Calculating the Transit of Exoplanet GJ436b

Deeti Patel

Abstract

GJ436b is a hot Neptune-sized exoplanet that orbits an M-dwarf star, which is located 10 pc away from our solar system. The infrared telescope Spitzer Space Telescope (SST) was used for data acquisition, which is specifically used to see dwarf stars and exoplanets. Using data from Deming et al. 2007, I was able to calculate the transit and the radius for exoplanet GJ436b. The transit data was plotted based on the emitted flux from the star and the planet passing in front. This approach allows for the identification of various factors that reveal relevant information about exoplanets.

Motivation

The primary objective of this project is to calculate the transit period for GJ436b as it passes in front of the M-dwarf star and calculate its radius. Going into the project, it was presumed that the planet would resemble characteristics of a hot Jupiter, suggesting that its radius would be large, and its transit would be short. To establish the hypothesis, 445 data points were gathered, which recorded the star's luminosity as GJ436b completed its path in front of the star, affecting the star's flux.

Methods

To calculate the radius and visualize the transit of the planet, 445 data points from Deming et al. 2007 were plotted. The y-axis represents the flux, and the x-axis represents the time. To account for errors in the flux determination, particularly because it is hard to discern the difference in luminosity during a transiting planet, error bars were incorporated. Upon creating the initial plot, I tried to create a similar model in two different ways, a box model and a trapezoidal model. The key parameters, center time, duration, depth, and delta flux, were estimated to recreate the models to match the curve. The center time denotes the midpoint of the dip, duration reflects how wide the box is, depth signifies how deep the curve is, and delta flux represents the slope of the lines. After inputting estimated values for each component, I used reduced chi-squared to analyze which model was more accurate. The estimated values and some additional data from Deming et al. 2007 were also used to determine the radius of GJ436b.

Results

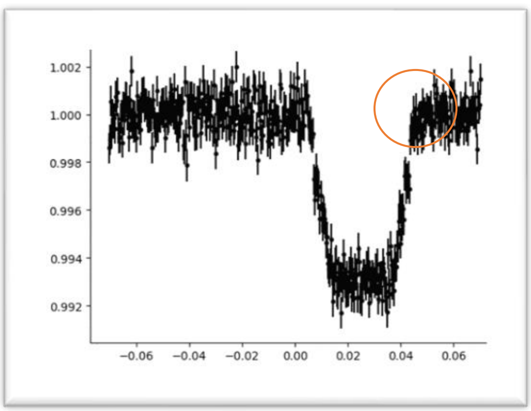

Figure 1

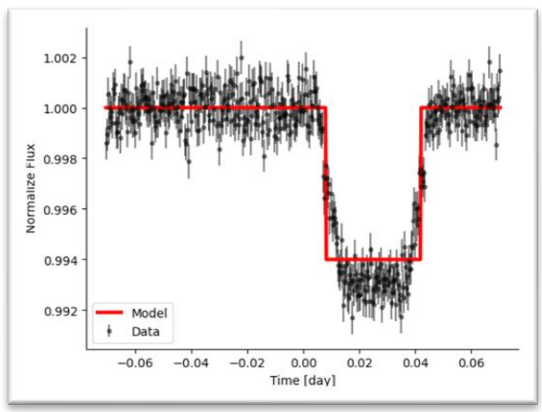

Figure 2- Box Model

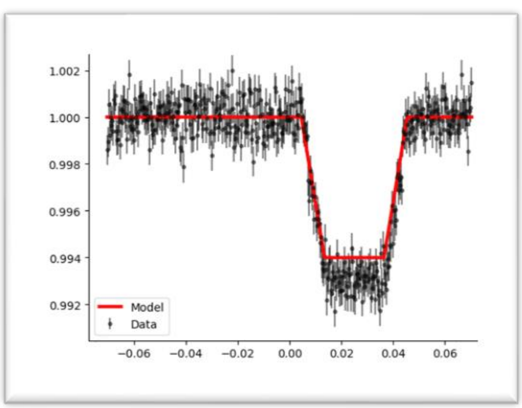

Figure 3- Trapezoidal Model

The transit data of GJ436b is illustrated in the graphs above. Figure 2 shows the box model (in red) overlapping the original data. Notably, near the bottom, it becomes apparent that the box model is not the most suitable for this type of curve. The trapezoidal model, shown in Figure 3, shows a significantly better fit as it closely follows the curve. To analytically prove the trapezoidal model is a better fit, I used reduced chi-squared. The box model yielded a high value of 2.5985, whereas the trapezoidal model had a value of 1.1. This proved that my estimated value for the delta flux was fairly accurate, leading me to utilize that value along with the star radius provided by Deming et al. 2007 to determine the radius. My calculations resulted in the radius being 27,160.92 km, which is within the range of what Deming et al. 2007 calculated, where their calculation is 27, 600±1170 km.

Conclusion

To conclude, the radius of the planet is 27160.92 km, and the transit is very short, only 2 hours, needing only 2.6 days to orbit the M-dwarf star. Considering how rapidly GJ436b orbits its star, the star's semimajor axis must also be small, given it's only 0.0291 AU according to Deming et al., causing the temperature to be considerably high as well, 712 K. Due to its proximity, the planet loses hydrogen from its atmosphere, it boils away leaving a trail behind the star's orbital path. This is evident in the graph provided in Figure 1. Once the planet's transit period is coming to an end, the graph slowly curves into a straight line, caused by the hydrogen tail. From this new information, an additional aspect of the project that would be interesting to me is calculating the difference in masses from the earliest to recent data, calculating the total mass loss from hydrogen depletion.

References

Deming, D., Harrington, J., Laughlin, G., Seager, S., Navarro, S. B., Bowman, W. C., & Horning, K. (2007). Spitzer Transit and Secondary Eclipse Photometry of GJ 436b. In The Astrophysical Journal (Vol. 667, Issue 2, pp. L199–L202). American Astronomical Society. https://doi.org/10.1086/522496

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