Eclipsing Binary RZ Cassiopeiae: Generating a light curve with a DSLR camera

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Introduction

Photometry is the process of measuring the intensity of light. It doesn't sound particularly glamorous, but it is an extremely important tool used by astronomers to study remote astronomical objects.

One area of study is the observation of variable stars, including eclipsing binary stars. I wanted to use this project as an opportunity to learn more about the technique of photometry. I was also curious as to the quality of data that could be gathered by the amateur astronomer with a relatively cheap consumer DSLR camera and lens.

Selecting a target: RZ Cassiopeiae

While I have done some astronomical observing before, this was the first time I had dabbled in photometry or astrophotography. Because of this, I wanted a target which was easy to observe. After consulting the American Association of Variable Star Observers (AAVSO) beginner guides and other resources on the web, I chose RZ Cas, an Algol type eclipsing binary.

RZ Cas has some characteristics which make it a very good target for beginners:

- **Period:** The primary eclipse repeats every 1.195258 days (∼28.7hrs)
- **Magnitude Range:** The magnitude ranges from ∼6.2 to ∼7.6
- **Eclipse Length:** The primary eclipse lasts just under 5hrs
- **Location:** RZ Cas is located at +69°, circumpolar for our latitude
- **Comparison:** Suitable comparison stars are located within a few degrees

This made it possible for me to observe the primary eclipse in one evening. If problems arose with weather, another observing opportunity would be available in a few days.

Due to light pollution at my observing location, the target star was not visible with the naked eye. However, it was visible in binoculars, and as the following finder chart shows, easy to visually "starhop" to from the familiar **W** asterism in Cassiopeia.

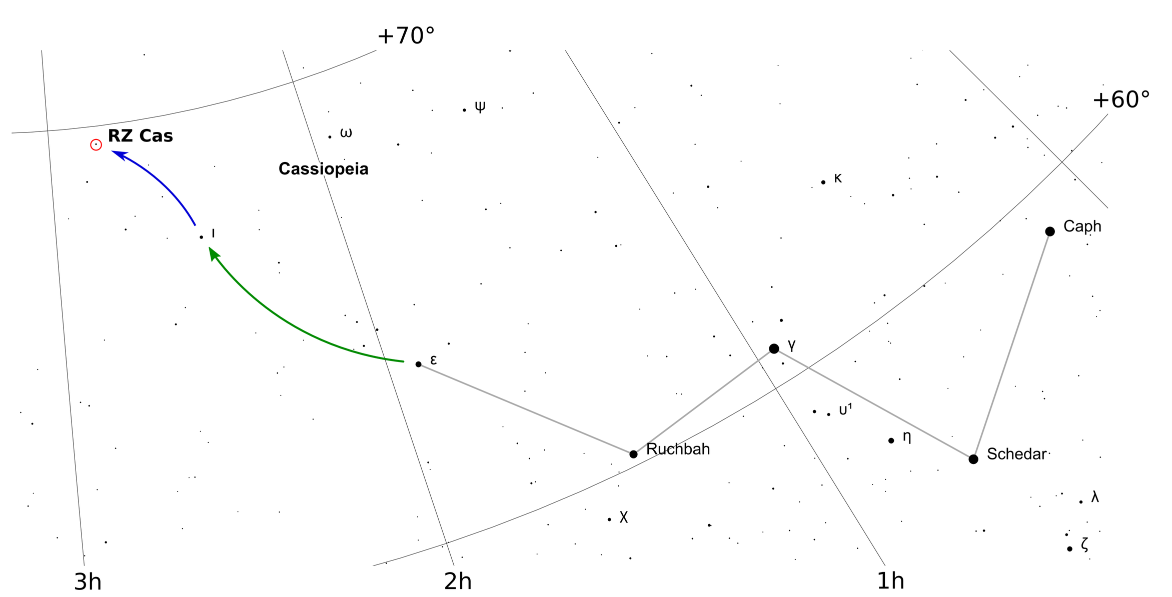

Figure 1. RZ Cas finder chart

Observation

A Canon EOS40D DSLR with a 135mm telephoto lens was used. This resulted in a field of view of ∼9°. Originally a 50mm lens was used but the wide field of view made placing photometric apertures more difficult. A polar finder scope was clamped along the axis of the manual RA adjustment mount. The scope was used to roughly align the axis with the celestial north pole near Polaris.

Conditions were cold (25°F) and clear during the evening. However, there was some cloud cover for over an hour during the midpoint of the eclipse. The camera and mount also had to be moved twice as the target star moved behind trees and other obstacles. Eclipse timing predictions are available online and were used to pick the observation time.

Figure 2. DSLR camera and cobbled together mounting hardware

Star Field

Sets of 20 images with exposure time of 10s each were taken approximately every ten minutes. These 20 images were subsequently calibrated using Dark, Flat and Bias frames to correct for camera noise, lens distortion and dust/defects. Calibrated images were then aligned and stacked by averaging. A annotated example of a fully processed image is below. The target, RZ Cas is visible near the center of the image.

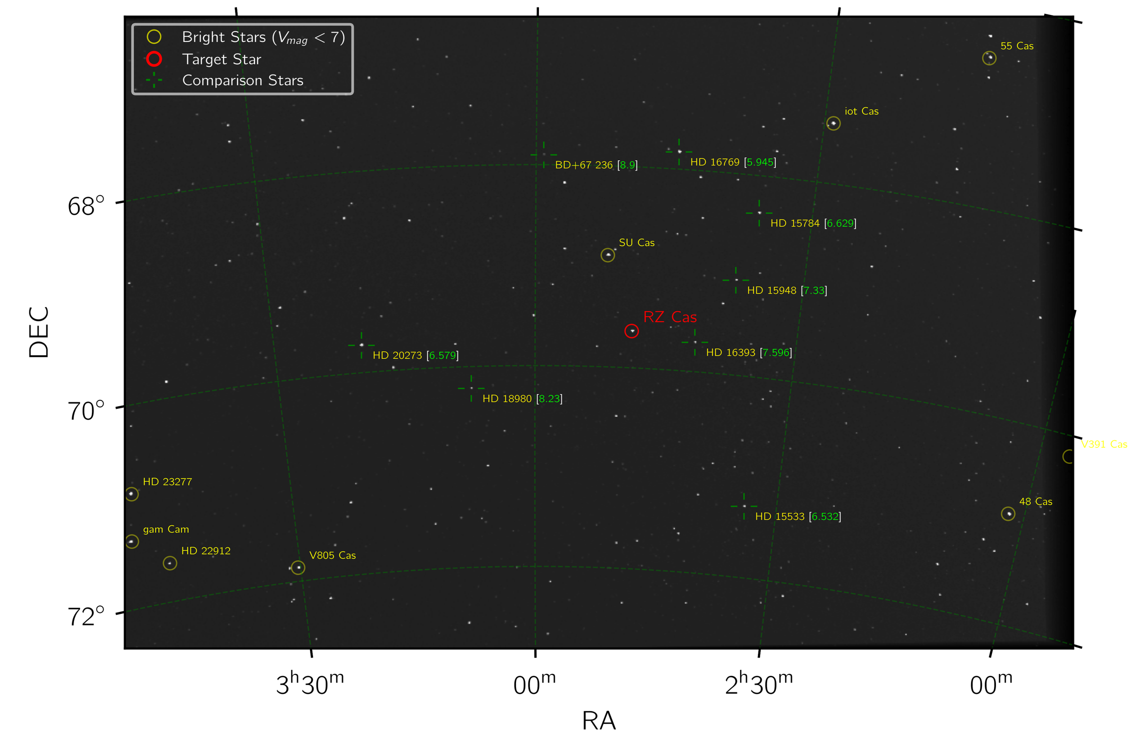

Figure 3. RZ Cas star field (stacked image), annotation data from [5]

Photometry

Rather than doing differential photometry against a single comparison star, 8 stars were chosen. This process is known as *Ensemble Photometry*. This minimizes errors from individual stars. At its lowest point during the night, RZ Cas was ∼ 22° above the northern horizon. Atmospheric effects are pronounced this close to the horizon and multiple comparison stars are one way to help to mitigate these effects.

Following is the list of the photometry comparison stars used to compute the relative magnitude of the target in each frame. Note that the Johnson V magnitudes of the list of stars encompass the full expected range of magnitude of RZ Cas during the eclipse (∼6.2 to ∼7.6). This ensures that the magnitude values can be *interpolated* rather than *extrapolated*. *AstroimageJ* was used to perform photometry.

Name	RA	DEC	Mag V
HD 16769	02:44:52.806	+67:49:47.54	5.945
HD 15533	02:34:00.550	+71:17:23.15	6.532
HD 20273	03:19:59.417	+69:43:41.31	6.579
HD 15784	02:35:45.859	+68:22:16.00	6.629
HD 15948	02:37:35.107	+69:03:28.63	7.33
HD 16393	02:41:36.217	+69:42:28.92	7.596
HD 18980	03:07:30.003	+70:13:04.80	8.23
BD+67 236	02:59:11.623	+67:54:11.10	8.9

Table 1. Photometric comparison stars, from [5]

Light Curve Results

After all the preparation, finally we can see the data! Unfortunately, due to the intermittent cloud cover, the entire eclipse minimum was missed. A Gaussian curve fit was generated so that the general shape of the light curve can be better seen.

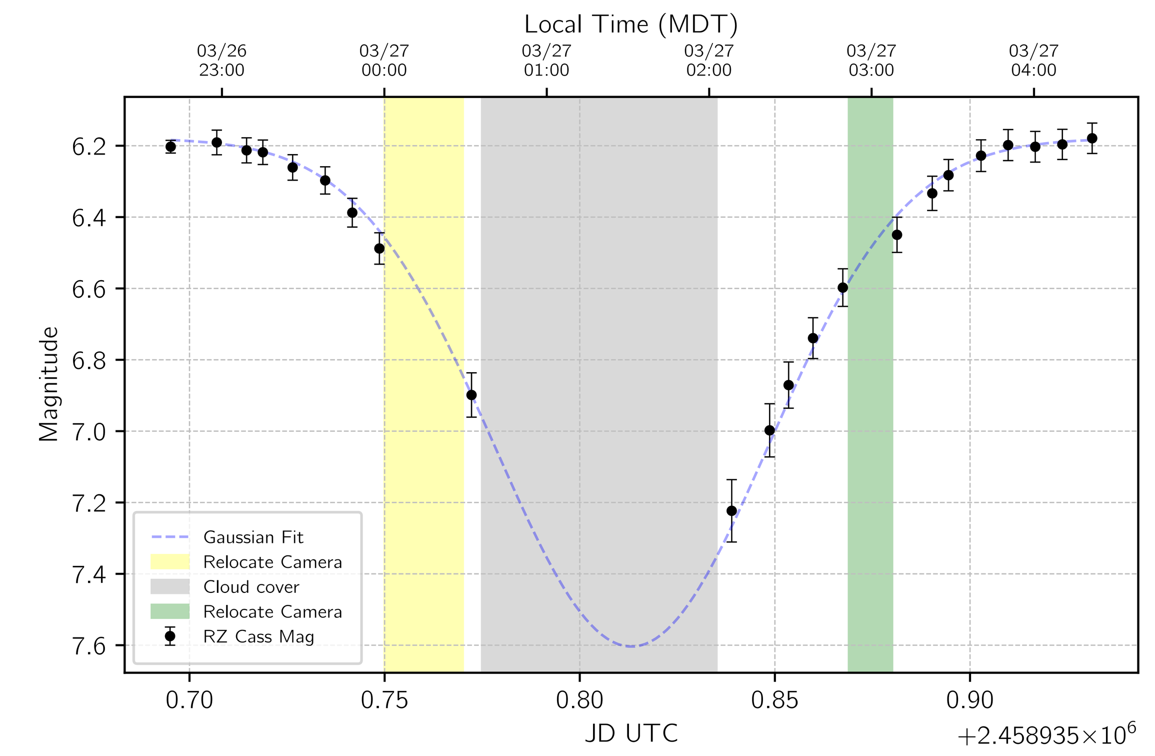

Figure 4. RZ Cas primary eclipse light curve

Reference RZ Cas Light Curve

For comparison, here is a light curve for RZ Cas measured in the 1970's which shows not only the primary eclipse, but also the much smaller magnitude but still clearly visible secondary eclipse.

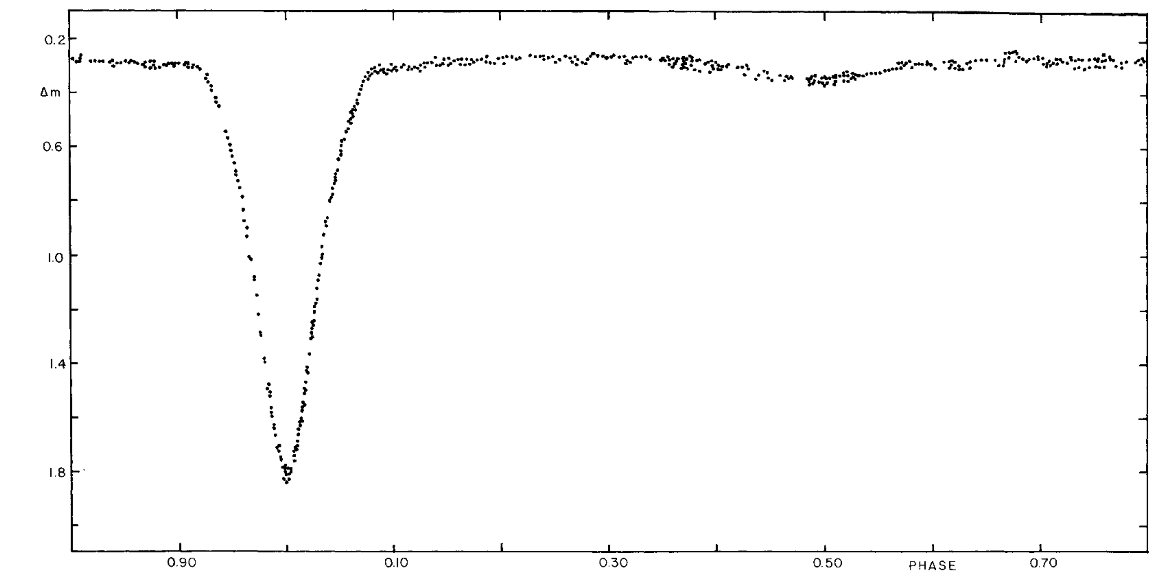

Figure 5. The light curve of RZ Cas in yellow light. The vertical scale plots Δm (RZ Cas - HR 791) [3]

Conclusion

Despite the incomplete results due to cloud cover during the observation session, I believe the project was a success. It demonstrated the practicality of using an affordable consumer DSLR camera and lens to gather useful photometric data.

However, if I continue making photometric observations in this manner, I would make some changes. A star tracker would limit the need to make constant camera alignment checks. A better observing location free from major obstacles and excessive light pollution would improve the quality of results.

References

[1] Richard Berry. *The handbook of astronomical image processing*. Richmond, VA: Willmann-Bell, 2017. ISBN: 978-1-942675-08-2.

[2] Mark Blackford. *The AAVSO DSLR Observing Manual*. Available at `http://www.aavso.org/sites/default/files/publications_files/dslr_manual/AAVSO_DSLR_Observing_Manual_V1.4.pdf` (2020/04/21). Version 1.4. Cambridge MA, 2016.

[3] C. R. Chambliss. "A three-color photoelectric investigation of the eclipsing binary system RZ Cassiopeiae". In: *Publications of the Astronomical Society of the Pacific* 88 (Feb. 1976), p. 22. DOI: `10.1086/129890`. URL: `https://doi.org/10.1086/129890`.

[4] D. Lang et al. "Astrometry.net: Blind astrometric calibration of arbitrary astronomical images". In: *The Astronomical Journal* 137 (2010). arXiv:0910.2233, pp. 1782–2800.

[5] M. Wenger et al. "The SIMBAD astronomical database. The CDS reference database for astronomical objects". In: *Astronomy and Astrophysics, Supplement* 143 (Apr. 2000), pp. 9–22. DOI: `10.1051/aas:2000332`. arXiv: `astro-ph/0002110 [astro-ph]`.