Homework 7 Write-up

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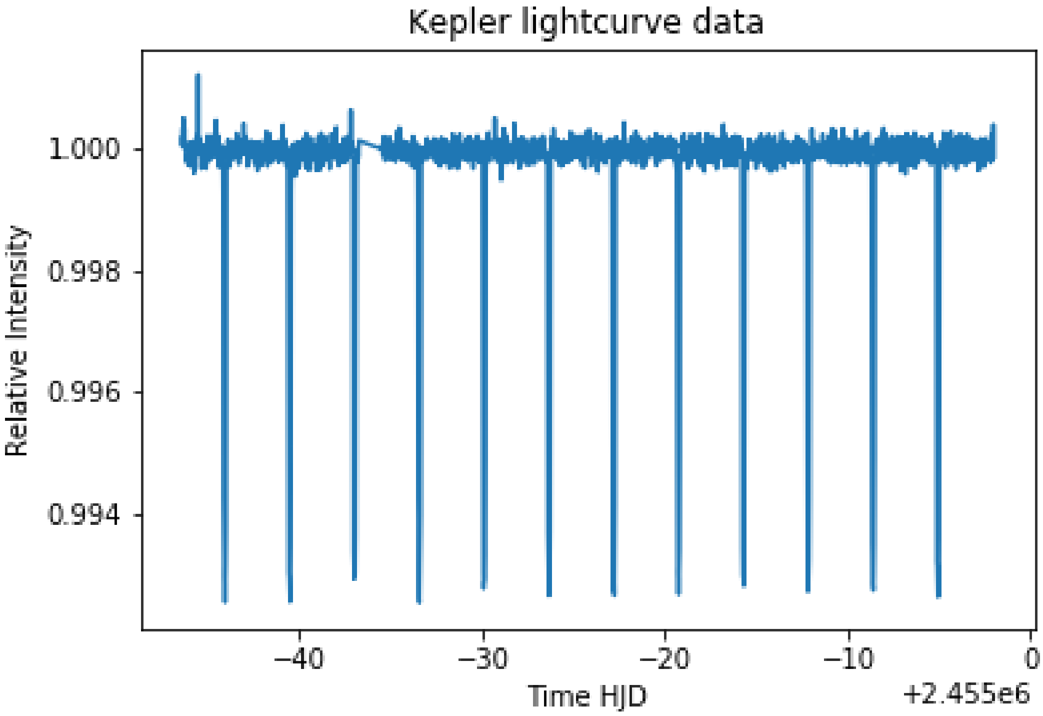
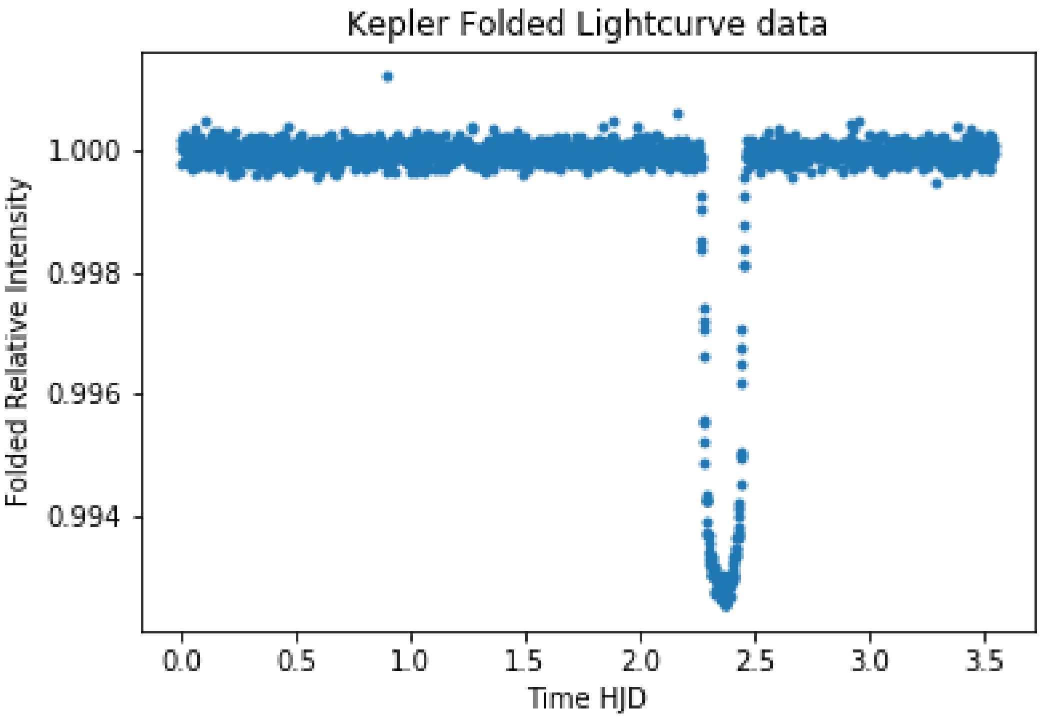
1 Question 1

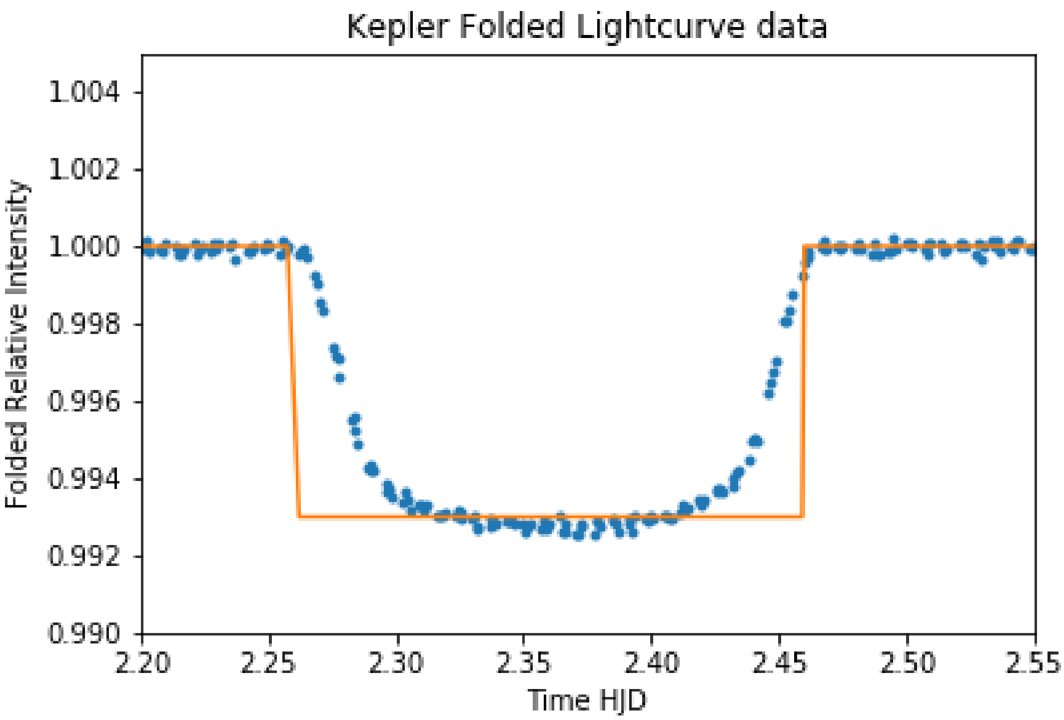
First, the data plotted simply looks like this:



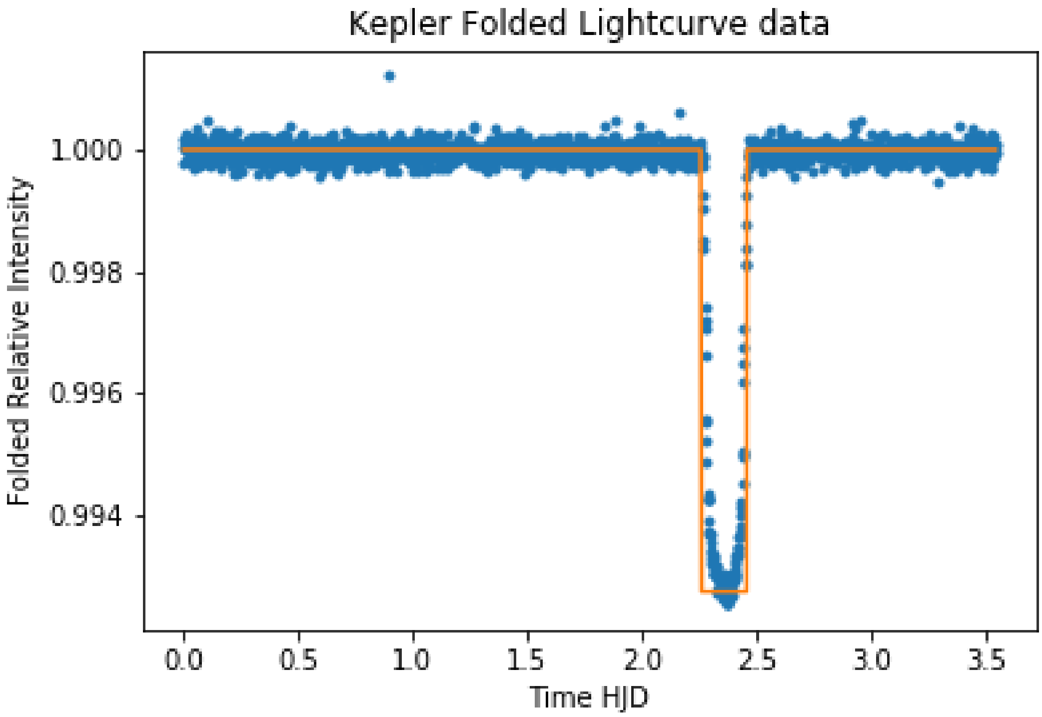
After folding the lightcurve at the period of 3.5485 days, the resulting lightcurve shows the planet transiting in front of the start in the form of the dip in the lightcurve



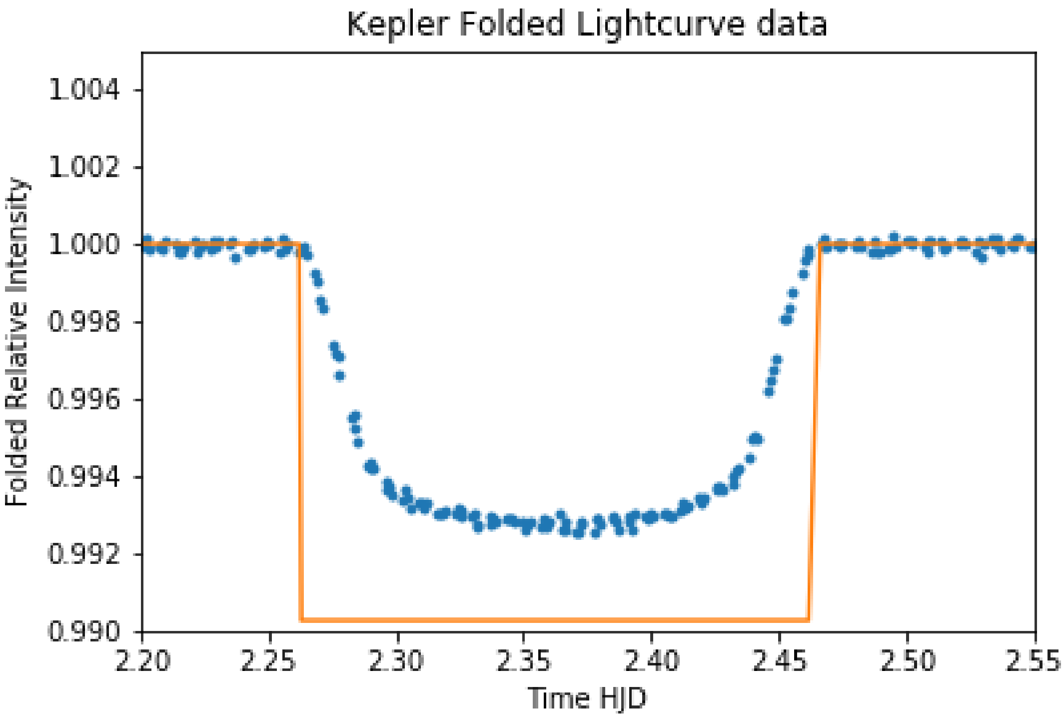
To fit a model to this folded lightcurve, I decided to solve for the best values of tau, the width of the transit t_{ref}, time at the start of the dip in the lightcurve and ΔI, the difference in the intensity of the dip. These parameters will be used to fit a plot to the curve. To get the best parameters for this model, I will follow the Metropolis-Hastings algorithm that is outlined in the notes. The initial guess parameters where:
$\tau = 0.2$ $t_{ref} = 2.26$ $\Delta I = 0.007$
these guesses come from simply looking what was close. The following plot is the guess parameters fitted to the lightcurve using the model. The fit already seems pretty close but obviously it could be better.



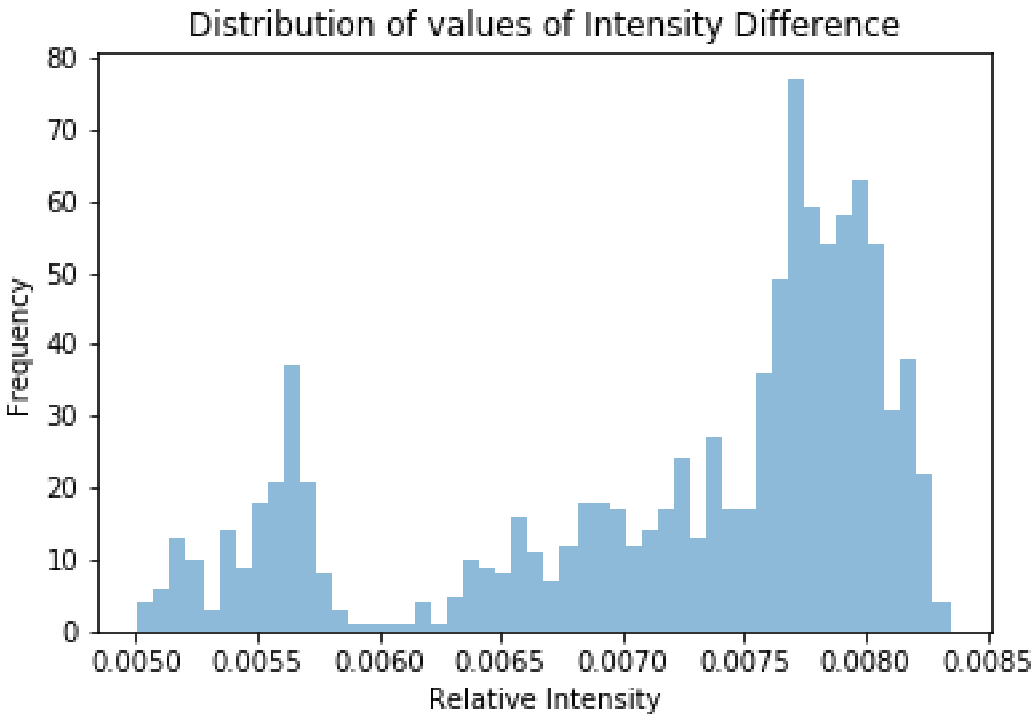
The MCMCalg function in the code performs the Metropolis-Hastings algorithm by looping a set number of iterations and in this loop it would take the guess parameters and perturb them by a random number between -0.0001 and 0.0001 to move the number around until it finds the best fit. For each parameter that I am looking to find I changed one at a time and compared that models likelihood to the likelihood of the new model when the single parameter is changed. If the ratio of these two likelihoods is less then 1 then it has improved the value of the parameter and will become the new guess value until it gets the best value. This is done for every parameter and these new values are returned as the best values. Modeling these best parameters give the following plot:

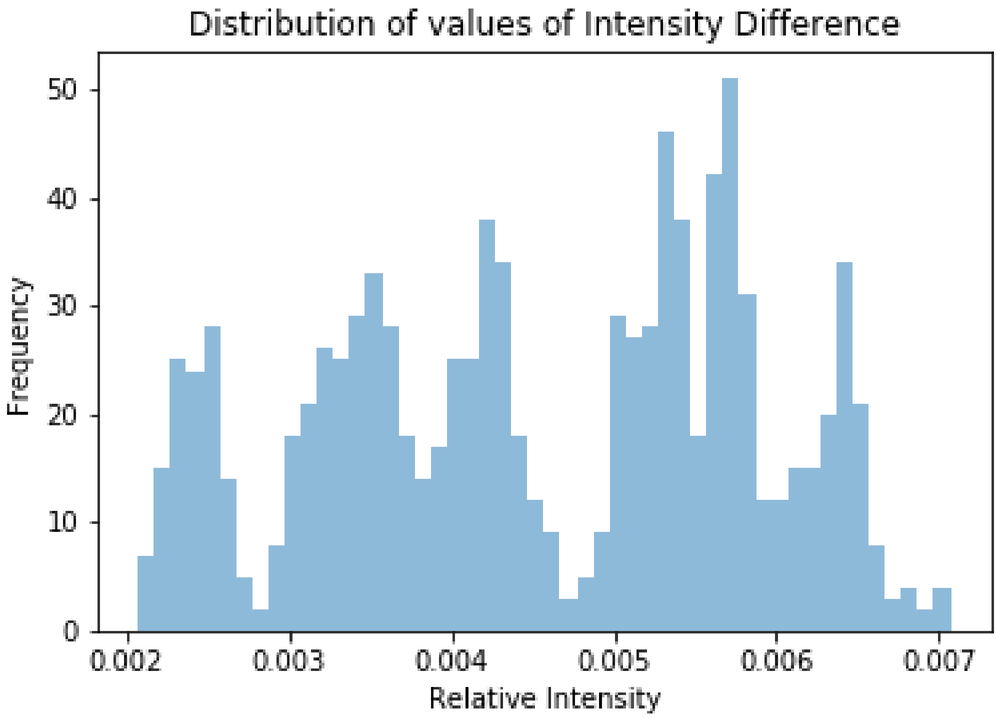


Now, this doesn't look too bad at this distance but when I change the x and y limits to look closer, they dont always look as good as you can see below. Also, I think that I must have done something wrong within the loops to get the best parameters because the random variables change the guesses too much and the best values are different every time that the code runs. This is why this plot look so much different then the other. The change in the intensity is the thing that changes the most which is unfortunate because this is the number we need to calculate the radius of the planet.



The following two one-dimensional histograms show the difference between two different runs of the code and how the estimated best values are distributed so differently. I think it must be a mistake somewhere to do with the random variables or maybe the way I did the acceptance criterion. The number should have been around 0.007 and sometimes it was.

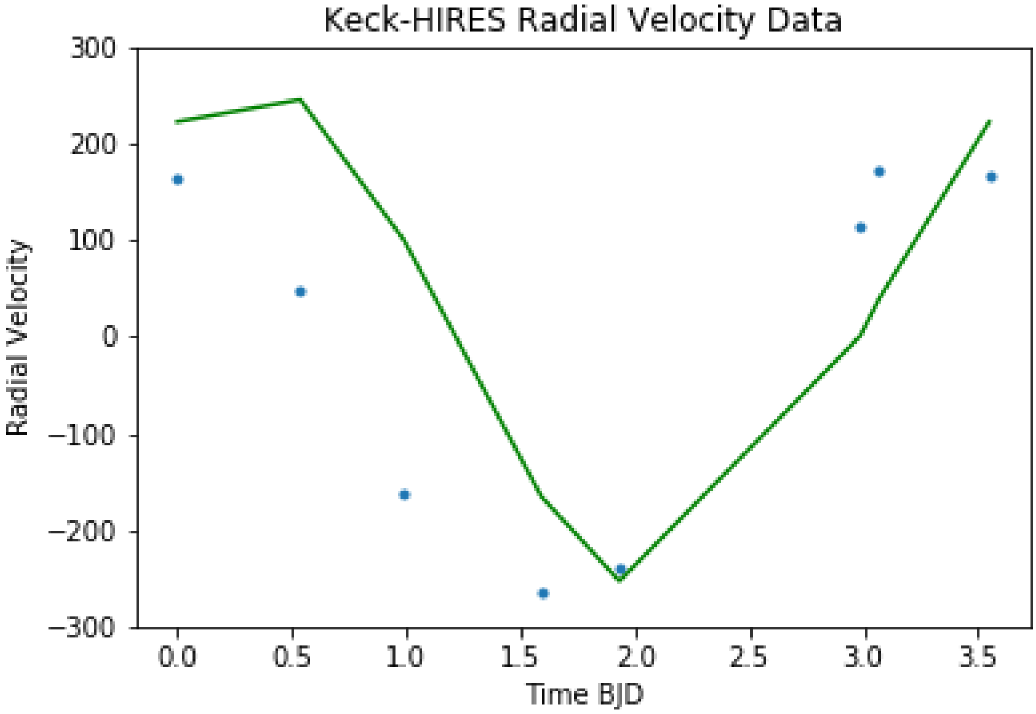




The final goal of this what to solve for the radius of the planet knowing that the star is $R_{star} = 1.79$ in solar radius. Unfortunately, because the δI value is changing so much the value of the planet radius also changes but it is between 0.14 and 0.15 solar radius roughly because the δI is around 0.007 for the most part.

2 Bonus

for this question we know the Period, the velocity and time in Barycentric Julian Date. for this problem I started by folding the data like I did in the last question and form that it looks to have a phase of 1.0 just by sight of the points and an amplitude of 263.88 because this is the value of the lowest point on the downward curve. Applying these knowns to a sine model to fit the curve the following plot is the result but I think that there needed to be more points to fit the model better. Not more data but maybe more information put into the sine model like more time points so the line doesn't look so choppy.



now to figure out what kind of properties this planet has like the mass and density, I have to first solve for the semi-major axis assuming it is a circular orbit and using Kepler's 3rd law:

$$a = \sqrt[3]{\frac{GMP^2}{4\pi^2}} \tag{1}$$

$a = 7.5 * 10^9$ [m]. the acceleration of the two bodies is the same so:

$$M_{star}v_{star} = M_{planet}v_{planet} \tag{2}$$

$$v_{planet} = \frac{2\pi a}{P} \tag{3}$$

adding these equations together

$$M_{planet} = \frac{M_{star}v_{star}P}{2\pi a} \tag{4}$$

Where v_{star} is 263.88 [m/s] because in the data this is the highest measured value that is moving away from the observer making it the most accurate velocity measured. I calculated M_{planet} to be $4.59{*}10^{27}$[kg] or 0.0023 solar masses

$$density = \frac{M_{planet}}{\frac{4}{3}\pi r_{planet}^3} \tag{5}$$

Where r is the radius of the planet that was solved for in part one but because of the problems I had I just used the value 0.14 solar radius. The density of the planet is $0.0012[kg/m^3]$. This planet is about the same mass as Jupiter and is inside the habitable zone so this would suggest that this planet is a hot Jupiter. This planet is suspiciously not very dense and I think this may be an error on my part though.