Observing Project

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Figures

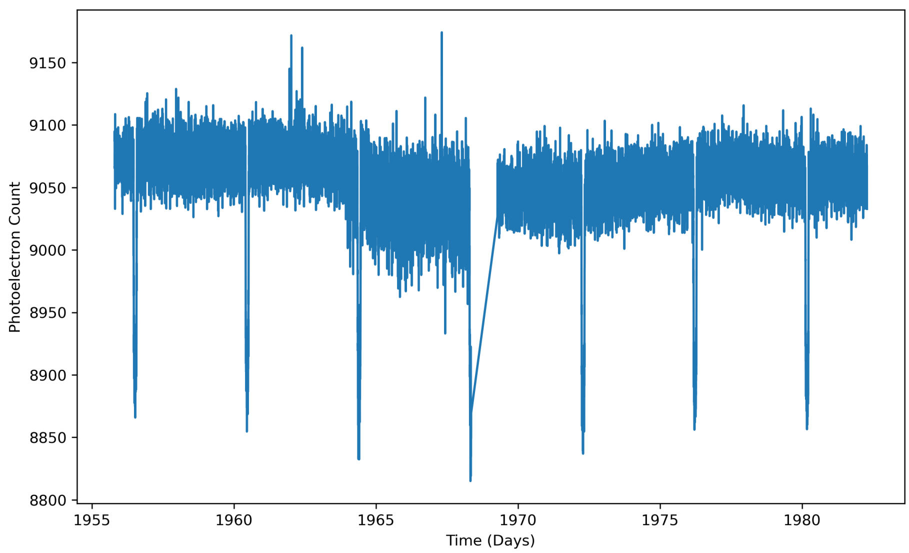

Figure 1: Raw lightcurve data from TESS catalog for exoplanet XO-1b

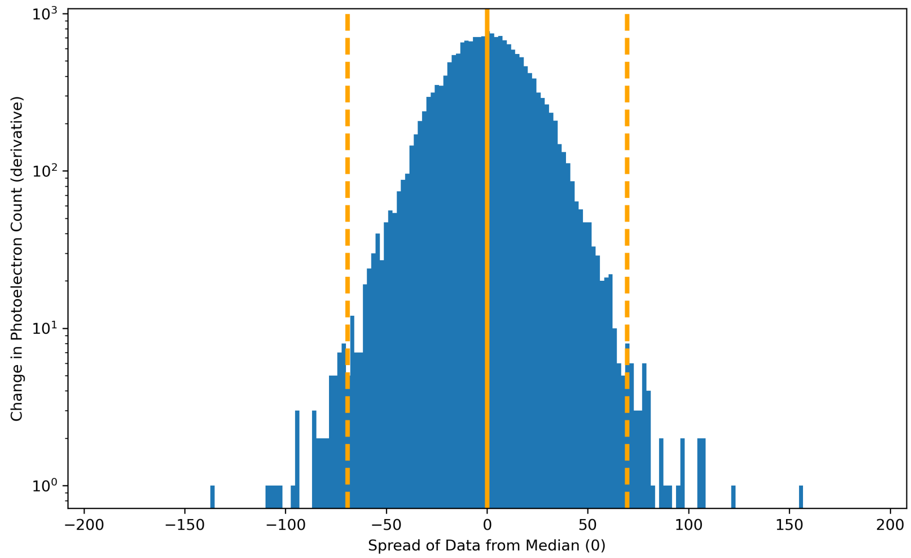

Figure 2: Derivative with regard to time of photoelectron count values centered with median at 0 and overlaid by first standard deviations

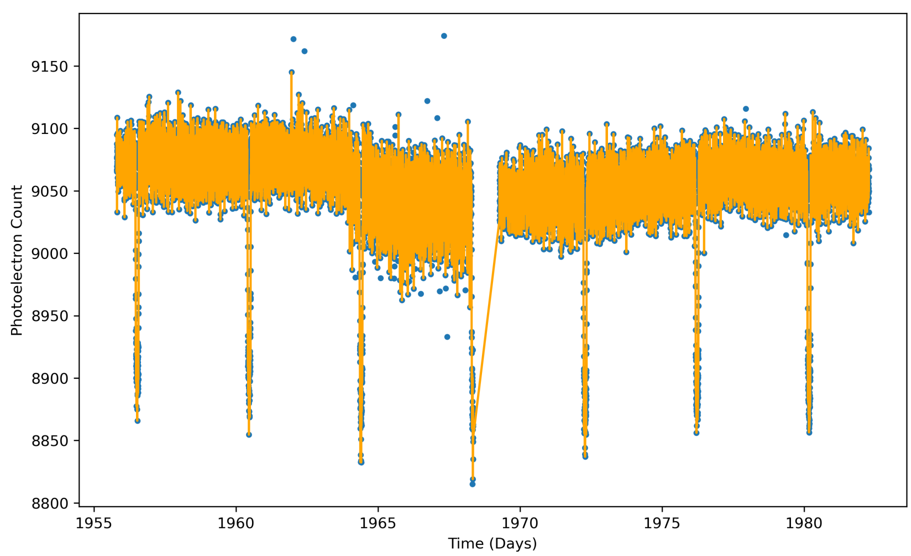

Figure 3: Original data compared with data filtered of outliers beyond the standard deviations displayed in Figure 2.

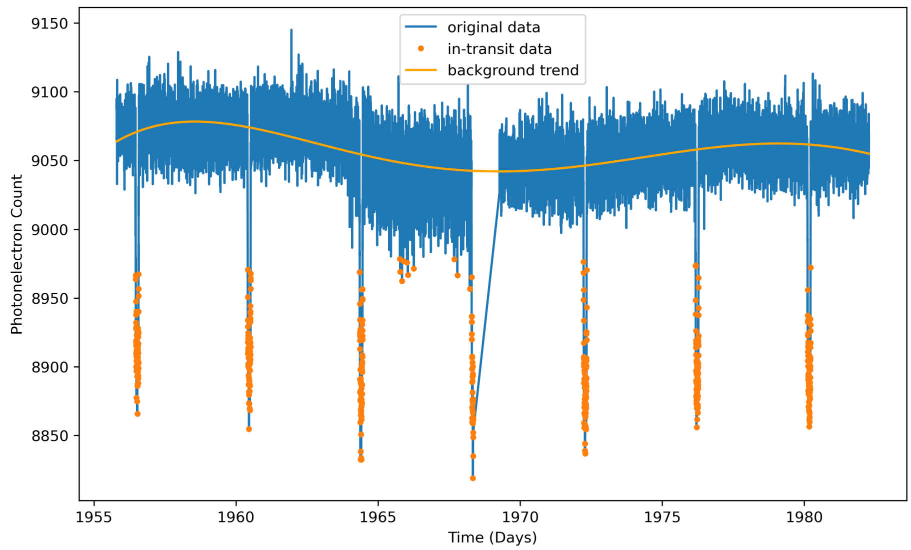

Figure 4: Adjusted data including the first approximations of transit data and a 40^{th} degree polynomial fitted to the curve

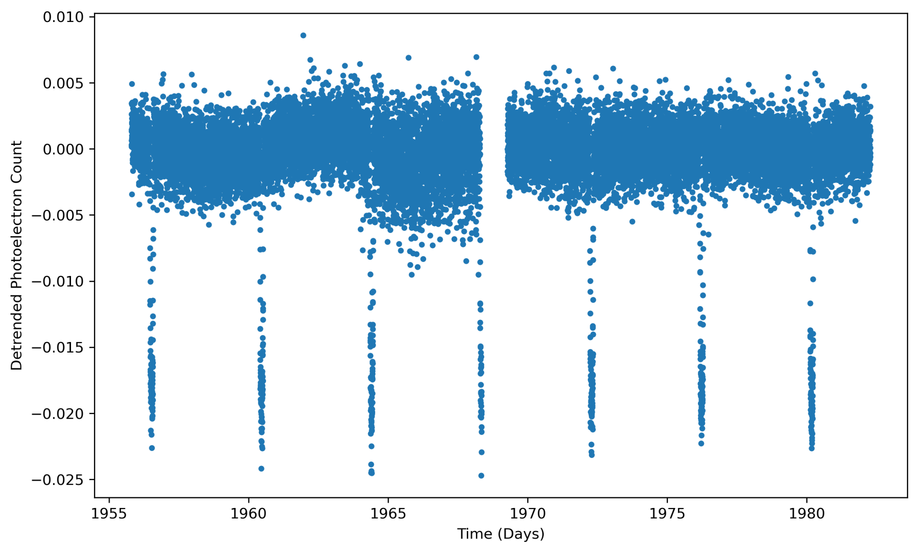

Figure 5: Detrended and outlier filtered data

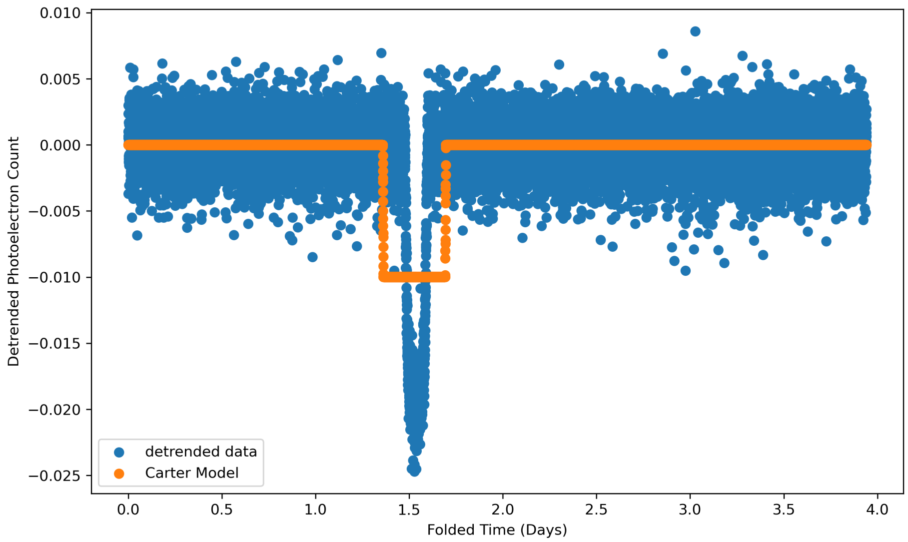

Figure 6: First folded Carter Model of detrended data

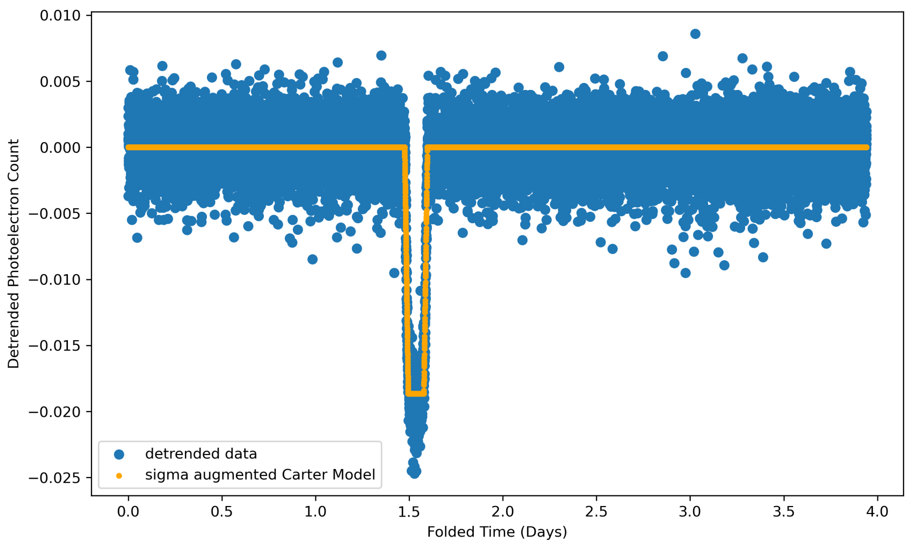

Figure 7: Sigma adjusted Carter Model for folded detrended data

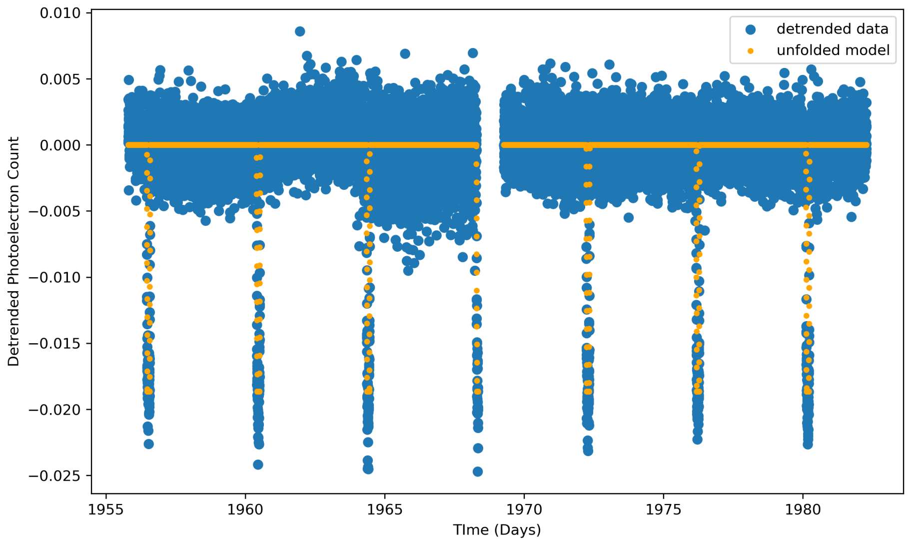

Figure 8: First check of unfolded Carter Model with adjustments

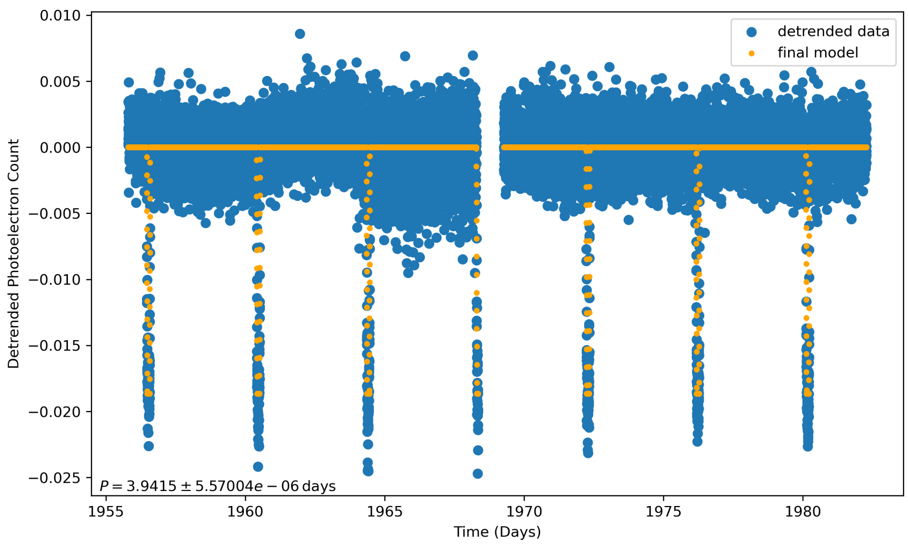

Figure 9: Final data and model, noticeably accounting for the gap in data and still predicting a highly precise period with less than 1% error from the observed value used!

Questions

1. Since these are photoelectron Counts it would make the most sense to use a Poisson Distribution to estimate the per-point uncertainty. I used the code to find the mean photoelectron count and used it to calculate average uncertainty of each measurement. Here is my process:

$$\sigma \approx \sqrt{N} = \sqrt{9054} \approx 9.5$$

Clearly since I used an average photoelectron count as my N value both the dips from the transits and the spiked outliers will affect the accuracy of my estimate. In order to mitigate these effects we could filter our data for the large values using median absolute deviation (MAD). This is what we do in the Jupyter code, cutting off any data points that fall outside of the first standard deviations of the data. This method assumes Gaussian distribution, however, which makes me question if I am calculating my per-point uncertainty correctly. In the code we set sigma at will, so I'm a bit lost here. ADDENDUM: From last Monday's class:

$$\sigma = \sqrt{\langle y_i^2 \rangle - \langle y_i \rangle^2} = \sqrt{82060440.0 - 82060438.47004032} \approx 1.237$$

This is a bit lower than the previously calculated uncertainty but it should still be affected by outliers by a relatively similar amount and thus we can use MAD method to mitigate the effect of outliers. It should be noted, however, that depending on how deep the transit is in the lightcurve, transits may be removed before applying MAD then overlapped on the resulting data so as to not cut them out.

2. Here's what I did:

$m = -2.5 \log \frac{F}{F_0}$
$m' = m - 2.5 \therefore 2.5 = 2.5 \log \frac{F}{F_0} - 2.5 \log (\frac{F'}{F_0}$
$\rightarrow \frac{F'}{F} = 10 \rightarrow$
so flux increases by ten times

$N = F * A * \tau$
$N' = F' * A * \tau \therefore \frac{N'}{N} = \frac{F'}{F} = 10$

now using the Poisson identity for σ :
$\frac{\sigma'}{\sigma} = \sqrt{\frac{N'}{N}} = \sqrt{10} \approx 3.16$

This result indicated that the uncertainty is now larger by about a factor of 3. This seems incorrect till we consider that the fractional uncertainty is the reciprocal of our result. I would expect the the per-point uncertainty to be higher since there are now more photoelectron counts. The fractional uncertainty, however, will be lower, and this makes sense since relative uncertainty should be proportional to $\frac{1}{\sqrt{N}}$. This result is expected!

3. This is a fun one, I'll refrain from explaining it mathematically. If I doubled the photometric uncertainty my uncertainty for the transit time would increase by a factor of 2. This makes physical sense from the propagation of uncertainty as we cannot possibly obtain a more precise result from a less precise value. If we are unsure of our photometric counts then we are unsure of when exactly the transit begins and ends. If I double my uncertainty for the photometric accounts then I must also double my uncertainty for the transit time.

Doubling the transit depth would decrease our transit time uncertainty by a factor of 2. A bigger planet would block out more light from the star, meaning the bottom of the transit curve should have much less photoelectron counts compared to a relatively smaller planet. With more light blocked out we can be more certain of the period in which the planet is transiting across the star simply because it is more easy to distinguish from the lightcurve. A planet that is double the size of another should be twice as easy to distinguish in the data meaning the uncertainty on its transit time should be half that of that smaller planet.

4. Equation 2.28 from the text states: $\sigma^2 = \sigma_1^2 + \sigma_2^2$. Looking at the function $f = P_{\text{mine}} - P_{\text{theirs}} = 3.9415 - 3.94150468 = -4.68 * 10^{-6}$. Now we can find the combined uncertainty: $\sigma = \sqrt{(5.57004 * 10^{-6})^2 + (2 * 10^{-7})^2} \approx 6 * 10^{-6}$. Now $|6 * 10^{-6}| > |-4.68 * 10^{-6}|$ so the difference in our modeled result and the observational result is less than the uncertainty of said results. Therefore we may confidently say that our result agrees with the Archive's!

5. 2460430.50877 is the Julian date calculated by Stellarium. So $t_c = 0.768274 + 2457000 + (3.9415 * E)$. Now we set t_c to the Julian date to find E: $2460430.50877 = 0.768274 + 2457000 + (3.9415 * E) \rightarrow E \approx 871$. So it takes 871 orbits for the object to be visible and transiting, $871 * 3.9415 = 3433$ days. This seems really high, let's convert back into calendar date: $t_c = 0.768274 + 2457000 + (3.9415 * 871) = 2460433.815$ which converts to be about May 3, 2024. This should be the next date when XO-1 b could be observed transiting.

Thus concludes the Observing Project, thanks for a wonderful semester :)