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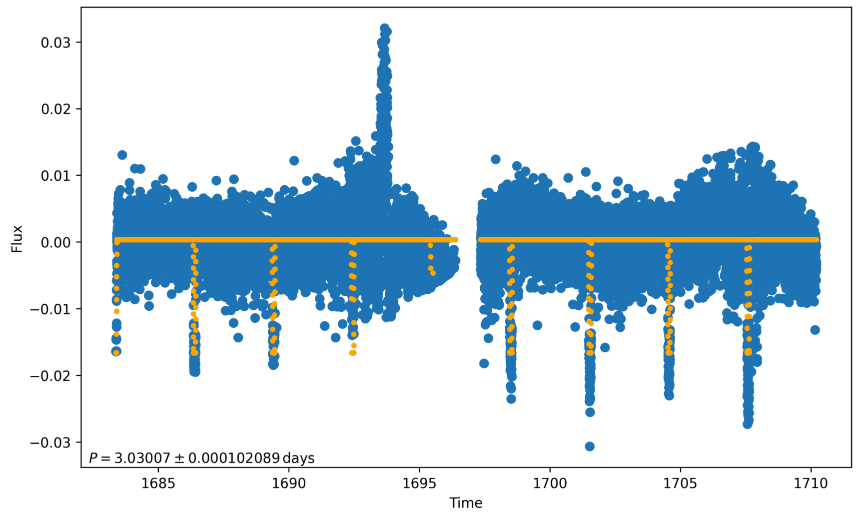
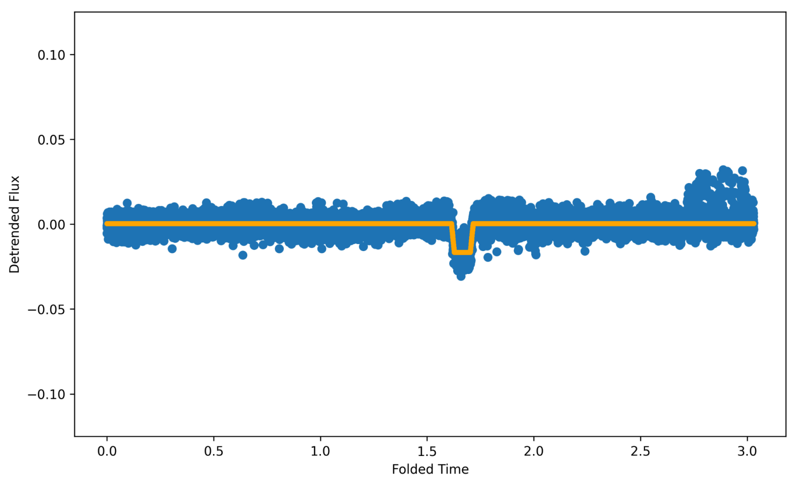
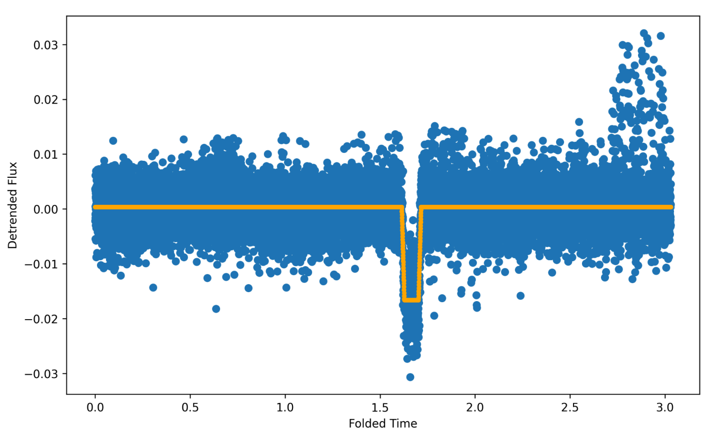
Dr. Jackson
PHYS 305
29th April 2024

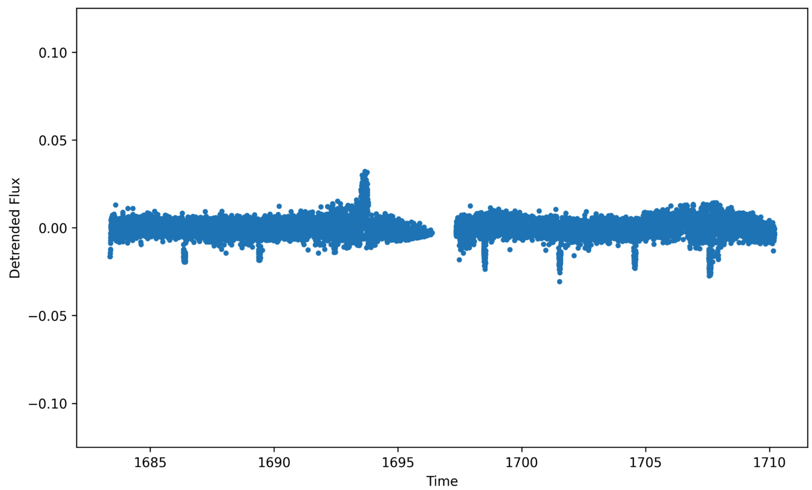
PHYS 305 Observing Project

Figures From Analysis





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Detrended Flux
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1695
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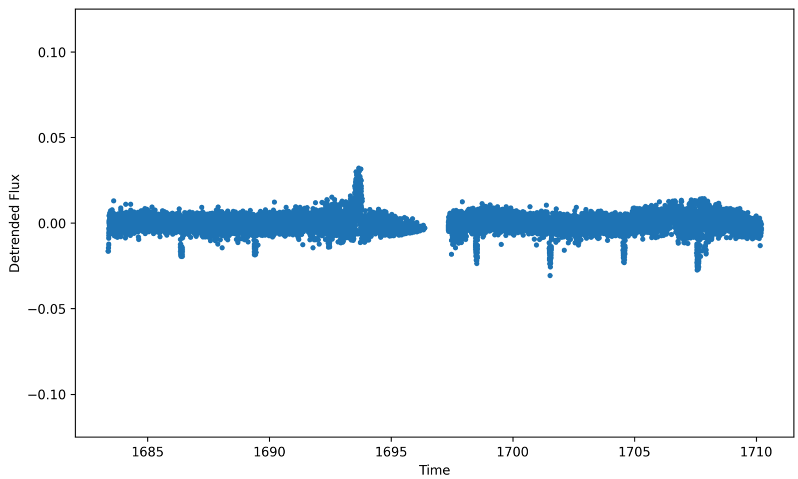
Time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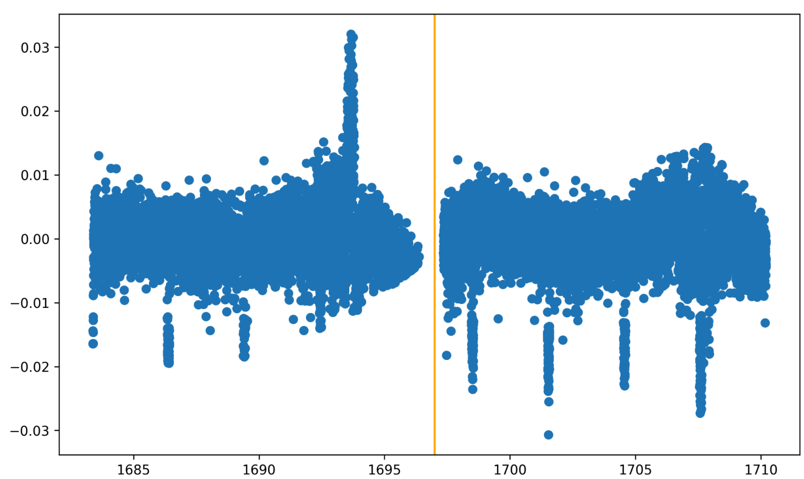
Time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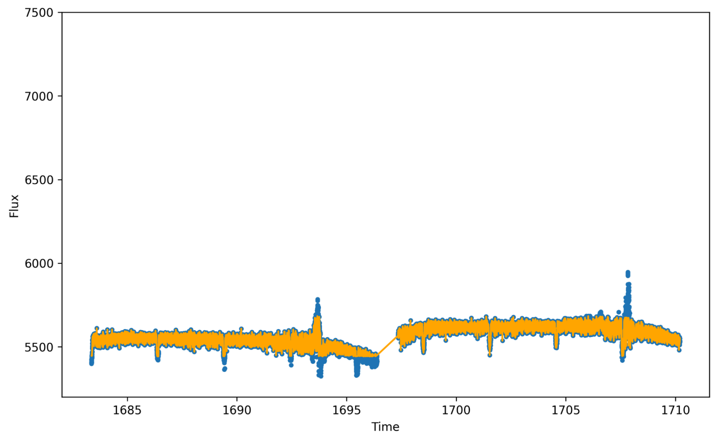
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Flux
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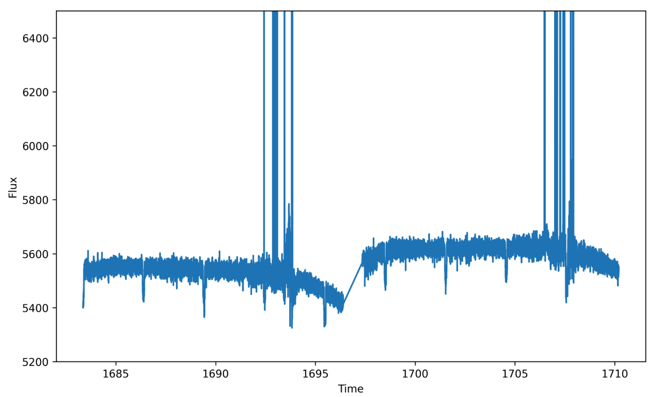
Time


6400
6200
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Flux
1685
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Time

Questions to Answer for the Final Report

Provide detailed answers to the following questions.

1. The photometric data points you analyzed have uncertainties σ associated with them. How could you estimate the per-point uncertainty? Using your method, what is that uncertainty? How would you expect anomalously outlying data points to affect your estimate? What are some techniques you could use to mitigate the effects of outliers on your estimate?

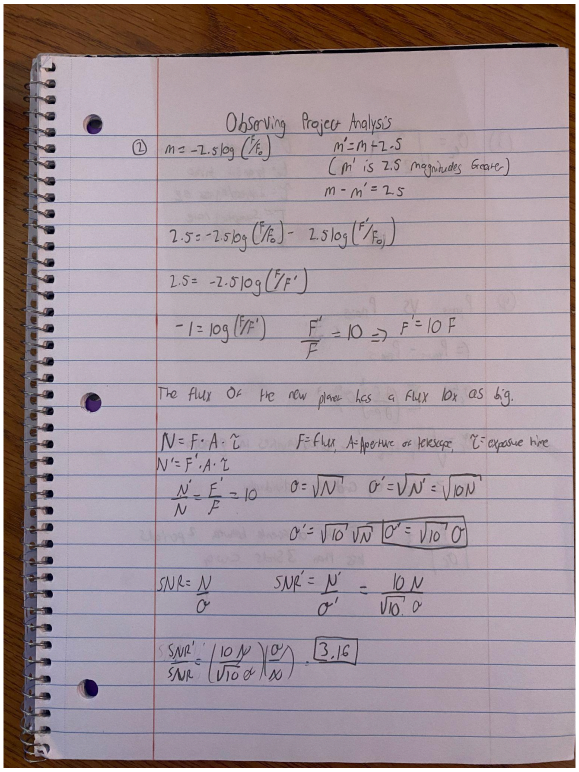
Answer:

1. You can estimate the per point uncertainty by using the median absolute deviation(MAD). Once we have the MAD value the per point uncertainty is equal to MAD* 1.4826.
2. Using my method, the per-point uncertainty is 0.00335.
3. Outlying data points will increase the standard deviation and mean unproportionally compared to the other day points.
4. To mitigate the effects of outliers, we can ignore them from our data. First, we must decide what the threshold for a point must be in order to be considered an outlier. Once we have done that, we can delete all those points that are greater than that threshold. We'd also want to use the median as our measure of average because these large outliers will skew the mean and make it an inaccurate representation of our data. After we have gotten rid of the outliers, we can calculate the standard deviation of the data set without them to get a more accurate number.

2. Imagine you switched planets to observe a star that was 2.5 magnitudes brighter than your first target. Assuming Poisson uncertainties, how would you expect σ to change and by how much?

Answer:

Since the new planet is 2.5 magnitudes brighter, sigma will decrease. This is because the new planet is emitting more photons so as N increases, sigma decreases. We then convert from magnitude to flux and we get that our new flux is 10x greater than that of the original. From there we determine the relative values of N and we will find that the new uncertainty goes down by a factor of 3.



Observing Project Analysis

(2) $m = -2.5\log(F/F_0)$ $m' = m + 2.5$
(m' is 2.5 magnitudes Greater)
$m - m' = 2.5$

$2.5 = -2.5\log(F/F_0) - 2.5\log(F'/F_0)$

$2.5 = -2.5\log(F/F')$

$-1 = \log(F/F')$ $\frac{F'}{F} = 10 \Rightarrow F' = 10F$

The flux of the new planet has a flux 10x as big.

$N = F \cdot A \cdot \tau$ F = flux, A = Aperture of telescope, τ = exposure time
$N' = F' \cdot A \cdot \tau$
$\frac{N'}{N} = \frac{F'}{F} = 10$ $\sigma = \sqrt{N}$ $\sigma' = \sqrt{N'} = \sqrt{10N}$
$\sigma' = \sqrt{10}\sqrt{N}$ $\boxed{\sigma' = \sqrt{10}\,\sigma}$

$SNR = \frac{N}{\sigma}$ $SNR' = \frac{N'}{\sigma'} = \frac{10N}{\sqrt{10}\,\sigma}$

$\frac{SNR'}{SNR} = \left(\frac{10N}{\sqrt{10}\,\sigma}\right)\left(\frac{\sigma}{N}\right) = \boxed{3.16}$

3. Of course, the photometric uncertainty *σ* will impact your results, specifically the results you get for the estimate of each transit time, t_c. The uncertainty on t_c depends on the system parameters according to the following equation:

$$\sigma_{t_c} = \sqrt{\frac{\tau}{2\Gamma}}\frac{\sigma}{\delta}$$

where *τ* is related to the ingress or egress duration, *Γ* is the sampling rate for your data (probably once every 2 minutes), *σ* is the per-point photometric uncertainty, and *δ* is the transit depth (how big the planet is compared to the star).

How would your uncertainty on the transit time change if you doubled the photometric uncertainty? How would it change if you doubled the transit depth (made the planet bigger compared to the star)? You can, of course, use the equation to make these estimates, but also explain qualitatively *why* you would expect that behavior? In words, why does the transit timing uncertainty go up or down as you change the photometric uncertainty and the transit depth?

Answer:

1. If the photometric uncertainty was doubled, then the uncertainty on the transit time would double.
2. If the transit depth was doubled then it would be half as big.
3. We would expect this behavior because the more photons that are being observed, the more obvious it is when the transit begins and ends. This is seen first hand in my code because the transit dips are not very obvious so it can be harder to determine the

starting and ending times of the transit. This is seen as my uncertainty is higher than that found online.

4. Now look at the period value reported on the Exoplanet Archive. We want to know whether your result is consistent (to within uncertainties) with their value. Look at your period value P_{yours} and their period value P_{theirs}, along with the corresponding uncertainties (σ_{yours} and σ_{theirs}, respectively). We want to consider the function $f = P_{yours} - P_{theirs}$, calculate the corresponding uncertainty for that function, and figure out whether the function might be equal to zero to within uncertainties. Consult Chapter 2 in Chromey to refresh your memory about how to propagate uncertainties.

   If your result does not agree with the Archive's, what are some possible reasons? Look at your transit model and compare it to the data. Does it look like a good fit to all the transits?

Answer:

1. To 5 decimal places(As far as mine goes out), my value of period is the exact same as the one found online. My data matches well and appears to be a good fit to most of the transits. One reason that it doesn't match all the transits is that the transit depth is rather small so the code might have trouble differentiating some of the transits which is what led to a higher uncertainty in mine as opposed to theirs.

δ = transit depth

σ_{tc} = transit time uncertainty

(4) P_{yours} VS P_{theirs}

$f = P_{yours} - P_{theirs}$

$\sigma_f^2 = \sum \left(\frac{\partial f}{\partial P}\right)^2 \sigma_P^2$

$\sigma_f = \sqrt{\sigma_y^2 + \sigma_t^2}$ - uncertainties in quadrature

$\sigma_f \geq$ both σ_y and σ_t individually

$\left|\frac{f}{\sigma_f}\right| \leq 3$ is the difference between 2 periods less than 3 stdvs away

$P_{theirs} = 3.03007$ $\quad P_{mine} = 3.03007$

$\boxed{f = 0}$

$\sigma_{theirs} = 1.3 \times 10^{-6}$ days $\quad \sigma_{mine} = 1.02 \times 10^{-4}$ days

$\sigma_f = \sqrt{(1.3 \times 10^{-6} \text{ days})^2 + (1.02 \times 10^{-4} \text{ days})^2}$

$\boxed{\sigma_f = 1.02 \times 10^{-4} \text{ days}}$

5. Using your period *P* and T_0 value (called "ephemeris_fit_params[1]" in your python notebook), you will estimate the next time that your planet could be observed in transit.

   First, you'll need to figure when your planet will next be visible. One way to check this is to use Stellarium (https://stellarium-web.org/). Most of your targets are in the web version, but a few (WASP-10, HAT-P-19, and Qatar-1) seem not to be. For those, you'll have to download and install Stellarium.

   In Stellarium, run time forward from today and check when your object will next be visible at night. Record that date and convert it to Julian date using this online calculator - https://www.aavso.org/jd-calculator. Don't worry about getting the exact instant the planet is visible at night; just get close.

   Next, you'll need to calculate the times in the future when your object will transit. You can calculate the transit time t_c for the *E*th orbit using this equation: $t_c = T_0 + P E$. The first thing you'll need to do is to convert your T_0 value from your fit into Julian date. The fit value you get is in Julian date - 2457000, so start by adding 2457000 to your T_0. Then determine the number of orbits you'll have to wait until t_c is greater than the date you estimated from Stellarium. That should give you the minimum orbit number E for when your object is both visible and transiting. Record the next date when your object could be observed transiting and include all your arithmetic (neatly written) as part of your answer to this question.

Answer

My Period = 3.03007 +- 1.02*10^-4 days

My T0 = 0.8313189249914816 days

T0(Julian date) = 2457000.8313189249914816 days

It is observable at night time on April 26th starting at 9pm.

Observable time in julian date: 2460427.33333 days

1. Tc = T0 + P*E

E =(2460427.33333 - 2457000.8310)days / 3.03007days

E = 1140.86 orbits