New distance and period estimates to OZ UMa, an RR Lyrae star

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We observed OZ UMa over a 14 night span between October 21st and November 3rd with the help of Las Cumbres Observatory Network. We utilized filters B, V, i, and z during OZ UMa's observation and imaging process to produce four distinct light curves that allowed us to calculate distance and period measurements. We report a new distance measurement of 1,276 parsecs to OZ UMa. We confirm OZ UMa's variability type, previously classified as an RRc, as well as provide an updated period estimate.

Keywords: *Starse: Variable: RR Lyrae, techniques: photometric, catalogs, parallaxes*

http://dx.doi.org/etc

INTRODUCTION

The study of RR Lyrae variable stars is crucial in calculating distances and providing researchers with information on the helium and heavy element content in the old disc population of the Milky Way Galaxy. To expand on this area of research, RR Lyrae variable star OZ UMa was chosen as our object of study. RR Lyrae stars are classified into two common groups: RRab and RRc. RRab pulsate in the fundamental radial mode, while RRc stars are defined as stars that pulsate in the first overtone radial mode (Smith, Catelan, Kuehn). OZ UMa's variability type was classified in AAVSO and GCVS as an RRc star.

In general, RR Lyrae type stars pulsate with a period between 0.2 and 1.0 days. OZ UMa was previously classified as an RRc star by observing that the star exhibited nearly symmetric, sometimes sinusoidal, light curves, that displayed periods between 0.2 and 0.5 days, and amplitudes no greater than 0.8 mag. in V. Thus, we describe OZ UMa as an overtone pulsator. The metallicity of our star was estimated by several prior studies, each of which reported an Fe/H of nearly ([Fe/H])=-0.62397 (SDSS QSO DR14 spectral properties). The parallax angle of OZ UMa has been measured to be 0.6549 mas, corresponding to a distance of 1453 parsecs (Gaia Collaboration, 2018). Although a previous study of this object produced a variability classification, further research is needed.

METHODS

We first chose an RR Lyrae star that would be visible within our time frame of October 2020-November 2020.

The next step was ordering a full cadence so that the source-sky count of each filter of each image was around 100,000. Approaching this goal we ordered a test image of OZ UMa with 12 a second exposure time for each of the four filters: B, V, ip, and zs. Images were captured using Las Cumbres Observatory's collection of .4m mirror SBIG telescopes located across all continents except Antarctica. The acceptability threshold was 90 percent, maximum airmass was 1.6, and minimum lunar separation was 30 degrees.

To count the pixels within an aperture and compare them to the sky background, AstroImageJ software was used. Moreover, with the known 12 second exposure times, the necessary cadence exposure times were determined. For each band, these times were determined to be 90 seconds, 34 seconds, 47 seconds, and 260 seconds for filters B, V, ip, and zs, respectively. Our cadence ran from October 21st to November 3rd.

We further analyzed our cadence images via Astropy-based python scripts called Astrosource, which identifies stars with lowest variability in the image, determines their apparent magnitudes, and uses them as comparison stars for each of the filters used. These are then used to determine the period of the RR Lyrae. We ran the Astrosource code for the psx photometry files. Our image reject was 0.1. In analyzing our images, we required calibration catalogs to provide comparison stars used to determine OZ UMa's magnitude in each filter. The table below provides the catalogs utilized for each filter.

Table 1. **B, V, i, and zs Comparison Catalogs**

Filter	Catalog
B	APASS
V	APASS
ip	SDSS
zs	PanSTARRS

CALCULATIONS

To determine the final distance measurement, we calculate the absolute magnitude of the star in the V, i, and z filters using the following theoretical period-luminosity relationships (Catelan, Pritzl, Smith).

$$M_V = 2.288 + 0.882\log(Z) + 0.108(\log(Z))^2 \quad (1)$$

$$M_i = 0.908 - 1.035\log(P) + 0.220(\log(Z)) \quad (2)$$

$$M_z = 0.839 - 1.295\log(P) + 0.211(\log(Z)) \quad (3)$$

The value of log(Z) used in the distance calculations was calculated using the following equation(Cáceres Catelan):

$$log(Z) = 0.977Fe/H - 1.699 \quad (4)$$

Following this, we calculate our distance in each filter by using the distance equation:

$$d = 10^{(\frac{m-M-A+5}{5})} \quad (5)$$

where the apparent brightness, m, was calculated from our images of the star. The quantity A is the extinction factor in the appropriate band (Cardelli, Clayton, Mathis).

Finally, we calculate a final distance by accounting for interstellar reddening shifts and extinction. To do this, we adjusted the color excess, $E(B-V)$, such that the variance in distance for each filter was made to be at a minimum (Cardelli, Clayton, Mathis). Similarly, we assume $R_v = \frac{A_V}{E(B-V)} = 3.1$, such that we are able to calculate A_V, the amount of extinction in the V filter, by adjusting the color excess (Schlegel, Finkbeiner, Davis). This measurement relates how much redder light emanating from a star has become to the amount of light that has been absorbed in total. We then averaged these values to produce a final distance estimate.

RESULTS

From our data, we produce final calculations for the distance and period of OZ UMa. Previous studies have found the period of the star to be .34528 days or 8.2 hours (GCVS). The period calculated by Astrosource is .3460 days with an error of $.00135$ days.

The period in each of the filters was determined by the String-Length method (Dworetsky). The lightcurves for all four bandpasses using the SL period are shown in Figures 2-5. The period error is shown by the width of the tallest peak in the string likelihood plot (see Figure 6). To calculate the period error, the tallest peak must be first be identified. This peak represents the most likely value of the period. Then, the point at which the tallest peak has dropped off by 5% of its value is used as the period error.

Moreover, GAIA data release 2 estimates OZ UMa's distance to be 1,453 parsecs with an error of 85 parsecs. By averaging the distance measurements in the B, V, ip, and zs filters, our Astrosource calculation provided a final distance measurement to OZ UMa of 1,276 parsecs and an error of 52 parsecs. Comparison of estimated distance measurements in individual filters, alongside Gaia's own estimate, is shown in Figure 1 and Table 2.

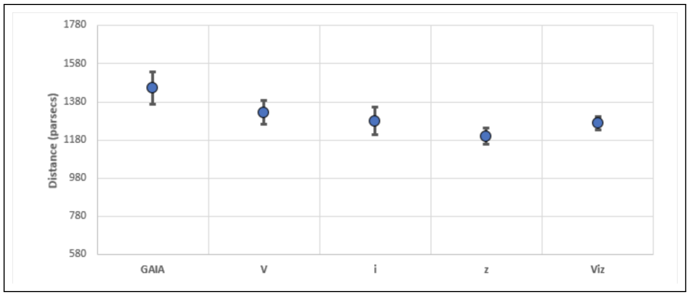

Fig. 1. Estimated distance to OZ UMa in several filters compared to GAIA's published value.

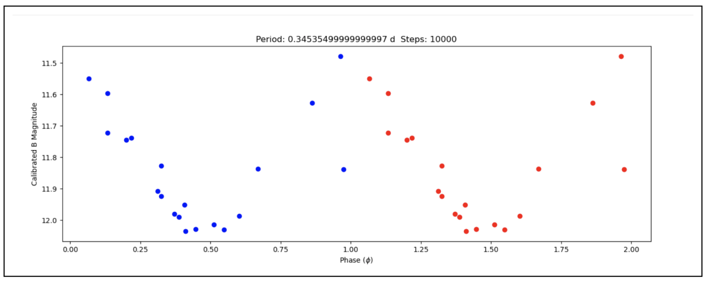

Fig. 2. Phased light curve of OZ UMa in B band using SL period.

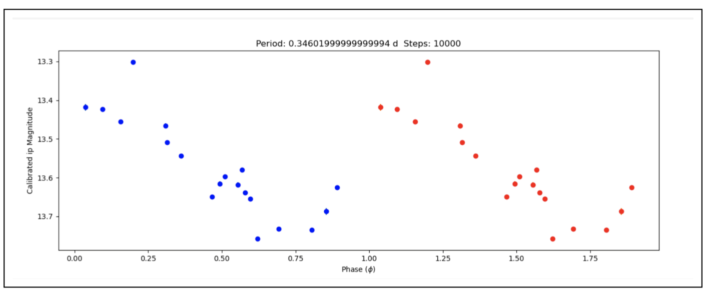

Fig. 3. Phased light curve of OZ UMa in i band using SL period.

DISCUSSION

Observing OZ UMa provides crucial information that can be used to compliment previously performed GAIA measurements. Verifying measurements allows further, increasingly accurate observations in Ursa Major.

We observe that OZ UMa exhibits behaviours characteristic of an RRc type star. This was determined

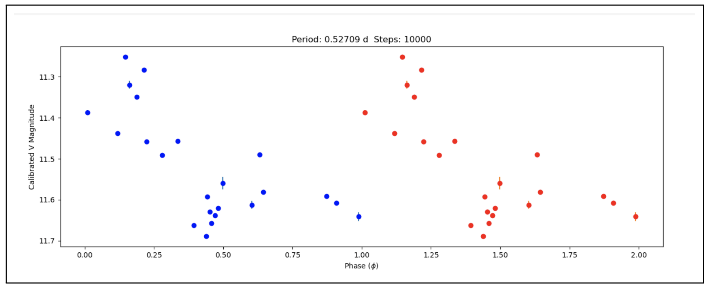

Fig. 4. Phased light curve of OZ UMa in V band using SL period.

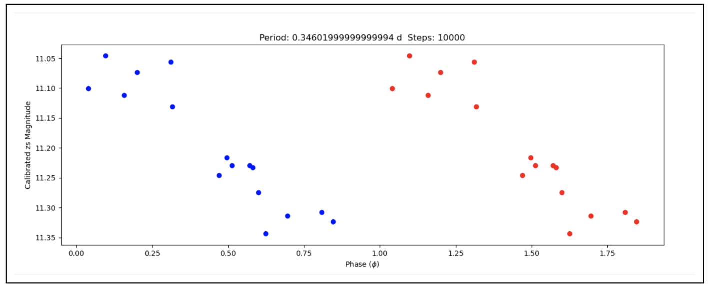

Fig. 5. Phased light curve of OZ UMa in z band using SL period.

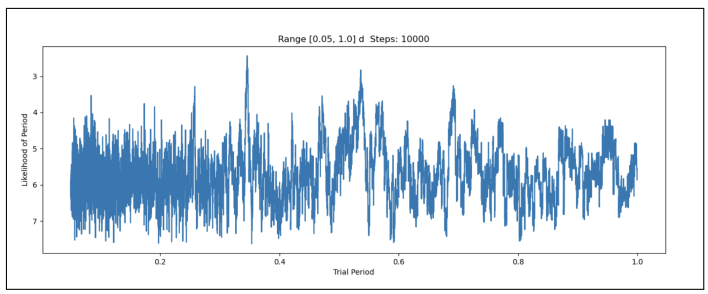

Fig. 6. Likelihood plot for OZ UMa using String-Length method.

Table 2. Distance Measurements from GAIA and V, i, z, and Viz Filters.

Distance Measurements		
Type	Distance	Error
GAIA	1453	85
V	1325	62
i	1281	70
z	1200	43
Viz	1269	34

by observing the star's smooth, nearly symmetric sinusoidal light curves in addition to its distinctly short period. Moreover, the amplitude of an RRc type star is generally no greater than 0.8 mag. in V, which is also the case for OZ UMa.

Our distance estimate appears to be relatively close with GAIA's measurements. The calculated values will provide useful information for future research regarding the distance to OZ UMa. Likewise, our period calculation serves to further confirm previously measured estimates. Both new calculations of the stars distance and period will add to the breadth of research on OZ UMa and potentially spur further investigation.

CONCLUSION

In this paper we have observed OZ UMa over a period of 14 days to sufficiently investigate the star's intrinsic proprieties. Our data provides new measurements for the estimated period, and further confirmation of the star's spectral type: RRc. We have also provided a new estimate of the reddening $E(B-V) = 0.01$ and distance, 1276 parsecs. With the establishment of new data we have contributed to the development of understanding of our universe. Standard candles are a necessary tool to learn more about other celestial bodies. This is now more possible due to our new calculations for period, distance, and reddening of OZ UMa. OZ UMa is relatively under-researched star so this serves to increase the importance of this new data.

ACKNOWLEDGMENTS

We would like to thank Our Solar Siblings for supporting this research. In particular, we thank Michael Fitzgerald and David Sukow for continued assistance. Furthermore, this project makes use of images provided by Las Cumbres Observatory Network without which observations could not have been made.

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