2], we sought to get data over two full periods, so four hours of observations. One of us started observations around 8:00 pm and started taking 500 frames. At 10:00 pm we switched observers and ran until the end of the night. In all we gathered 483 science frames and 5 dark frames.

III. DATA ANALYSIS

Our data analysis pipeline has two major parts. The first is the differential photometry of all 583 frames and the second is using a Lomb-Scargle periodogram to determine the optimal period for fit.

For differential photometry we used AstroImageJ (AIJ) due to its ability to process large stacks of images. We used multi-aperture mode and set the reference magnitudes according to section I. We tried using the automatic mode that would use image analysis to place the apertures on every frame, but since the position of the stars is changing in every frame, the automatic processing failed. That left us with one-click mode where, after placing initial apertures, we could move through each frame and click on the same reference point to place all apertures.

For our apertures, we used the same for each object, with circular inner aperture with radius 10 pixels and outer sky annulus with inner radius 15 pixels and outer radius 25 pixels. In AIJ we could set the multi-aperture photometry to reference the image header for the electron gain, which was nice. The algorithm AIJ uses is a sky-median subtraction, which takes the median value of the sky annulus times the area and subtracts it from the integrated aperture sum of the target.

We ended up with two results tables for each observation date, which we concatenated together into one large CSV table which is stored at this github page.

For determining the optimal period, we used Astropy's Lomb-Scargle methods for fitting and modeling our data. We modeled using a single term Fourier series (sine wave) and allowed the package to automatically parameterize the FFT. Even though our data is more regularly sampled than an RR-Lyrae would be, we chose the Lomb-Scargle over a classic periodogram. Because of this, we can treat both observation nights as one dataset with a 21 day gap and helps smooth out the irregular sampling rate caused by small interruptions on the second observation night.

We wrapped this method with Pandas DataFrames to read our CSV table and using matplotlib to present our data. All of the analysis was done in a jupyter notebook at this github page. For more information about Lomb-Scargle periodograms in python, please reference[3].

IV. RESULTS

The differential photometry yielded the magnitudes, with errors, shown in Figure 1. The plot is broken to show both observation nights easily side by side. The

Table I. Information about target and reference stars

Object	Type	RA	DEC	V	Ref
DQ Cep	*dS	20 57 48.6082	55°29′15.602″	7.40 to 7.48	2
HD 235411	*	20 57 31.1094	55°31′38.697″	9.76(3)	1
HD 200017	*	20 58 27.2026	55°39′0.459″	8.20(1)	1

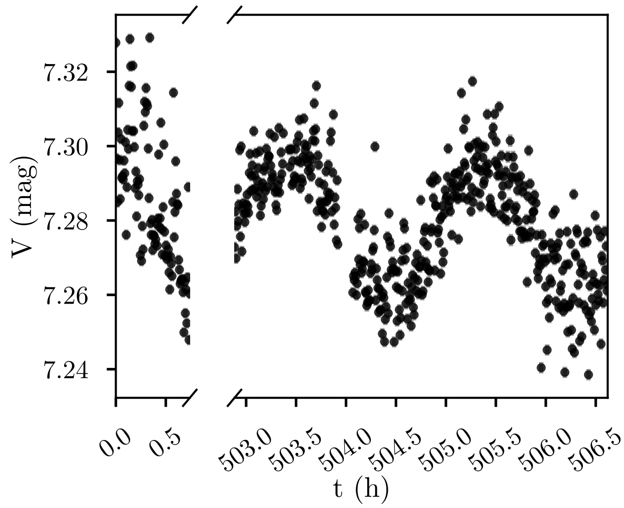

Figure 1. Photometry results for both observation nights

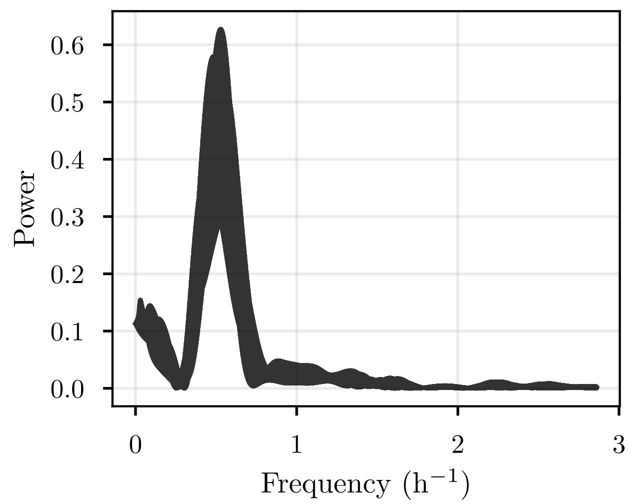

Figure 2. Lomb-Scargle Periodogram. Peak is around $0.53\,\mathrm{h}^{-1}$

time is referenced as the time since the first image was taken.

The Lomb-Scargle periodogram is shown in Figure 2. We can see a clear peak around $0.53\,\mathrm{h}^{-1}$. This corresponds to a period of 1.89 h or 0.079 d. We use this to fold all of our data and use Astropy's single-term model to show the fit in Figure 3. From this model, we can say the magnitude range for DQ Cep is 7.26 mag to 7.30 mag (0.04 mag), while the raw data has a range of 7.24 mag to 7.33 mag (0.09 mag).

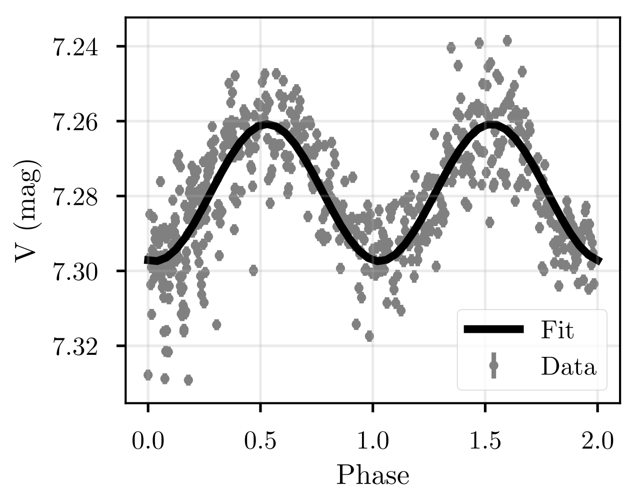

Figure 3. Folded data with single-term Fourier series fit based on best frequency from Lomb-Scargle Periodogram

V. CONCLUSIONS

ACKNOWLEDGEMENTS

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REFERENCES

[1] E. Høg, C. Fabricius, V. V. Makarov, S. Urban, T. Corbin, G. Wycoff, U. Bastian, P. Schwekendiek, and A. Wicenec. The Tycho-2 catalogue of the 2.5 million brightest stars. 355:L27–L30, March 2000.

[2] B. V. Kukarkin, P. N. Kholopov, Y. P. Pskovsky, Y. N. Efremov, N. P. Kukarkina, N. E. Kurochkin, and G. I. Medvedeva. The third edition containing information on 20437 variable stars discovered and designated till 1968. In *General Catalogue of Variable Stars, 3rd ed. (1971)*, 1971.

[3] J. T. VanderPlas. Understanding the Lomb-Scargle Periodogram. March 2017.

Appendix A: Observation Log

Table II. Observed 27 September 2017 by Miles Lucas

Time	File	N Frames	Object	Filter	Exposure	Camera Temp.	Notes
0927/21:22	DqCep_V_15s_	100	DQ Cep	V	15 s	5 °C	

Table III. Observed 18 October 2017 by Miles Lucas and John Brandon

Time	File	N Frames	Object	Filter	Exposure	Camera Temp.	Notes
1018/20:15	DqCep_V_15s_	482	DQ Cep	V	15 s	5 °C	

Appendix B: Analysis Scripts

Please reference the jupyter notebook at this github page.