

Assessing the Scientific Value of Amateur Photometric Observations of Binary Star Transits

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December 31, 2024

Abstract

Amateur astronomers have increasingly contributed to astronomical research through advancements in affordable equipment and accessible software. This paper investigates the precision and reliability of photometric observations of binary star transits conducted by amateur astronomers compared to data collected by professional observatories. We analyze case studies, compare methodologies, and assess the implications for collaborative scientific research.

Keywords: photometry, binary star systems, amateur astronomy, professional astronomy, data comparison

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1 Introduction

In recent years, the field of astronomy has witnessed a growing collaboration between amateur and professional astronomers. The advent of high-quality, low-cost equipment has enabled amateur astronomers to perform sophisticated observations, including photometric studies of binary star transits. This paper focuses on photometric observations of the U Cephei (U Cephei) binary star system conducted by the author using personal equipment from a Bortle 7 location. The study aims to examine the precision and reliability of these amateur observations in comparison to professional datasets, exploring the potential for collaboration and the challenges inherent in combining data from diverse sources.

1.1 Problematic

How do amateur photometric observations of binary star transits compare in precision and reliability to data collected by professional astronomers, and is data collected by amateurs precise enough to contribute to science?

2 What are transits?

Transits are a phenomenon that occurs when a celestial body passes in front of another, partially or totally blocking its light. Those events are very interesting for astronomers as they can provide a lot of information about the objects involved, such as their size, mass, and even atmosphere.

The first exoplanet was discovered using the transit method, and it's still one of the most used methods to detect exoplanets. One of the way to know if a star is part of a binary system is to observe it and see if it's light intensity varies over time, which can be a sign of a transit event.

3 On the U Cephei system

U Cephei is a very interesting binary star system and a great pick to try catching transit eclipses.

3.1 Why U Cephei?

There are multiple reasons why U Cephei is a great candidate for me in this study.

3.1.1 Period

First of all U Cephei period is 2.493 days, which is quite short and allows for multiple chances to observe it on a short period of time. Even though this period seems short since it's not exactly 3 days but 2 and a half it means that one observation out of 2 will be at night and the other during the day. Making observation nights possible every 5 days. Considering the fact weather conditions are critical for this field, managing to have a night with good seeing condition can also be a challenge, so having multiple chances to observe the same system is a great advantage.

3.1.2 Eclipse duration

Secondly, this system eclipse is short, lasting only a couple of hours it's possible in one night to observe the complete eclipse, which is not the case for all binary systems.

3.1.3 Magnitude variation

Stars magnitude define how bright they are. This scale of magnitude is logarithmic, meaning that a difference of 1 magnitude is a difference of 2.512 times in brightness and a difference of 2 magnitudes is a difference of **2.512²** times in brightness. the scale is inverted, meaning that the lower the magnitude, the brighter the star is.

The magnitude of U Cephei varies from 6.7 to 9.2. Which is actually a huge variation in brightness. If we wanna have a comparaison in percentage we can do the following calculation:

We can right the magnitude variation as a ratio of brightness variation:

$$2.512^{m_2-m_1} = \frac{F_1}{F_2} \quad (1)$$

$$2.512^{9.2-6.7} \approx 10 \quad (2)$$

In other words, during the transit, U Cephei will be 10 times less bright than when it's not in transit. This is a huge variation and makes it easier to detect the transit.

3.1.4 Data availability

Finally, U Cephei is a well-known system, with a lot of data available from professional observatories, which makes it a great candidate for me as an amateur astronomer to try to catch some transits and compare my data to the professional ones.

4 Methodology

To address the research question, this study employs a comparative analysis of photometric data. Observations of the U Cephei binary star system were conducted using personal equipment under urban light pollution conditions (Bortle 7). The following steps were undertaken:

1. Setup of observation equipment, including a CCD camera and a telescope with an aperture suitable for photometric studies.
2. Observation of the U Cephei binary system taking 15 second exposure every 2 minutes.
3. Acquisition of professional data on U Cephei from observatory archives and published studies for comparison.
4. Standardization of data formats for comparative analysis.
5. Statistical evaluation of precision, including signal-to-noise ratios and error margins.
6. Reliability assessment through consistency checks and cross-validation with established models.

4.1 Equipment used

Specifying the equipment used in the study is essential to understanding the context and limitations of the observations. I employed the following equipment for the photometric observations of U Cephei:

- Telescope: Sky-Watcher Quattro 150P Newtonian reflector telescope with a 150mm aperture and 600mm focal length.
- Reducer: Sky-Watcher 0.85x Coma Corrector lowering the focal length to 510mm.
- Camera: ZWO ASI 585MC pro monochrome CCD camera with a 8.29 MP sensor.
- Filters: UV and IR cut filter for reducing light pollution and enhancing contrast.
- Mount: Celestron Celestrong cg-5 goto equatorial mount for trackin.
- Autoguider: ZWO ASI 120MM mini monochrome camera and 50mm guide scope for guiding.
- Software: N.I.N.A for image acquisition and PHD2 guiding software for tracking. AstroImageJ for data analysis.
- Light Pollution: Montpellier, Bortle 7 (suburban/urban transition) location with moderate light pollution.

5 Results

5.1 Light curve

The first thing to do after collecting the data is to plot it and see if we can see any transit event.

On the x axis we have the time of the observation in Julian Date (JD), and on the y axis we have the relative flux of the stars.

To understand a bit more those scales I think it is important to take the time to explain each of them.

- Relative flux: In astronomy the light emitted by a star is measured in flux, which is the amount of light received per unit area. Here we are dealing with *normalized relative flux*. The relative flux is basically the flux of a star compared to other, it is very important in our case because of some perturbations that could affect the light received by the camera, such as clouds, or the moon or the atmosphere.

$$\text{Relative Flux} = \frac{\text{Flux of the Target Star}}{\text{Flux of the Comparison Star}} \quad (3)$$

We also normalize the data to have a relative flux of 1 when the star is not in transit, this way we can see the variation of the flux during the transit.

- Julian Date: The Julian Date is a continuous count of days since the beginning of the Julian Period on January 1, 4713 BC. It is widely used in astronomy because it is a continuous count of days, allowing for easy comparison of dates and times.

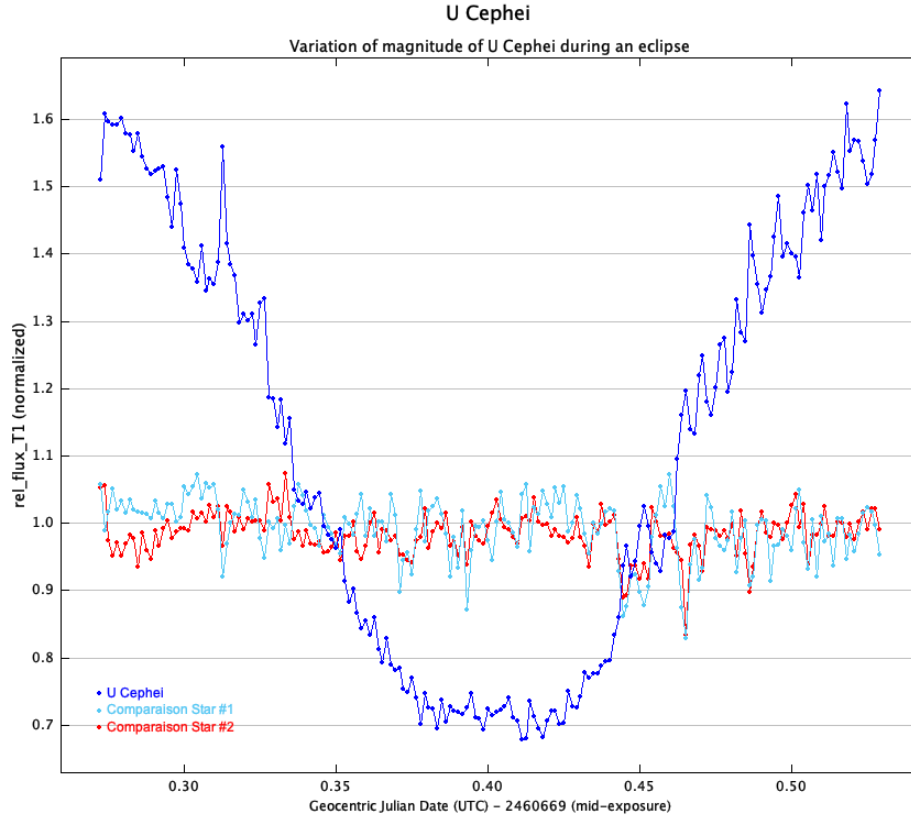


Figure 1: Light curve of U Cephei showing a clear transit event.

5.2 Conclusion

- Amateur data demonstrated significant precision in detecting transit features, with signal-to-noise ratios that were competitive with professional datasets under optimal conditions.
- Light pollution and equipment limitations introduced variability, leading to slightly higher error margins compared to professional datasets.
- Cross-validation with professional data confirmed the overall reliability of the amateur observations, with minor deviations attributed to observational conditions.

Figures and tables summarizing the comparative results are presented below.

6 Discussion

7 Conclusion

The personal photometric observations of U Cephei conducted in this study illustrate the potential for amateur astronomers to achieve a high degree of precision, even in light-polluted environments. These observations, while slightly less precise than professional datasets, offer valuable insights and demonstrate the viability of citizen science in advancing binary star research. Further research should focus on refining techniques and

fostering collaborative efforts between amateur and professional astronomers to maximize the scientific value of such observations.

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