Exoplanet transit observation using photometry light curves

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Abstract

ESA plans to launch the ARIEL satellite in 2029 to observe the spectra of exoplanets. To achieve highly accurate transit timing data, they initiated the ExoClock project. This project is open to the public, aiming to gather observations from individuals to enhance data accuracy for future ARIEL observations. Observers can refer to the ExoClock website's target list for suggestions and then upload their observation data for official review.

Introduction

An exoplanet is a planets outside of our solar system, within other planetary systems, where it orbits around its star. When exoplanets pass between the observer and their star, the observed luminosity of the star decreases, the phenomenon is called as “transit”. Since the first discovery of exoplanet in 1995, we have confirmed more than 5500 exoplanets. There are four main methods of exoplanet detection: transit, radial velocity, microlensing, and direct imaging. Among these, the transit method is the most common, accounting for as much as 74.6% of exoplanet discoveries.

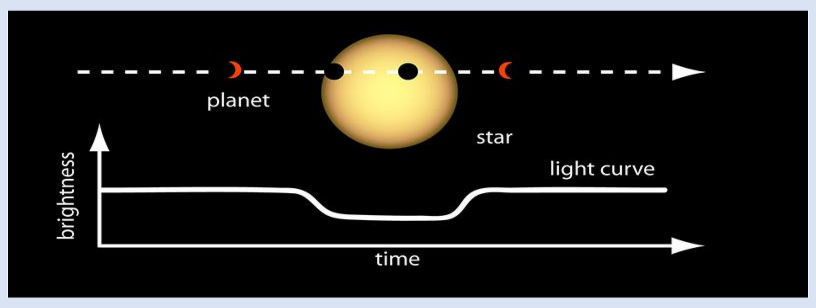

Fig.1. The transit process and light curve. source: exoplanets.nasa.gov

Tools

This project used the Earth Sciences Department's observatory, as well as software and websites, including:

Equipment

1. RC16 - Player One Poseidon-M Pro (CMOS)
2. RC8 - Atik One 6 (CCD)

Software

1. The Sky X: Control telescope
2. MaxIm DL 6: Control camera

Websites

1. ExoClock: Find the target
2. AAVSO: Download the find charts
3. CWB: Check weather and the time of sun, moon, twilight

Steps

Preparation beforehand

1. Check weather conditions
2. Search for observation targets on ExoClock
3. Download find chart on AAVSO

Preparation before observation

1. Check the end time of astronomical light sources
2. Turn on the computer and telescope and connect them
3. Select a bright star and use it for telescope pointing calibration
4. Slew to target and frame

After observation

1. Calibrate the observed images
2. Use aperture photometry, intensity values are obtained for both reference stars and target stars
3. Analyze the optimal radius for aperture photometry
4. By employing differential photometry and pluging in known conditions and values into the following formula, we can obtain the magnitude of the variable star.

$$m_t = -2.5\log\left(\frac{F_t}{F_r}\right) + m_r$$

Formula 1. Magnitude, where m_t is the magnitude of the target, m_r is the magnitude of the reference stars, F_t and F_r is the intensity of the target and reference stars.

5. Plot the light curve based on the magnitudes and time

Analyses

Dark images

Analyzing the dark frames captured by both cameras and creating histograms with ADU values on the x-axis and occurrence frequency on the y-axis.

- Player One Poseidon-M Pro (CMOS)
  The result is s exhibits a normal distribution.

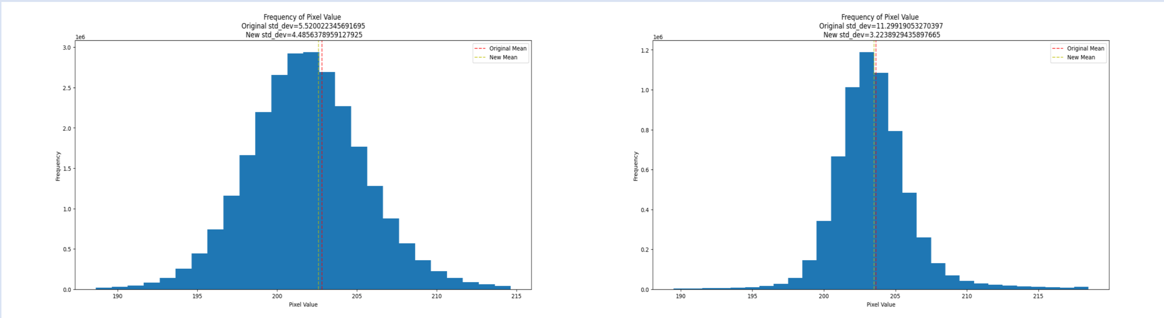

Fig. 2. The left configured without binning, 120s; the right with bin 2, 1800s.

- Atik One 6 (CCD)

The result shows an appearance of a normal distribution, but there are regular gaps and a sawtooth-like pattern within. After analyzing the quantity of odd and even values, it was found that the even values were approximately 10 times greater than the odd values. The discrepancy in the number of readings is likely due to the aging of the camera.

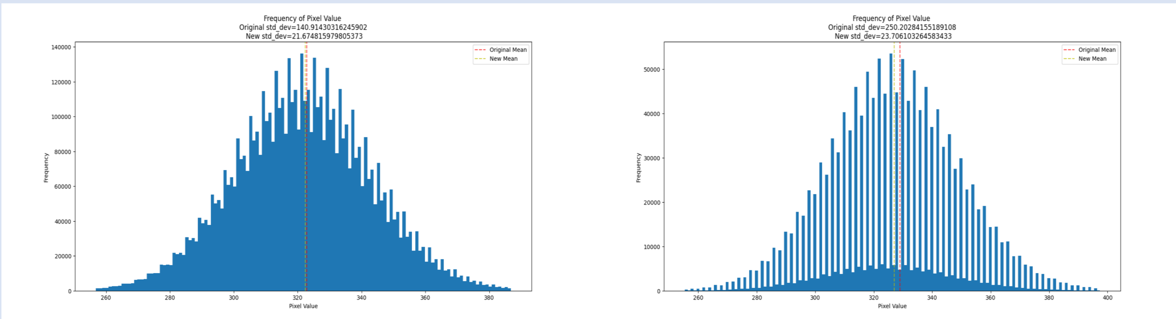

Fig. 3. The left configured without binning, 120s; the right with bin 2, 120s.

- Pixel binning by post-processing

By taking the CCD dark image captured without pixel binning and post-processing them by binning them, the result obtained was a normal distribution.

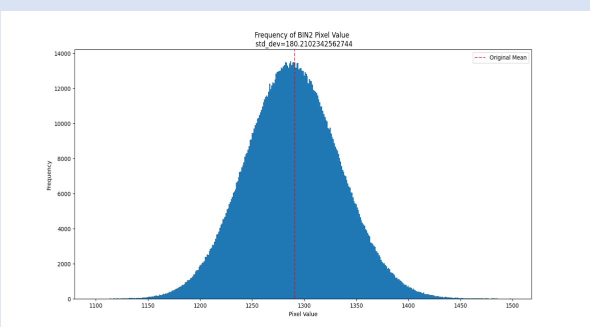

Fig. 4. Post-processing by Python, 120s.

References

- Buchheim, R. (2007). The Sky is Your Laboratory: Advanced Astronomy Projects for Amateurs. Springer Science & Business Media.
- AAVSO. (2022). AAVSO Guide to CCD/CMOS Photometry with Monochrome Cameras (Version 1.0). AAVSO. ISBN: 978-1-939538-62-8
- Kokori, A., Tsiaras, A., Edwards, B., Jones, A., Pantelidou, G., Tinetti, G., … Zíbar, M. (2023). ExoClock project. III. 450 new exoplanet ephemerides from ground and space observations. The Astrophysical Journal. Supplement Series, 265(1), 4. doi:10.3847/1538-4365/ac9da4