Final Paper for Observational Astronomy AST401L

Light Curve Period and Phase Study of the Eclipsing Contact Binary SW Lacertae

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Contents

1 Abstract

SW Lac is a well observed short-period contact binary system. The first photoelectric UBV light curves of the system collected highlighted the light curve asymmetries from cycle to cycle. These asymmetries were confirmed and assigned to the existence of cool spot regions. The data collected of the object SW Lac was in B, V and R bands with a total of 2,275 images taken at $3, 1.5, 0.7$ second exposure times in the BVR filters respectively. Magnitude differences were calculated between the two comparison stars and the object, and between the two comparison stars. Plots of the difference in magnitude verses julian.

2 Introduction

Overcontact binary stars are systems where both components share an envelope and are in physical contact with each other. This leads to luminosity and mass exchange between the stars. W Ursae Majoris (W UMa) binary systems are well known overcontact systems that have F, G and K-type stars with common envelopes. It is important to understand their internal structure and evolution to be able to model their observed properties (Terrell et al. 2012). SW Lacertae is a short-period contact binary star system (P 0.d32, Vmax=8.m91). The variability of the system was first discovered in 1918 by Miss Ashall (Leavitt 1918), evaluating photo plates taken at the Harvard Observatory. The first photoelectric UBV light curves of the system were collected by Brownlee (1956). They highlighted the light curve asymmetries from cycle to cycle and these asymmetries were confirmed and assigned to the existence of cool spot regions by multiple authors (Albayrak et al. 2004, Alton & Terrell 2006, and references therein). The distance from SW Lacertae to earth is 70.773 parsec and its mean magnitude is 8.51. As it is common for contact binaries, the two minima of one period are from different magnitudes. Due to it's high visual magnitude changes, $\Delta mag = 0.8$, the system is well studied. It has a period of 0.32 day and a orbital inclination of 80°. Seasonal light curve asymmetries, which are usual for over-contact binaries, were observed when Brownlee (1956) used the photoelectric effect for his observations. This effect is called O'Connel effect and it is connected to cool star spots (Liu et al. 2003). In the following, the phase of the binary star system is studied.

Pribulla et al. light curves were asymmetric, with the first max (at phase 0.25) is about 0.02 mag brighter than the second max (at phase 0.75). The descending branch of the secondary minimum in the U filter is fainter than the ascending one. The overall changes in the light curve were approximately 0.01 mag over the whole interval of observations. They found the differences in maxima could be explained by a dark spot visible at phase 0.75. A similar result can be accomplished by positioning a hot spot that is visible at phase 0.25. They found a mass transfer of $2.32 \cdot 10^{-7}$ explained the period increase in the system (Pribulla et al 1999).

The aim of this study is to present additional minima times of SW Lac and calculate the phase in relation to previous studies to observe a potential period change.

3 Observations

The first images collected were twenty four Bias images. They were collected by setting the exposure time to zero while the shutter is closed. Then the seven dark images were taken at 300 second exposure times with the camera shutter closed. The data collected of the object SW Lac was in B, V and R bands with a total of $2,275$ images taken at $3, 1.5, 0.7$ second exposure times in the BVR filters respectively. Nine flat field images were taken in each filter for 3 second exposure times. The images were collected at the 0.5 meter Lutz telescope at Northern Arizona University on 11 05 2021 (UT). The Apogee instruments U47 CCD camera (1024 x 1024 pixels) was used with a plate scale of 0.65 arcsec/pixel with a field of view of 11.1 arcmin x 11.1 arcmin.

4 Data Reduction

The data collected was imported into IRAF to correct the object images using our Bias, Dark and Flat images. The images that were affected by the camera shutter malfunctioning had to be discarded. This caused the stars in our images to streak and added uneven exposure to our image frame. After discarding our bad files, the remaining observations were run through the CCDPROC procedure in IRAF to reduce the object data. The first step was to set our instrument to the “blt” using “setinstrument” in IRAF. Then run zerocombine, darkcomine, flatcombine and ccdproc (found in the packages NOAO, IMRED, and CCDRED). Zerocombine selects the bias images from our dataset and combines them into a master bias image. Darkcombine selects the dark images to create a master dark and subtracts the master bias, then scales them by exposure time and combines them. Flatcombine selects flat-field images then bias and dark subtracts them, scales to the modes and combines them in each filter to create master flats in each filter. Next, we used the task setjd (found in the ASTUTIL package) to calculate and add the Julian Date keywords to our dataset. Within the parameters for this task we set the observatory to “aro”, the date keyword, the “ut” time keyword, exposure time keyword, right ascension (in hours) keyword, and the declination (in degrees) keyword. Additionally, we set the “utdate” and “uttime” parameters to yes because our observation date and time is in UT.

The field is in two different orientations caused by flipping the telescope at the meridian. The meridian flip began at 20211105_1055.fit. The object was labeled as 1 and two comparison stars and 2 and 3. One image was chosen before the meridian flip and one image after to record the x and y coordinates and the Full Width at Half Max (FWHM) value for the object and comparison stars. For the image East of the Meridian our x and y coordinate for the object was $(489.89, 800.88)$, for comparison star 1 was $(235.13, 460.29)$ and for comparison star 2 was $(762.15, 365.42)$. The FWHM value for the object was 4.80, for comparison star 1 was 5.03 and for comparison star 2 was 5.00. For the image West of the Meridian our x and y coordinate for the object was $(425.08, 95.35)$, for comparison star 1 was $(682.16, 434.13)$ and for comparison star 2 was $(156.04, 532.72)$. The FWHM value for the object was 5.26, for comparison star 1 was 4.95 and for comparison star 2 was 4.72. The average FWHM value was 4.92. To confirm the FWHM value was approximately uniform throughout the observation window we checked several random images. To confirm the autoguider was functioning properly we used imexamine to verify the coordinates of the three stars matched within 5 pixels.

As the final step, photometry was performed on the object and comparison stars. The aperture was set to the FWHM average value and the annulus to three times of FWHM average value. The IRAF command "phot" was used non-interactively with east and west lists that contained the coordinates of the object and comparison stars before and after the meridian flip. Finally, the IRAF command "txdump" was used to extract the photometry data from the mag-files to analyze the final data.

5 Results and Conclusions

5.1 Data

The data collected for the magnitude of SW Lacertae is graphically displayed in the following depiction.

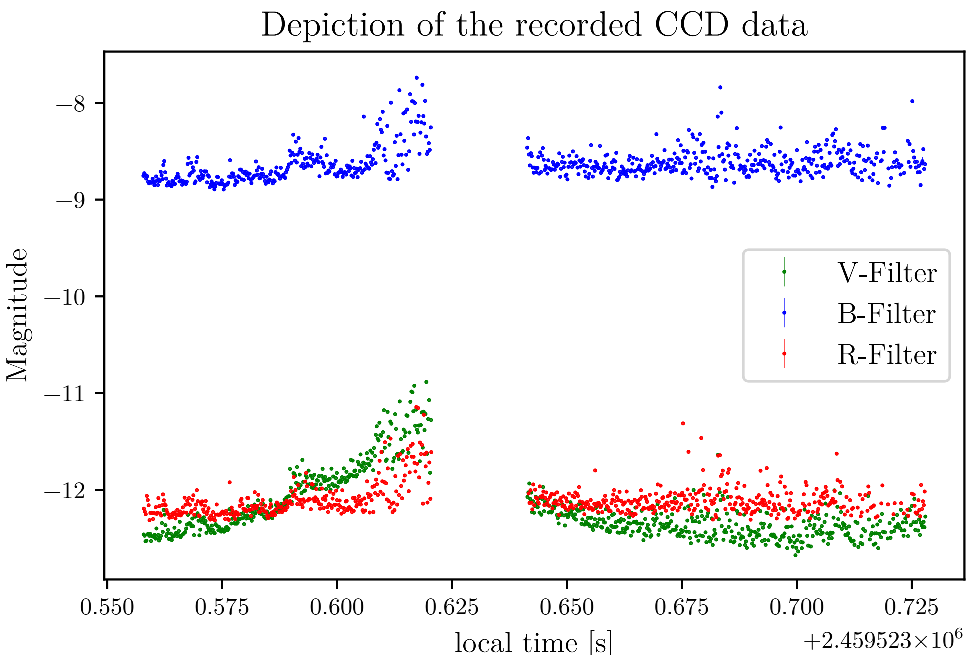

Figure 1: Magnitude of SW Lacertae in B-, V-, and R-filters; data was collected with a CCD array at 11 05 2021 (UT) at the 0.5 meter Lutz telescope at Northern Arizona University

Additionally, data from the two comparison stars was taken. The gap in the data originates from the meridian flip. When an observed object crosses the meridian, the telescope has to be directed to the other side of the sky (East and West). During this operation, there are obviosly no images taken. The slight diverge towards the meridian flip vanishes when taking the difference of magnitudes from SW Lacertae and a comparison star. This is consistent with the assumtion, that it is a telescope or light disturbance artefact.
The uncertainties in the following procedure were calculated with the package uncertainties from python **??**.

5.2 Ensemble Photometry

The method of comparison stars was used in order to excluded errors as a result from different exposures to external light sources. Hence, the magnitude of the star was not utilized, but the difference between the star's magnitude and the magnitude of the comparison stars. For this study, the stars (1) TYC 3215-1586-1 and (2) TYC 3215-1406-1 were chosen as comparison stars. In the following image, their position in the sky in relation to SW Lacertae is depicted.

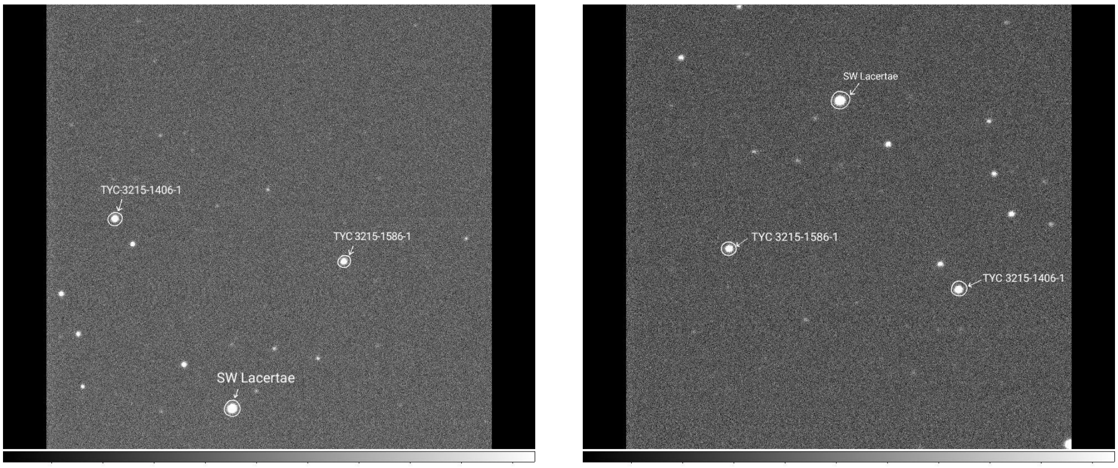

Figure 2: Position of comparison stars in the sky; western sky on the left, eastern sky on the right

The comparison to two stars was utilized to reduce the likelihood of variation in the comparison star brightness and other intruding factors. The difference between the two comparison stars was calculated and didn't display a certain trend. Furthermore, the stationary brightness was looked up in the catalogue of the Centre de Données astronomiques de Strasbourg **??**. This method was conducted for each filter seperately, because of the different exposure times and colors of the stars. The resulting data for the V-filter is shown in the following plot.

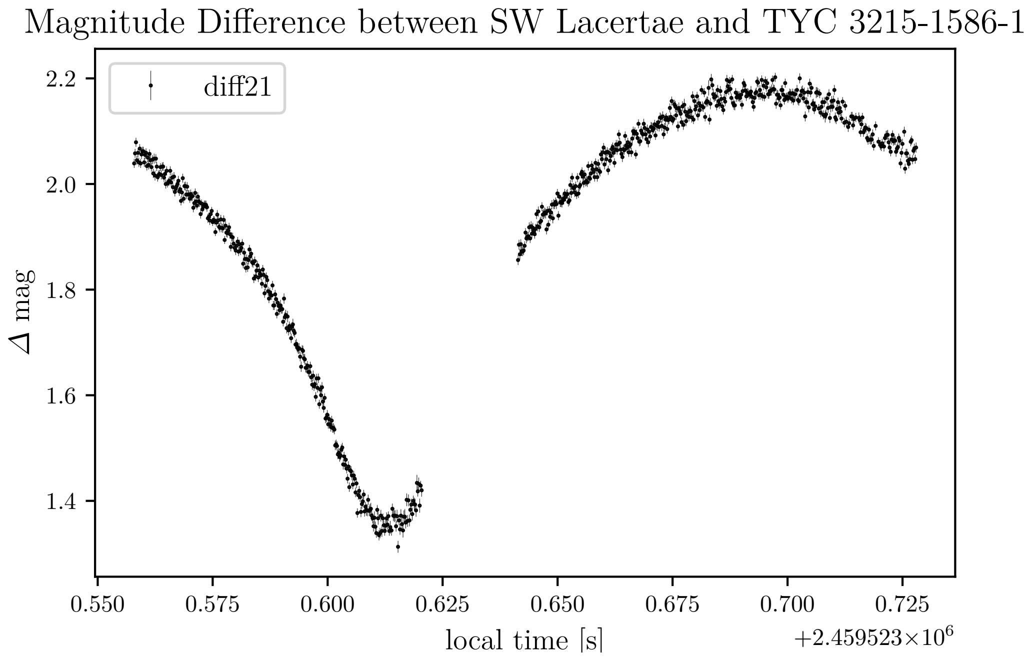

Figure 3: Magnitude Difference between SW Lacertae and TYC 3215-1586-1 in V-Filter. Data was collected at the

5.3 Phase

In order to obtain the phase, in relation to a measured phase 49594.4684 (, the first step is to calculate the epoch.

$$E_{measurements} = HJD - 240000000$$

is calculated in a first step. The data for an earlier Minimum were provided by the instructions for this lab.

$$E_{min} = 49594.4684$$
$$period = 0.3207209$$

The phase in comparison to the given data is retrieved through the formula

$$phase = \frac{((E_{measurements} - E_{min}) \ \% \ period)}{period}. \tag{1}$$

This leads to the following results:

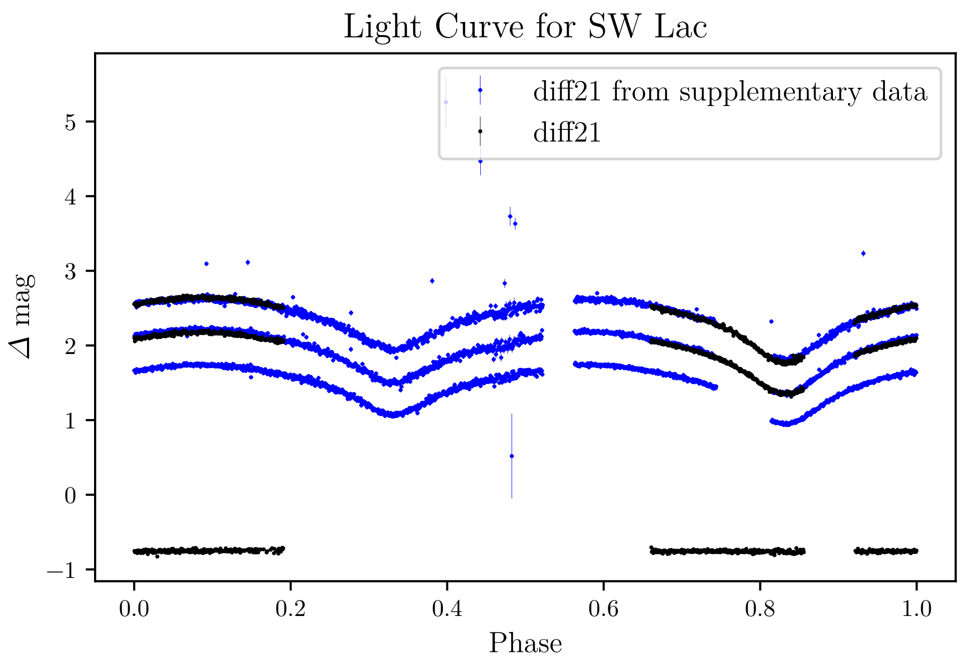

Figure 4: Magnitude difference plotted against the Phase; contains data from another group **??**. Their data is phase-shifted, so that it matches with our observations.

The smaller gap in our data is, as mentioned before, caused by the meridian flip. Due to difficulties whith the telescope shutter, the observations had to be terminated, before a whole period could be observed. Therefore, there is a bigger gap in the data. For this reason, data gathered from another group **??** is included. They observed this binary star system at the same observatory. Since their observation, a phaseshift occured. In order to fill the gaps in our data, a phase of $+0.647$ was added. Due to the fact, that Gordons group used other comparison star and different exposure times, the light curves are also shifted in their magnitude. Therefore, the magnitude of the other groups data was also shifted by -0.59 for V-filter and -0.56 for B-filter.

5.4 Conclusion

On account of difficulties, which occured while recording the data, a full period could not be observed. The conclusions base therefore mostly on the data, collected by the other team. Saying this, the lightcurves of both observation nights fits perfectly to each other and therefore, it can be presumed, that the supplementary data will deliver results, which match those of our observations.
It can be clearly seen in plot 4, that there is an offset of the first minimum and $phase = 0$ of 0.338. That implies a period change of the system. As can be extracted from the other groups data, which had to be shifted by a phase of $+0.674$, the period change is

quite big. This developement should be further researched, because it could lead to new knowlegde on mass transfer of contact binary star systems.
As expected, the Minima are of different magnitudes. This is caused by the different brightness of the two stars. The discrepancy of the magnitudes of the Maxima has a different reason. The source of this discrepancy lies in the McConnel effect. It is common for contact binary star systems and is connected to cold star spots.

5.5 Discussion

6 References

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