Light Curve Analysis of an Eclipsing Binary

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This project showsa a detailed photometric analysis of an eclipsing binary system. We do this through the use of flux measurments across time. The main objective is to analyze the flux and Julian Heliocentric (HJD) measurments and find the primary eclipsing point for this curve.

In order to do this, I began with cleaning a set of data from my best observation night. Orginally it was a .dat file with numerous headers and values, using linux commands I pulled the necessary flux and HJD data. Once the data was "cleaned" I began writing the python script to read and process the `flux_final.txt` file containing the data. The script used standard scientific libraries to plot the light curve, calcualte an average, and detect the minimum flux value. The eclipse and duration were also calculated from the plotted data.

The inverse square law was applied to convert the relative flux into an estimate of the system's intrinsic luminosity. After manually calculating this system distance from earth start at 94.54 milliarcseconds, I found it was 34.13 light-years away. Changing the distance in lighyear value will be needed for various systems.

The final output gives us three figures: a raw light curve, intrinsic luminosity curve, and a plot highlighting the eclipses various characteristics. This method helps demonstrate how computational methods can be used in the field of astrophysics to efficiently read through data. This code can take in and process any set of varying flux systems to find its characteriscs, speeding up the system intepretation process.

1 Introduction

The study of variable stars, and in particular eclipsing binaries, provides much-needed insights into the properties and behavior of stellar systems. Eclipsing binaries, the system we observed, are part of this category and are two stars that orbit each other and periodically eclipse. This process causes measurable dips in the observable brightness of the system and can be detected through photometric methods.

Photometry, the science of measuring light, allows astronomers to construct light curve graphs showing observed flux over time of a system. These light curves play an essential role in characterizing the physical properties of the celestial body in mind. Some of these physical characteristics include orbital periods, size, shape, temperature difference, etc. Even without the lack of high-resolution imaging, we can still learn quite a bit about far-reaching systems.

Recent studies have demonstrated the effectivness of photometric methods in analyzing eclipsing binary systems. For example, Mazeh, Tamuz, and North (2006) developed the Eclipsing Binary Automated Solved (EBAS), an automated algorithm that processes light curves. EBAS allows efficient and fast interpretation of large datasets and shows how computational techniques can help our understanding of stellar systems Mazeh et al. [2006].

In this project, we applied photometric analysis techniques using Python code to a dataset. This dataset contained flux measurements and the Julian Heliocentric time for each measurement of a specified eclipsing binary. The goal was to analyze and identify various features of the system, in particular the primary eclipse and the luminosity of the system. Meaning we need to use the flux of the system over time to calculate luminosity, depth, and duration of the eclipse. We will then apply the calculated information to a graph for visualization, showing how computational methods can extract valuable information from large data sets.

2 Data

The data used in this project consists of time-series photometric observations recorded in the file `flux_final.txt`. Each row is in the data set contains an Heliocentric Julian Date (HJD) value and the corresponding relative flux measurement of the observed binary star system. The orginial raw data was obtained from a larger observational file and the processed to isolate only the relevant columns: time and flux.

The data cleaning process was performed using Linux command-line tools to extract the third and fourth columans of the original dataset, which represented the HJD and `rel_flux_T!` values. A header row was added to label the columns for compatibility with Python's `pandas` library. This simplified the data importing and analysis proves in the python script.

The head of the dataset is shown:

```
HJD_UTC    rel_flux_T1
2460634.648530    0.069839
2460634.649953    0.075013
2460634.651376    0.072118
```

This format was primarly chosen to keep efficiency and ease with Python. The data is assumed to be free of major outliers and errors. Some variability is shown but most likely due to the presence of natural atmospheric and eclipsing during collection.

3 Visualization

In order to generate a visualization of the light curve over time, the cleaned data was loaded into a python script using the `pandas` library. The data was plotted using `matplotlib`, with Heliocentric Julian Date (HJD) values on the x-axis and relative flix on the y-axis. We used Python-based strategies described by Scopatz and Huff Scopatz and Huff [2015] for automation and visualization.

The resulting plot, a light curve, shows how the brightness of the system changes over time. This shows a clear representation of the systems periodic behavior, while also showing the primary eclipse.

Figure 1 shows the light curve of Target 1. A clear drop in brightness reveals the likely time of the primary eclipse. This figure serves as a oundation for the quantitative analysis.

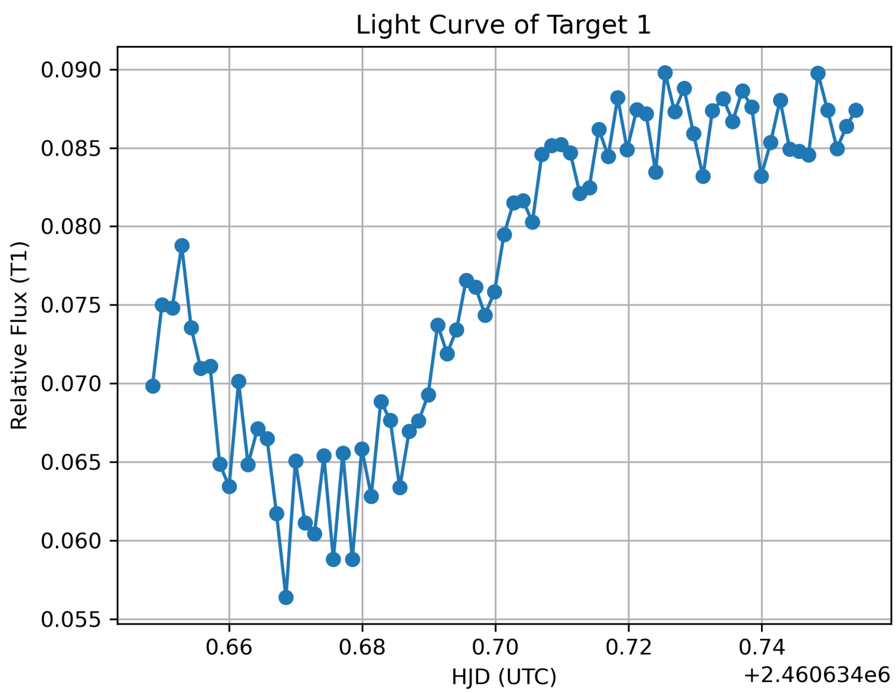

Figure 1: Light curve of Target 1 plotted from telative flux measurments over time.

4 Analysis

The intial visualization of the light curve was further analyzed to idnetify and quatify key features of the curve. Using Python, the script calculated the average flux level and identified the minimum flux point, showing the center of the primary eclipse. This point occurred at approximately HJD 2460634.67.

Measuring the eclipse depth, the difference between the maximum and minimum relative flux was also computed. The depth was found to be about 0.032, showing a significant contrast in brightness during the eclipse. Secondly, the duration of the eclipse was estimated by identifying the time range in which the flux was below the average. The calculated duration was about 0.038 days (or about 55 minutes.

Figure 2 illustrated the annotated light curve with the mean flux, minimum flux, and eclipsing event clearly marked. This figure highlights the This graphic demonstrates how well photometric analysis works to identify important physical characteristics of eclipsing binary systems.

The intrinsic brightness of the system was computed using the inverse-square law in order to further interpret the flux data in a physically meaningful manner. For every data point, the brightness was calculated using the known distance of 34.13 light-years. This change is visualzied in Figure 3, which shows the variation in luminosity over time, corresponding to the change in flux over time.

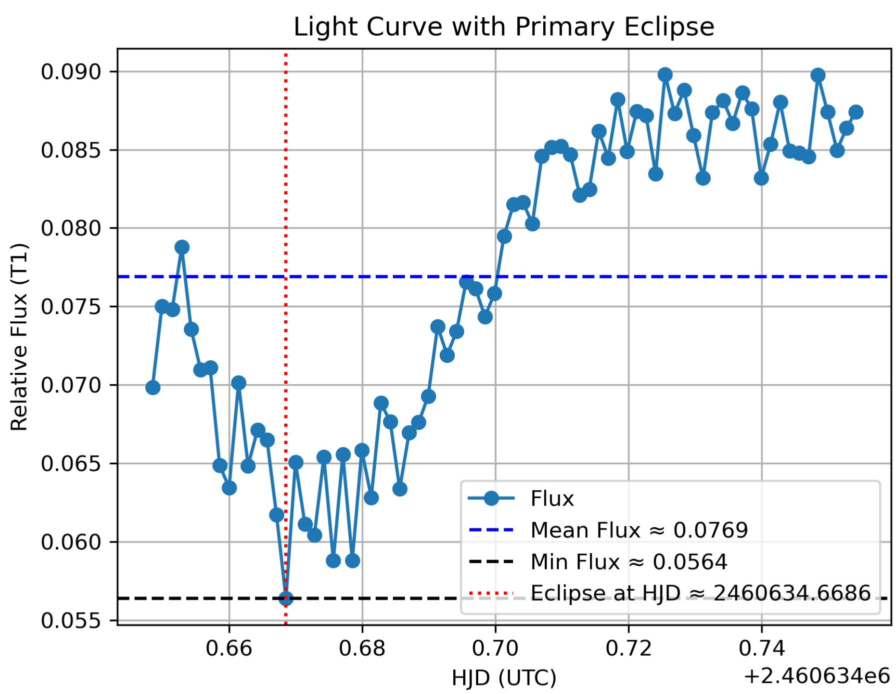

Figure 2: Analyzed light curve showing mean flux, minimum flux, and estimated duration

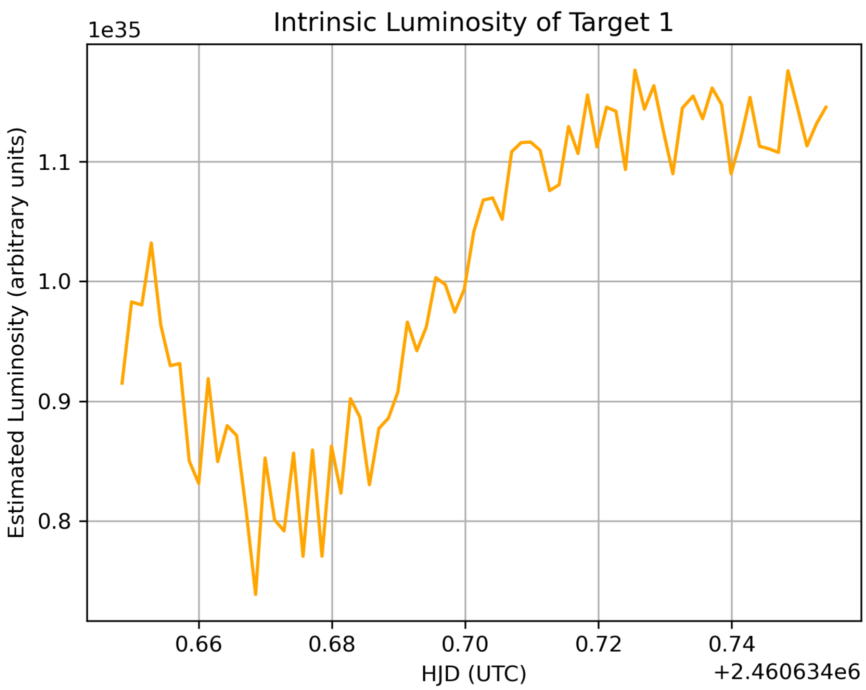

Figure 3: Intrinsic luminosity of the system calculated using inverse-square law and known distance of 34.14 light years.

5 Conclusion

This effort successfully showed the analysis of an eclipsing binary star system using photometric data. We were able to create a distinct light curve that showed the system's basic eclipse by cleaning and structuring a dataset of relative flux values. Using Python-based analysis tools, significant eclipse parameters emerged from this, including as timing, depth, and length.

Using the inverse-square law and the given distance to the system, we were able to visualize the relative flux and translate it into intrinsic luminosity. This highlighted the physical relevance of the photometric observations and made it possible to evaluate the behavior of the system in a deeper way.

The final annotated graphs confirmed the binary structure of the system and gave insight on the eclipse's nature. All things considered, this effort proves the efficiency of combining observational data with computational techniques to reveal astrophysical processes in a measurable and repeatable manner.

To attempt to identify trends in system parameters, future research might compare several eclipsing binaries or apply similar techniques to a larger dataset. In addition, more accurate measurements of star masses, orbit characteristics, and inclination angles may be possible by fitting models to the light curve.

References

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