Calculating the Best-Fit Model of the Transit of HD189733b

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I. Abstract

Using data from Winn et. al, (2007), which was found using the Nasa Exoplanet Archive, I was able to calculate the best-fit model for the transit data of exoplanet HD189733b. This was accomplished by plotting the transit data and exploring two different types of models: the box-model and the trapezoid-model. After the chi-square of both plots was determined, I concluded that the trapezoid-model was the better fit of the two, but that there is most likely a better model that has yet to be considered.

II. Introduction

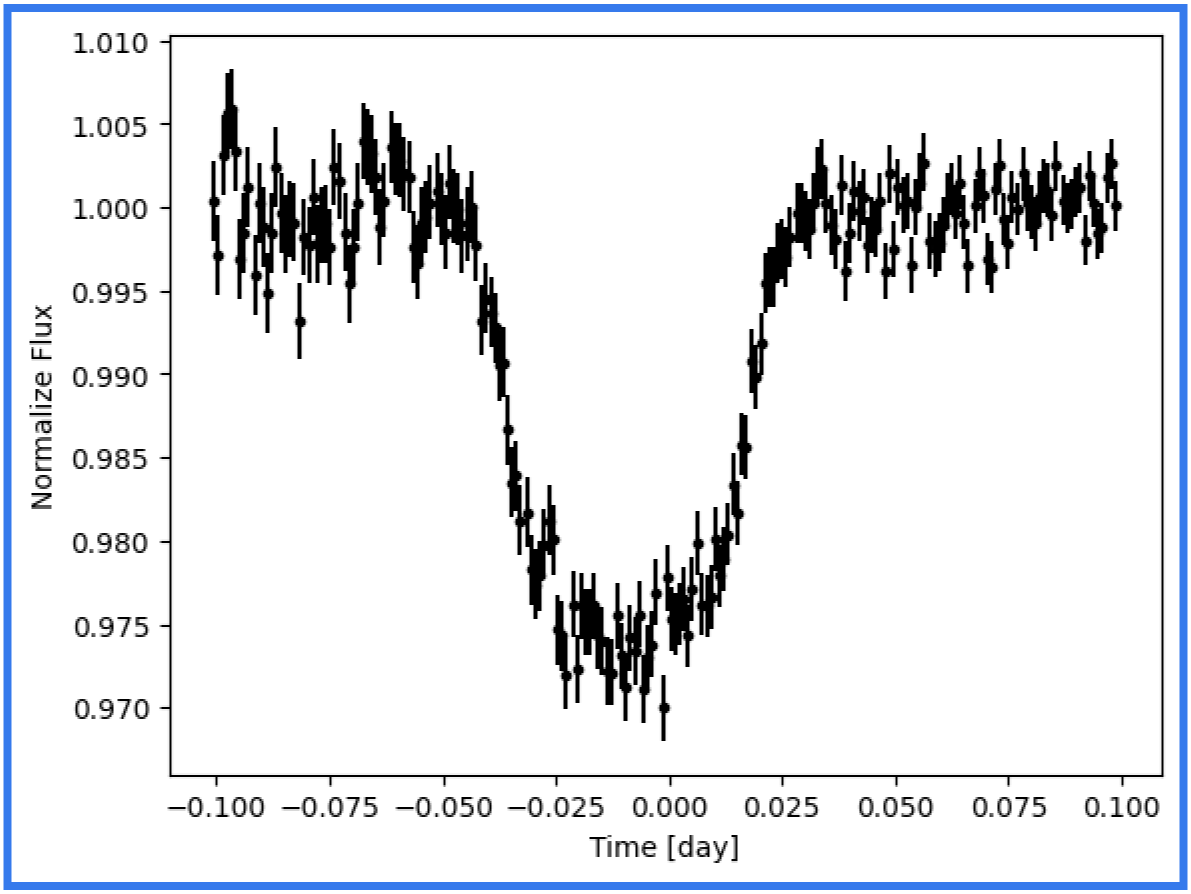
HD 189733b is an exoplanet, best categorized as a hot jupiter due to how close it orbits its host star, HD 189733. It was discovered by a team in France on October 5, 2005 and is located approximately 64 light-years away from our solar system, making it one of the closest transiting hot jupiters to Earth. Since then, this exoplanet has been studied extensively, resulting in us uncovering many of its secrets. For example, the planet itself is a deep blue color, much like the Earth. However, this is where the similarities end. This blue-color is due to its fuzzy, blow-torched atmosphere which contains high clouds imbued with silicate particles. Additionally, HD 189733b experiences extreme winds, about 8700 km/hr. Along with the heat-condensed silicate particles, they cause quite the deadly storm. In fact, it is even hypothesized that molten glass rains horizontally on this planet. This makes HD 189733b a poor candidate for life, which, although disappointing, further progresses our search for potentially habitable worlds.

III. Motivation

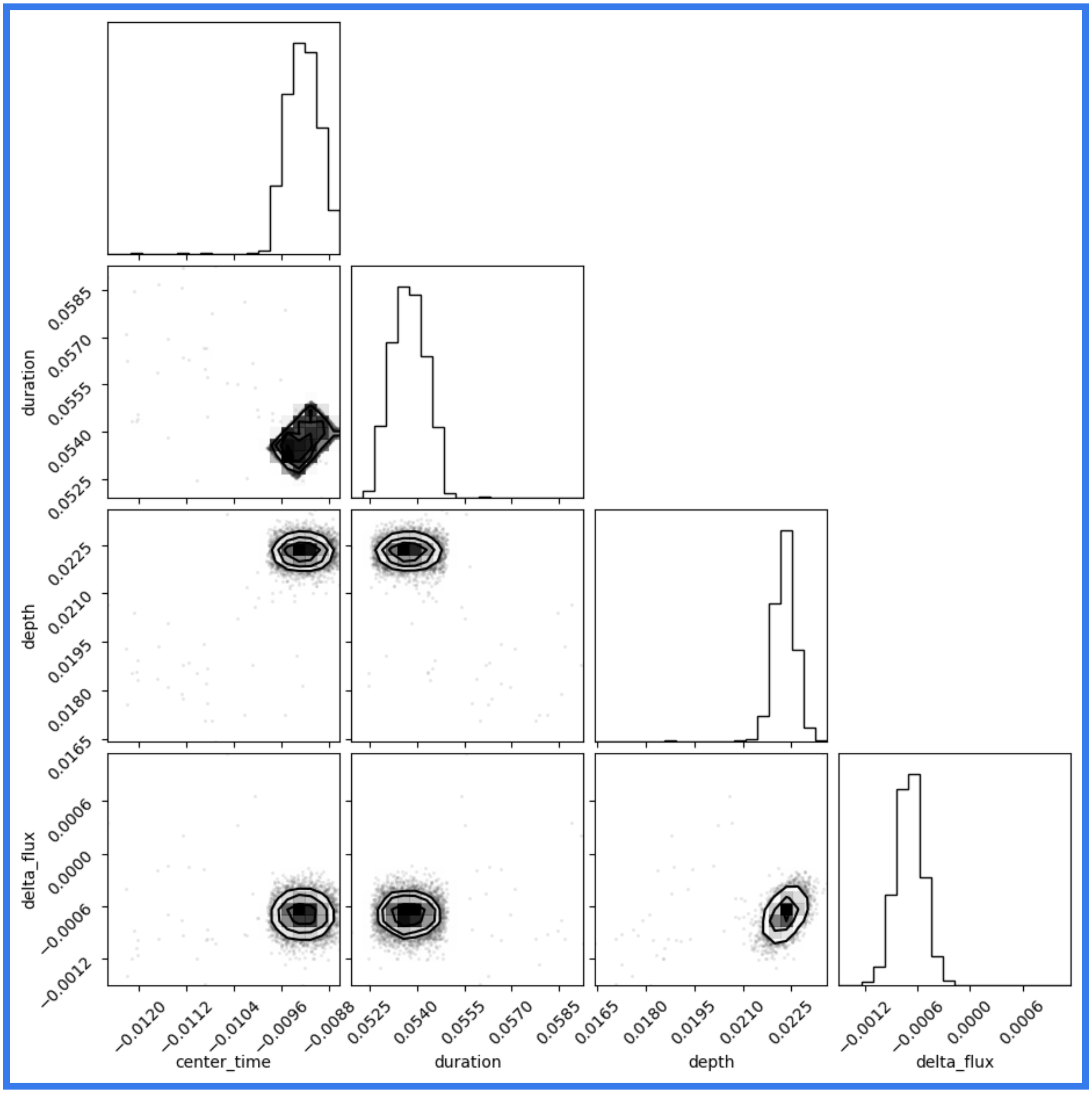
There are many reasons as to why we study exoplanets. The most prominent of which is humanity's eternal quest to find extraterrestrial life. So far, we haven't had much luck in finding intelligent life, but we are still able to identify potentially habitable candidates inside and outside our solar system. There is much that needs to be considered when labeling a planet as habitable, such as what type of star the planet orbits, how fast is its orbit, what is the shape of the orbit, how far away it is from its host star, and if it has an atmosphere. First, however, the exoplanet needs to be detected. With the various methods at our disposal, the one that is focused on in this report is the transit method. As a planet passes in front of its host star, the star's brightness dims, which can give us a good idea of the size of the planet, the characteristics of its orbit, and its atmospheric composition. By finding the best-fit model for the transit data, we will be able to further our understanding of this specific exoplanet as well as continuing to build our intuition on how our universe and even how our solar system formed.

IV. Methods

The first step was to find the transit data of an exoplanet, preferably one that was a hot jupiter since that would mean the planet is orbiting close to its host star, making the data much more clear. Since HD189733b was recommended, I found a set of data with a good amount of data points, 202 points, from Winn et. al, (2007) that had a well-defined transit curve. I then plotted this curve for myself with the axes flux vs. time.



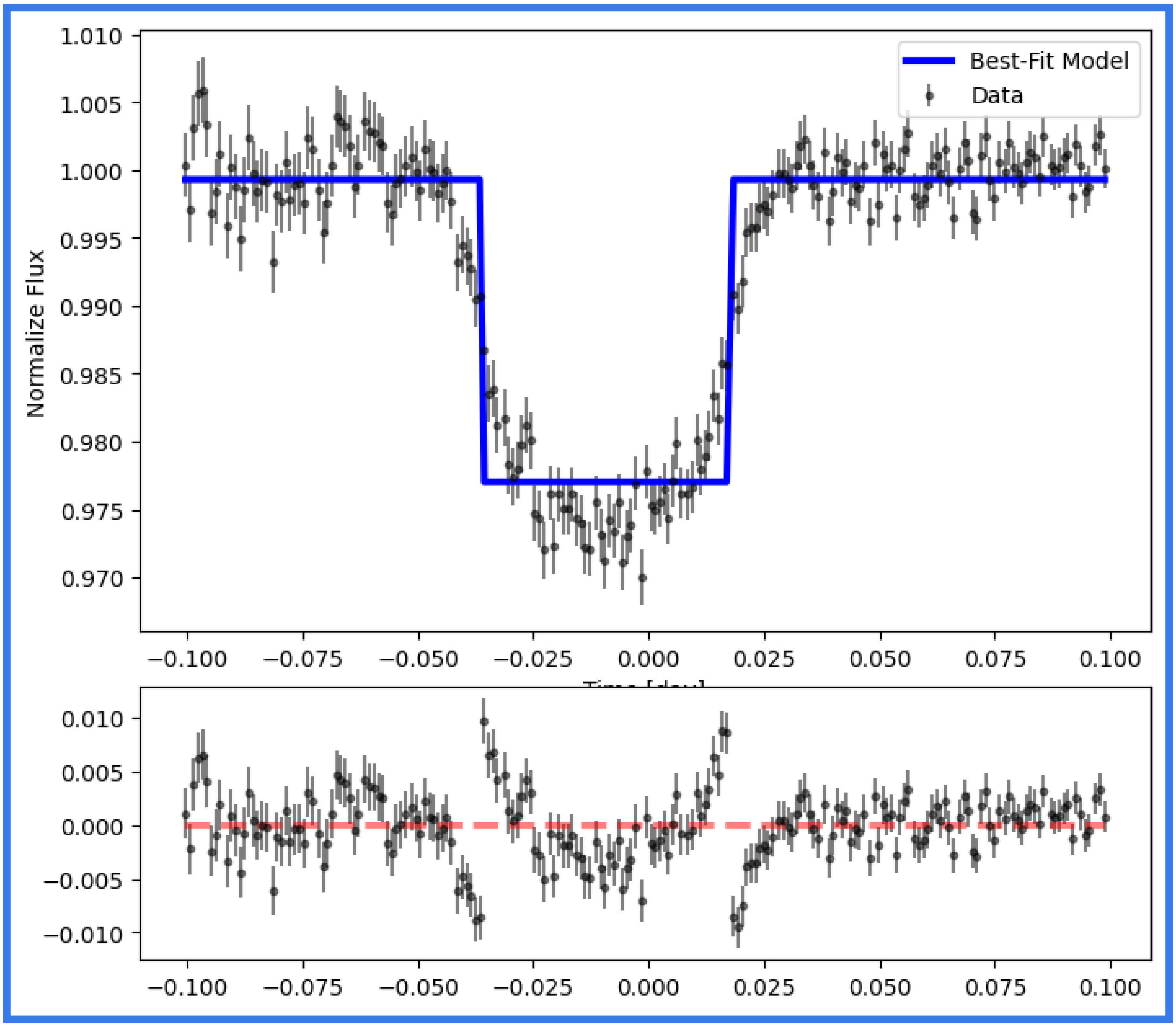
From there, I created a box-model with specific parameters that I could alter in order to get the best fit possible. Those parameters are time, center-time, duration, depth, and change in flux. While I could've played around with the numbers of these parameters until I felt that the model fit the curve, instead, I found the exact numbers I needed by creating a corner plot which determined those numbers for me.



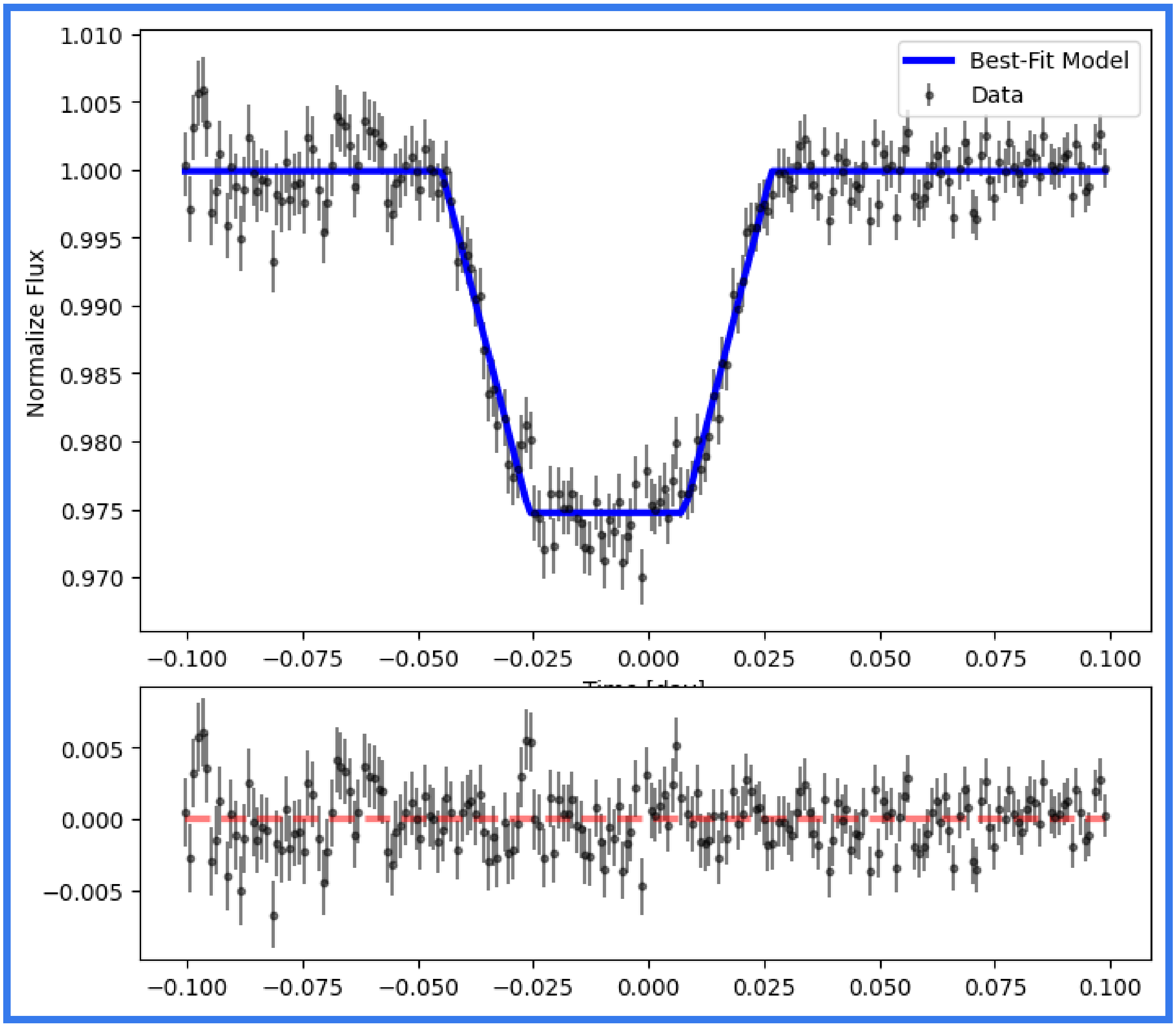
With this, I was able to plot the best-fit box model for my data. However, after calculating the chi-squared value, which tells us how well the model fits the data, I found that the box-model wasn't suitable for what I was trying to accomplish. So, I carried out a similar process with the trapezoid-model, which resulted in a much better fit for my data, visually and by comparing the chi-squared values of the models.

V. Results

Once I was able to plot the data and find the best numbers for my chosen parameters for the box-model and the trapezoid-model, these are the plots that were created as a result:



In this figure, the model fits the data much better, however, due to how rigid it is, it's clear that the model is much too simple to be the best-fit. Also, the chi-squared value is 2.58666392978909, which even further shows that the box-model does not fit the data well.



Visually, the trapezoid-model is more suitable for this data set than the box-model is. It follows the trend of the data much better and there is not as much empty space between the data points and the model like with the box-model. However, the chi-squared value of this model, 1.1139302477017554, shows that even though this model fits much better, it's still not the best. Moreover, with this data, I was able to calculate the radius, orbital velocity, and orbital period of HD189733b using these equations:

$$\frac{\pi R_{Pl}^2}{\pi R_{Star}^2} = \frac{R_{Pl}^2}{R_{Star}^2} \qquad T = 2\pi\sqrt{\frac{r^3}{GM}} \qquad v_{orbital} = \sqrt{\frac{Gm}{R}}$$

What I found was the radius = 12.5 R_E , the orbital period = 2.2 days, and the orbital velocity = 152 km/s.

VI. Conclusion

Both of these models could work, however, there are better model-fits out there that have yet to be considered since their chi-squared values are not as close to 1 as they could be. So, some future steps that I could take would be to research and try out other types of models that could possibly fit my data. Furthermore, the problem may not lie with the models themselves, but with my data choice. I chose a set of data for HD189733b that included 202 data points. I could've instead chosen to look at a set of data that include even more data points as it could make my plot, and therefore my best-fit model, much more accurate. In the future, not only could I explore other models, but other data sets of HD189733b to find the best-fit model.

Oral Presentation Link:

https://docs.google.com/presentation/d/1UVrwsxMvN7_Gmnyp1OcRbLt4-WqxiBTYwQBhzB6jwEQ/edit?usp=sharing

Github/Code:

https://github.com/NireAstro/1221-dark-matter/blob/a68823321091b1285e63d66edc7fafb455a08165/Exoplanet_HD.ipynb

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