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ASTRO 1221

Project 4 Exoplanet Written Report - Ji Wang

08 December 2023

## Exoplanets

### Scientific Importance and Motivation

Understanding the properties of exoplanets is important for increasing our knowledge of planetary systems and the universe. The study of exoplanet transits, where a planet crosses in front of its central star as observed from Earth, provides good information about the planet's size, orbital characteristics, and atmospheric properties. This information contributes to the broader field of exoplanetology and helps scientists classify and characterize exoplanets.

### Underlying Physics and Math

This project began by extracting data from a file provided by the Czech Astronomical Society which includes time, relative magnitude, and error values of a given instance of an exoplanet transit, in this case, HD 209458 b. The relative magnitude is converted to flux which is related to the amount of light blocked by the transiting object. The conversion involves using the formula “ $\text{flux} = 2.514(1 - \text{rel\_mag})$ .” Two models were used to show this data: a simple box model and a more complex trapezoid model. Both are based on the idea that the observed flux decreases when the planet transits the star. The code calculates the reduced chi-squared to assess how well the modeled data fits the observed data. The reduced chi-squared is a statistical metric used to evaluate the quality of a fit, taking into account the uncertainties in the data.

## Methods

Two methods were used to model the data: box and trapezoid. The box model assumes a rectangular shape for the transit, characterized by parameters such as center time, duration, depth, and delta flux. The trapezoid model provides a better representation of the transit, introducing an ingress parameter to account for the decrease and increase in flux during the two phases of transit. For both models, it is possible to automatically adjust the parameters to minimize the chi-squared value. For the purposes of this project, parameters were chosen manually to simplify the output. While the transit method is a powerful and widely used technique, there are some limitations. Mainly low probability of alignment. The probability of a random planetary orbit being aligned with the line of sight is relatively low. This means that, even if a star has planets, the chance of observing a transit is small unless the planetary system is oriented in a specific way. There is also some bias associated with this method because it is more likely to detect larger planets or planets orbiting close to their host stars. Smaller or more distant planets are harder to detect because their transit produce less dramatic changes in brightness. Despite these limitations, the transit method has led to numerous discoveries of exoplanets. Researchers use the transit method alongside other observational strategies to mitigate individual limitations and further enhance our understanding of exoplanetary systems.

## Results and Interpretation

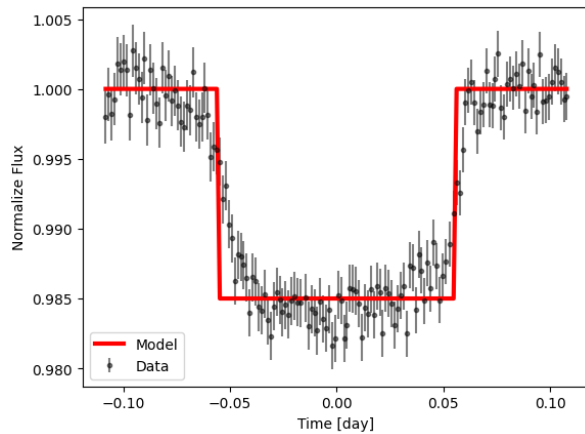


Figure 1

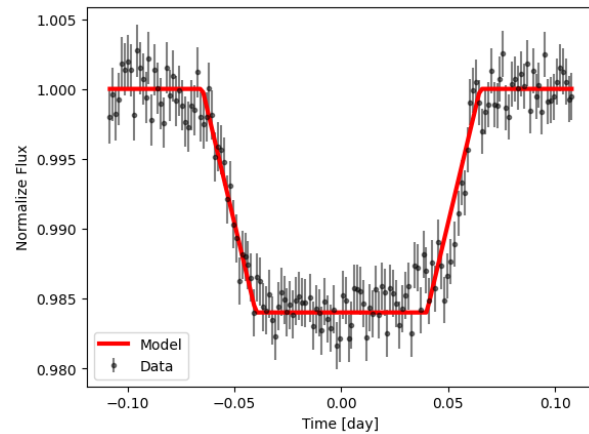


Figure 2

The code produces visualizations comparing the observed data to the models (box and trapezoid, figure 1 and 2 respectively). The reduced chi-squared values are calculated for both models, providing a quantitative measure of how well each model fits the data. Lower chi-squared values indicate better fits.  $\chi^2$  for the box model is approximately 1.92, where the  $\chi^2$  for the trapezoid model is approximately 0.89. Since the trapezoid model is below 1, this indicates an “overfit” of the data, meaning it is too close to the observed data. In order to create a model closer to but above 1, a more sophisticated shape is needed.

## Conclusion

The analysis shown in the code is an initial step in the process of characterizing exoplanets through transit observations. The comparison of different models allows researchers to explore which model best describes the observed data. The reduced chi-squared values provide a statistical basis for evaluating the goodness of fit, aiding researchers in refining their models and drawing more accurate conclusions about the properties of the transiting exoplanet.

## References

[<http://www.webservices.cz>], W. (n.d.). *Transit observations (tresca database)*. Novinky RSS.

<http://var2.astro.cz/EN/tresca/transit-detail.php?id=1535045428>