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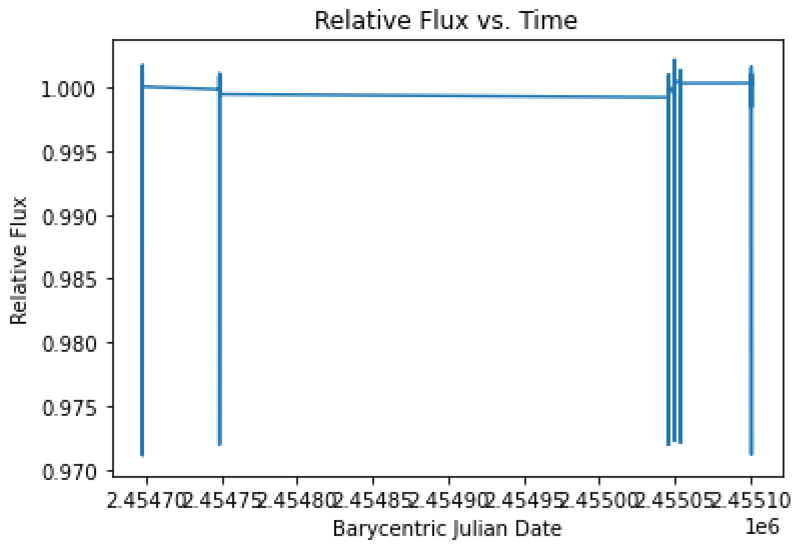
Project 6

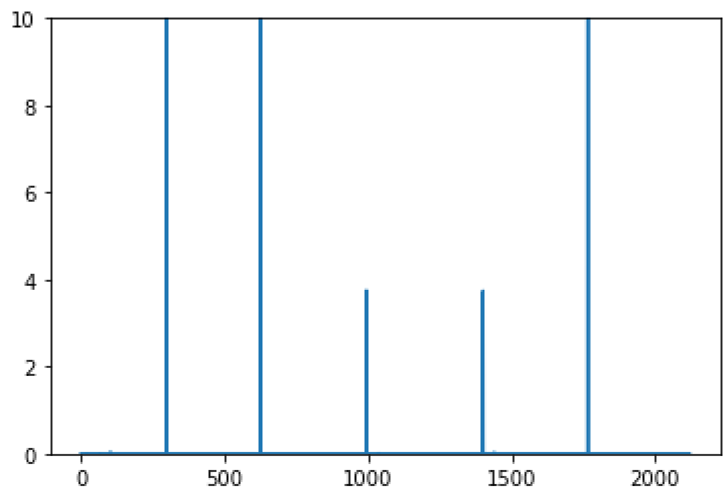
<u>Write Up</u>

After loading in the data from the wasp_4b.tsv file using the numpy.genfromtxt function, I plotted the the flux from WASP-4 vs. time:



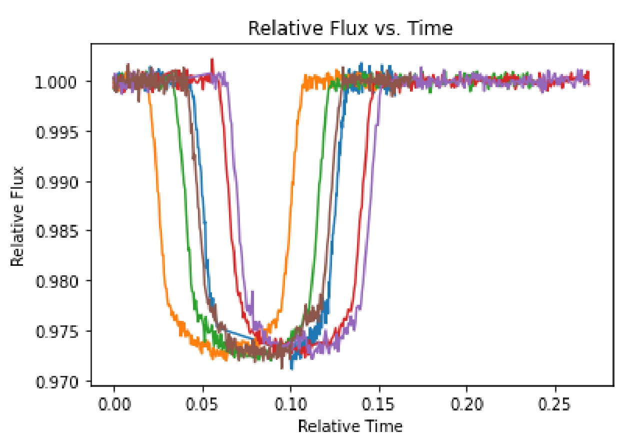
Based on this plot, the flux data is not continuous with time and I was able to pick out 6 different transits, which helped me identify each transit period in the next step.

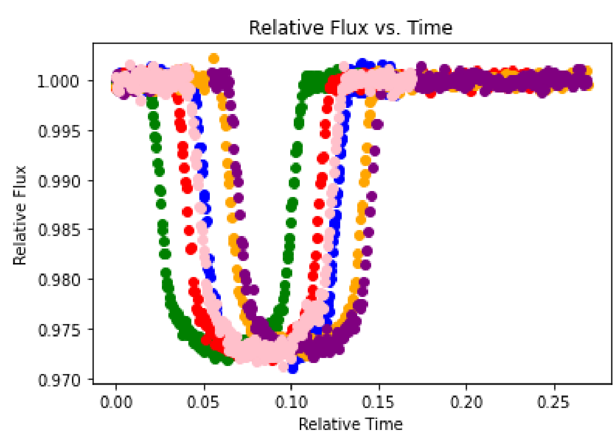
Next, I used the numpy.diff function to find the largest jumps in time, which represents the six different transit times:



Using these numbers, I was able to splice the flux and time data into six different, which correspond to each transit.

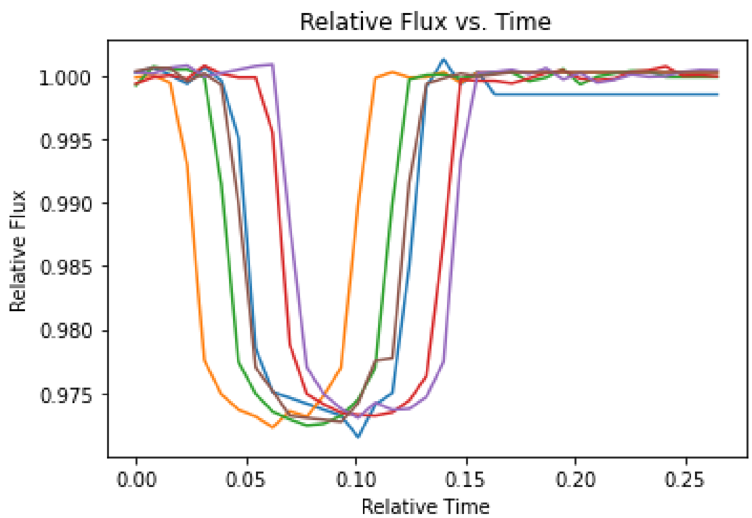
Then, I took each transit and set the starting time to t = 0, and plotted them normally and then with a scatter plot:



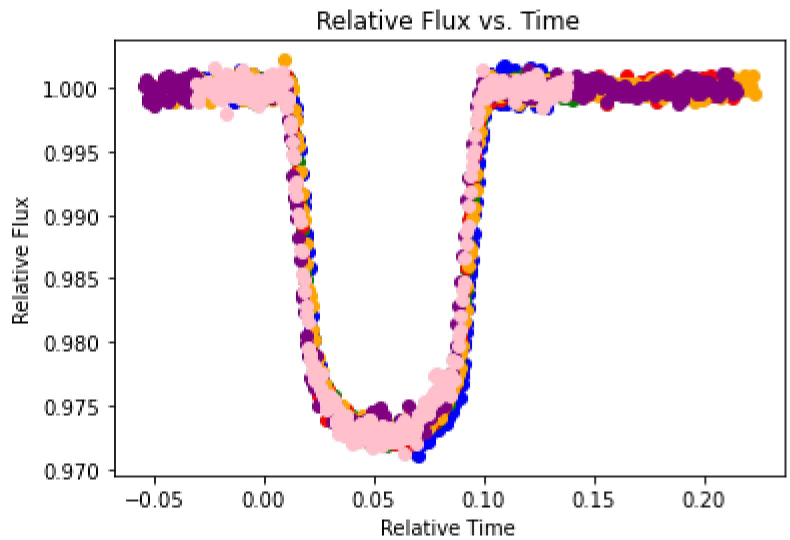


As you can see, the six different transits are quite similar, but the maximum transit depth is misaligned for each transit, which we'll fix next.

Next, I used the longest transit time array to create a new time array for all the transits. Then, I interpolated all the flux data with my new time array to get the six transit data sets to have the same shape and length:

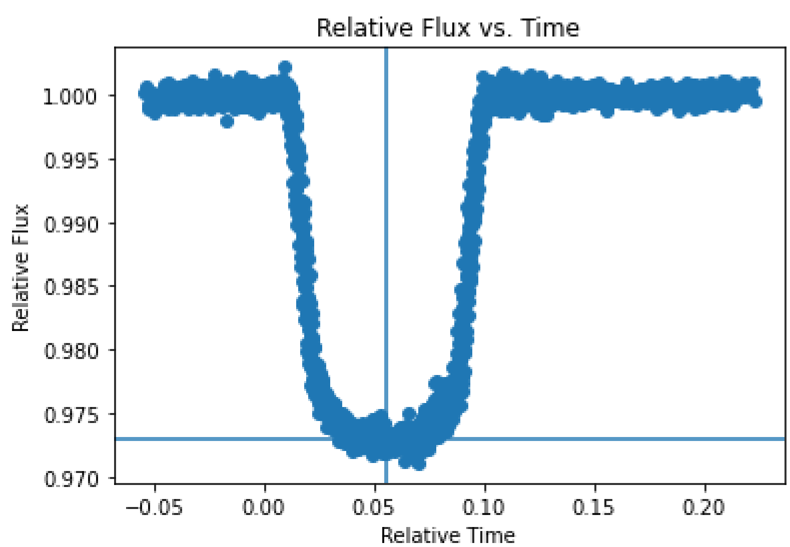


Using the second transit as a reference I found the maximum in the cross-correlation between it and each of the others using two methods. First, I did this in physical space by interpolating each flux time-series to the reference, shifting each with respect to the reference one time-step at a time, multiplying, and summing. Next, I did this in spectral space by using the correlation theorem on the reference and interpolated fluxes. Finally, I used the maximum cross-correlation to find the time-shift for each transit, and scatter plotted the transits over each other:



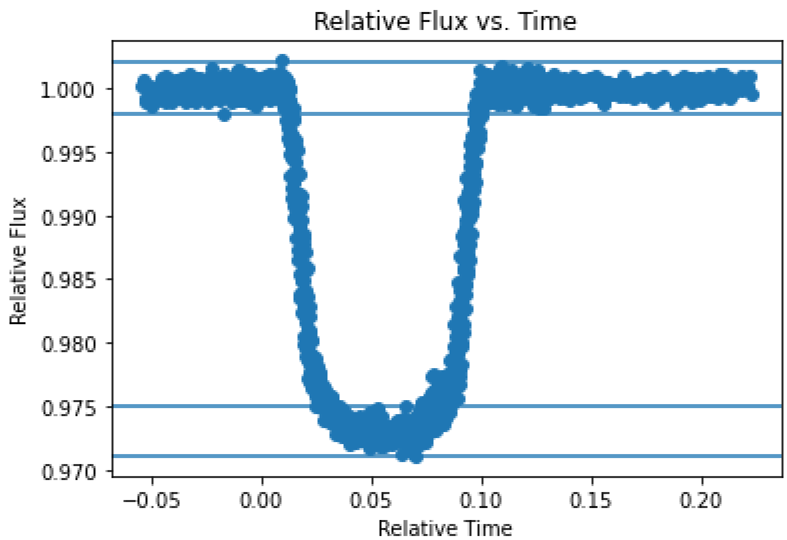
Now that all the transits are aligned, we can use the graph to find the spread of data, which will determine the uncertainty in any calculations we decide to do with the data.

So first, I combined all the transit data into a single array, and estimated the x and y values of the maximum transit depth:



I found that the average transit depth is about 0.973, and since our data is normalized to non-transit flux = 1, that means we can still see 97.3% of the star's light during the transit (or the planet blocks 2.7% of the light).

Next, I estimated the spread of data using horizontal plotting lines:



I found that the spread of data is about +/- 0.002, or +/- 0.2%, which we can propagate into the calculations for transit depth ratio, planet radius, and planet density.

Next, using all six transits, I determined a single ratio of the depth of transit to the non-transit flux and it's uncertainty to be 0.973 +/- 0.002 Relative Flux.

Then, I used the fact that the planet radius is related to the transit depth by the cross sectional areas of the planet and the star to calculate the radius of WASP-4b to be 0.143 +/- 0.007 Rsun.

Finally, I used the given mass of WASP-4b the calculated radius to determine the planet's density and it's uncertainty to be 547.1 +/- 69.6 kg/m^3

Therefore, I think WASP-4b is more likely to be a gaseous planet because it has larger mass and larger radius than Jupiter.

Thought Questions

1. Using the second transit as a reference as opposed to aligning all with all in a single algorithm means the transits are aligned by their maximum cross correlation specifically, with transit 2, which, in practice, would likely be different than using all the data together with a single algorithm to align them.
2. If you wanted to construct an average transit profile from this data set, it might be difficult because there are very steep sections of the curve, with a large spread of data. So, it would be quite hard (and computationally expensive) to try to determine an average transit profile.
3. Treating the uncertainty as random error means we assume there were/are small perturbations in the data, whether it be small, unpredictable changes in the measuring instruments or in the environmental conditions. For systematic error (like the precision of the measuring instrument), this would be introduced at the beginning (when the data was collected) and could easily be propagated throughout any calculations. An algorithm that could be used to assess the impact of systematic error would be to propagate the systematic and random errors separately, so you know how much uncertainty comes from which type of error in the final result.
4. I can answer the question in Part C(iv) with almost complete certainty, as the upper bound for the density of WASP-4b is around 620 kg/m^3 and the lower bound is around 480 kg/m^3, which is MUCH lower than what we would expect for rocky planet with the same mass.

Comment

This project was really cool!! It was quite satisfying to find the maximum cross-correlation and time-shift to align all the transits together.