Project 4 - Exoplanets and Transit Light Curve

Justin M. Lewis, O'Brein Carr, Abdullahi Omar

The Ohio State University

ASTRON 1221: Astronomy Data Analysis

Dr. Ji Wang

December 6, 2024

Abstract

In this project, we will be going over how to identify whether there is an exoplanet or not. We will be showing one of the 5 methods to find out whether there is an exoplanet and this method is called transit. This method is to find whether planets are orbiting the star by looking at whether some of the light is obstructed periodically. Depending on the size of the planet or its distance from the star we can determine whether or not there is a planet by its orbiting pattern. This method is considered the most accurate among the 5 methods and most exoplanets are found using this method.

Methods

The observational data used in this project consisted of relative time and magnitude, as well as any associated uncertainties. To make calculations easier, the time values from the data were centered by subtracting each value's median value A box and trapezoid transit model was used, with the trapezoid model building on the box model, essentially improving its accuracy by providing a finite period between ingress and egress, this is assuming that there is a linear flux variation during ingress and egress and a flat flux while in full transit. We found the parameters of both models by using three functions of parameter estimation to evaluate the posterior probability of the observed data which would assist in inferring what parameters would be best for our transit observed light curve. To test the model's goodness of fit, the reduced chi-squared statistic was evaluated using the data points, parameters, the modeled and observed flux, as well as uncertainty

Motivation

Our motivation behind analyzing transit data is we can use said data to characterize exoplanets. This is because as they are in transit we can make a mathematical model of the flux at the event.

This is because a transit event only occurs when a planet passes in front of its star, blocking some of the light which in turn causes a temporary drop in the events observed flux. Making a plot of a light curve where you plot the brightness of the star vs the amount of time of the event is what astrophysicists would use to find out things like how fast(ingress/egress) a planet enters and exits its transit, or the orbital period of a exoplanet from multiple successions of transit

Results

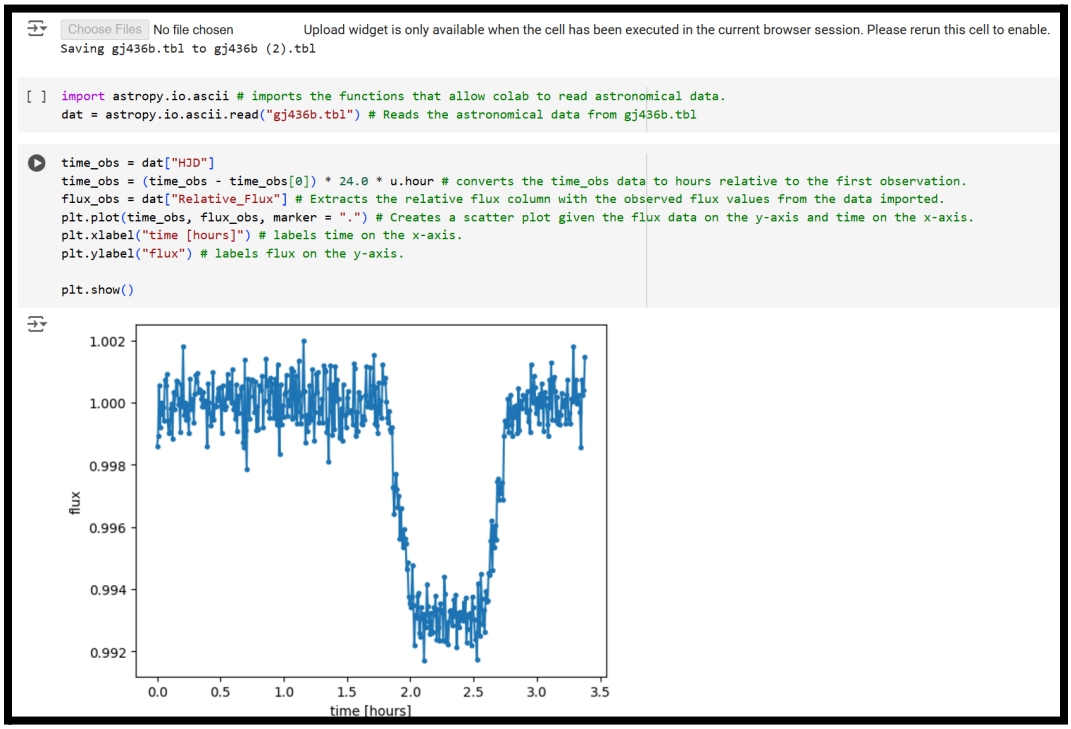

Figure 1.1

```
[ ]  # Now lets define the parameters for a transit light curve model

     t_0 = 2.3 * u.hour # Defines the mid transit time
     tau = 0.75 * u.hour # defines the transit duration
     delta = 0.007 # Defines the change in brightness the star experiences during transit.
     flux_model = generate_transit_lightcurve(time_obs, t_0, tau, delta) # Generate the model light curve.
```

```
     time_obs = dat['HJD']
     time_obs = (time_obs - time_obs[0]) * 24.0 * u.hour # converts the time_obs data to hours relative to the first observation.
     flux_obs = dat['Relative_Flux'] # Extracts the relative flux column with the observed flux values from the data imported.
     plt.plot(time_obs, flux_obs, marker = ".") # Creates a scatter plot given the flux data on the y-axis and time on the x-axis.
     plt.plot(time_obs, flux_model, linestyle="-", color="red", label="model") # plots the model light curve on top of the observed, raw data.
     plt.xlabel("time [hours]") # labels time on the x-axis.
     plt.ylabel("flux") # labels flux on the y-axis.

     plt.show()
```

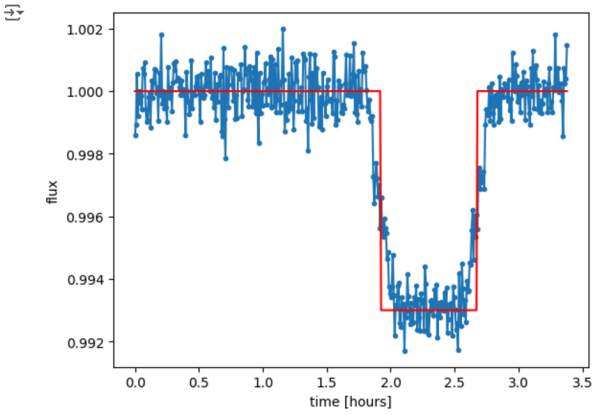

Figure 1.2

```
num_parameters = 3 # I have 3 parameters: t_0, tau, and delta
flux = flux_obs # Our observed flux
model = flux_model # Our model of the flux
err = np.std(flux_obs-flux_model) # The error/difference between our observed flux and the flux model.


def calculate_reduced_Chi2(flux, model, err, num_parameters): # function that takes the established values above
  degree_freedom = len(flux) - num_parameters #  Calculates the degrees of freedom.
  rChi2 = np.sum((flux - model)**2 / err**2) / degree_freedom # Calculates the reduced chi squared.
  return(rChi2) # Returns the reduced chi squared value.

print("Reduced Chi2 = ", calculate_reduced_Chi2(flux, model, err, 3))
```

```
Reduced Chi2 =  1.0068442409769263
```

Figure 1.3

AI Contribution Statement

We used GeminiAI to improve the calculations with the numbers to help fix the reduced chi-squared.

Conclusion

Thanks to the transit method we can determine a lot of things such as how to determine whether are exoplanet is orbiting a star and how long is its cycle period. This is by observing a star we can see how the flux fluctuates and use this information by observing changes in the star's look such as dark spots. This will allow us to determine whether there is an exoplanet orbiting periodically if this change continues to persist. Using this information we can conclude there is an exoplanet orbiting a star later. We can also state there is another solar system after which we determine if life is possible on said planet.

Member Contribution

Methods and Motivation: Justin Lewis

Results: O'Brein Carr

Abstract and Conclusion: Abdullahi Omar