Modeling the Transit of Gliese 436 b

Brandon Lam

I. Abstract

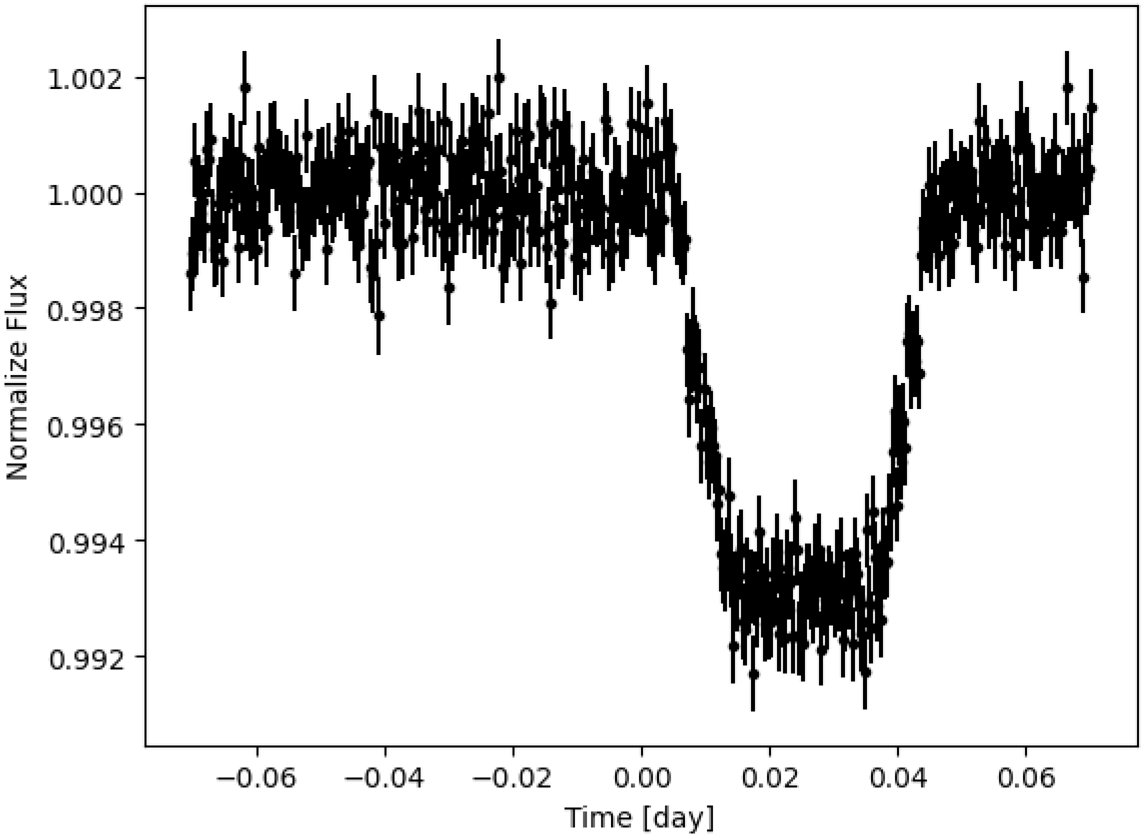
Using data obtained by Deming et al. from the Spitzer Space Telescope, the light curve of Gliese 436, a red dwarf in Leo, was plotted. I fitted this light curve with two models: a box model and a trapezoidal model. I also calculated the radius of the planet Gliese 436 b, or GJ 436 b, given the change in flux due to its transit across the disc of the star using data from Pineda et al.

II. Motivation

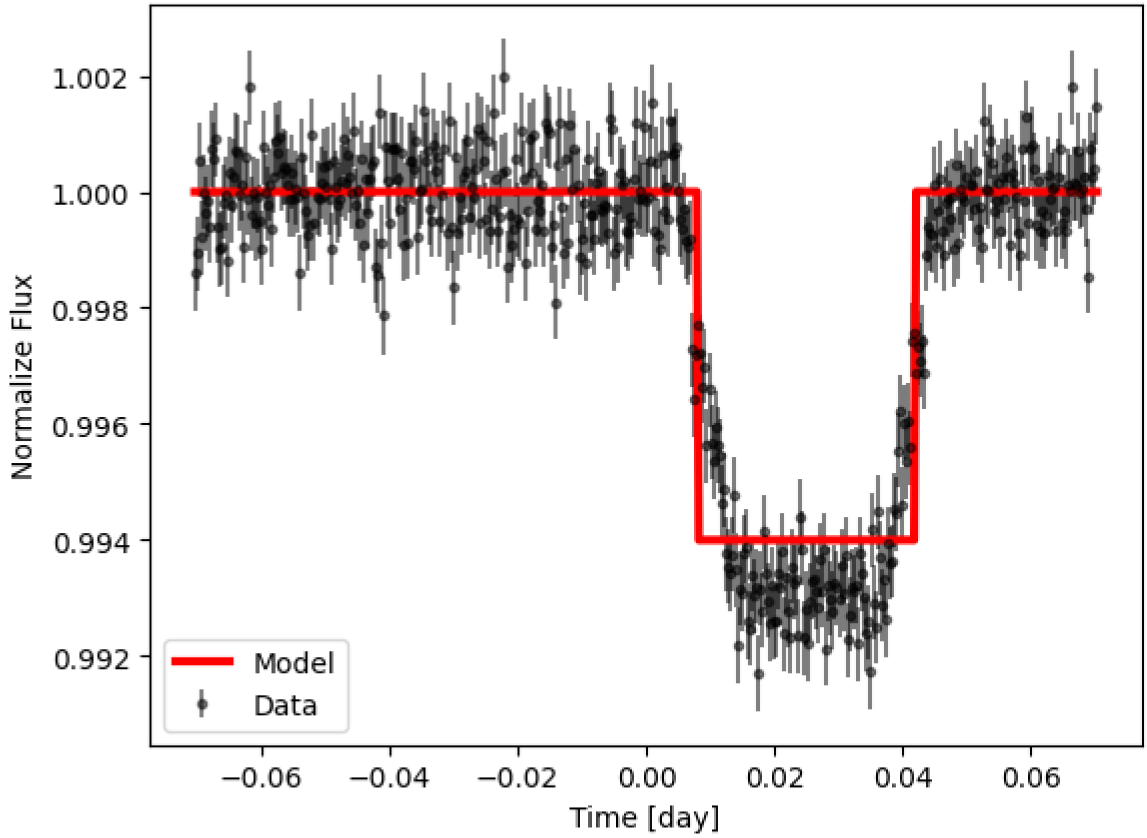
The main goal was to understand the method that goes into detecting and analyzing exoplanets better. The transit method, which is being analyzed here, involves the planet transiting the disc of the star and blocking some of the light. We can measure this dip in light and gather valuable information on the planet. Other information, like the atmospheric composition, can be determined as well, though that will not be analyzed in this project.

III. Methods

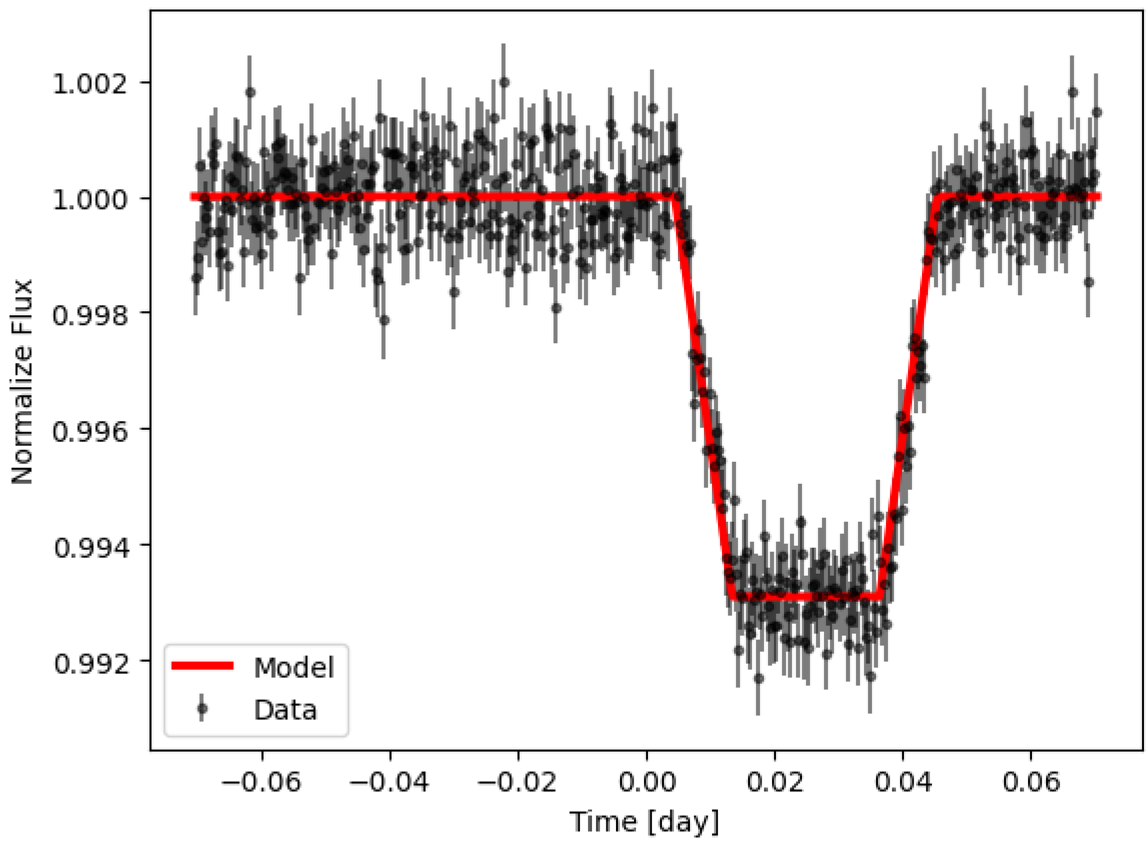
To begin, I downloaded the data on the light curve Gliese 436 from Deming et al. and plotted this flux against time.



From there, I started by attempting to fit a box model to this light curve with the parameters of the center time, duration, depth, and change in flux, which were 0.025, 0.034, 0.006, 0.0 in this case.



Knowing the box model is flawed just by looking at it, I tried to use a trapezoidal model instead, plotting it with the parameters center time, duration, depth, change in flux, and ingress which were 0.025, 0.023, 0.0069, 0.0, 0.009 in this case.



By calculating the Reduced Chi-Squared, I could determine if the model overpredicts or underpredicts the curve, with 1 being a perfect fit from the box model. Using the equation $\Sigma\frac{(O-C)^2}{(n-m)\sigma^2}$, O being the observed value, C being the modeled value, n being the number of data points, m being the number of data points, and σ being the error. Knowing the change in flux equation relating the radius of the planet to the radius of the star is $F = (\frac{R_p}{R_s})^2$, I rearranged this equation to isolate R_p.

IV. Results

I got a Reduced Chi-Squared value of about 2.37 for the box model, suggesting the model somewhat underpredicts the curve. Calculating the Reduced Chi-Squared value for the trapezoidal model, I got about 1.11, significantly better than the box model. Using the change in flux from the trapezoidal model as 0.0069 and using the value of the radius of

Gliese 436 as 0.432 solar radii from Pineda et al., I found the radius of GJ 436 b to be approximately 24965 km.

V. Conclusion

We can detect an exoplanet by measuring the light curve of the star and looking for dips. Using models, we can gather valuable information from the transit of the planet across the disc of the star. In the case of GJ 436b, I used both the box model and trapezoidal model, with the trapezoidal model proving far more accurate. Using the values from the trapezoidal model along with data from Pineda et al., I was able to calculate the radius of the planet, which was approximately 2600 kilometers off from the true value. This value could likely be more accurate with more work on a more accurate model, with a Reduced Chi-Squared closer to one.

References

Deming, Drake, et al. “Spitzer Transit and Secondary Eclipse Photometry of GJ 436b.” The Astrophysical Journal, vol. 667, no. 2, American Astronomical Society, 18 Sept. 2007, pp. L199–L202. Crossref, doi:10.1086/522496.

Pineda, J. Sebastian, et al. “The M-Dwarf Ultraviolet Spectroscopic Sample. I. Determining Stellar Parameters for Field Stars.” The Astrophysical Journal, vol. 918, no. 1, American Astronomical Society, 1 Sept. 2021, p. 40. Crossref, doi:10.3847/1538-4357/ac0aea.