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PHYS 309
29 April 2024

Observing Project

1) To estimate the per-point uncertainty you can conduct a chi-squared test.

$$\chi^2 = \sum_{i=0}^{N-1} \left(\frac{y_i - y(x_i)}{\sigma_i}\right)^2 \Rightarrow \chi_v^{\ 2} = \frac{\chi^2}{N-M} \approx 1 \Rightarrow \sigma_i^{\ 2} = \chi_v^{\ 2}\sigma_i^{\ 2} \Rightarrow \sigma = \sqrt{< y_i^{\ 2} > - < y_i >^2}$$

$$< y_i >= \Sigma \frac{y_i}{N} \Rightarrow median(y_i) \Rightarrow MAD(y_i) = median(|y_i - median(y_i)|)$$

$$\Rightarrow std, \sigma = 1.4826 \times MAD$$

The MAD value can be determined from the Python notebook. By doing mad(df), where df is the derivative of the difference of the flux (np.diff(flux)) you are given the median absolute deviation. My MAD is 10.7175 Photo-electrons.

$$std, \sigma = 1.4826 \times MAD$$

$$\Rightarrow std, \sigma = 1.4826 \times 10.7175\, Photo - electrons = 15.8898\, Photo - electrons$$

Anomalously outlying data points would skew σ quite significantly. I would expect these data points to skew σ so it was much higher. One way you can mitigate the effects of outliers on your estimate is to remove them from your data, either through a mask or manually removing them. Another way would be to use the median value instead of the mean value. This is because a mean value is an overall average of a data set and is heavily affected by outliers, while a median is just the middle point of the data set, which isn't affected by outliers as significantly.

2) If I were to switch planets to observe a star that was 2.5 magnitudes brighter than my original target, I could determine how σ would change and by how much through the following calculations.

$$\sigma = \sqrt{N}$$

$$\frac{N_2}{N_1} = \frac{F_2}{F_!} \Rightarrow \frac{\sigma_2}{\sigma_1} = \left(\frac{N_2}{N_1}\right)^{1/2} = \left(\frac{F_2}{F_1}\right)^{1/2}$$

$$m = -2.5log\left(\frac{F}{F_0}\right) \Rightarrow m_2 - m_1 = -2.5log\left(\frac{F_1}{F_0}\right) + 2.5log\left(\frac{F_1}{F_0}\right) \Rightarrow m_2 - m_1 = 2.5log\left(\frac{F_2}{F_1}\right)$$

$$m_2 - m_1 = 2.5log\left(\frac{F_2}{F_1}\right) \Rightarrow \frac{F_2}{F_1} = 10^{(m_2 - m_1)/2.5}$$

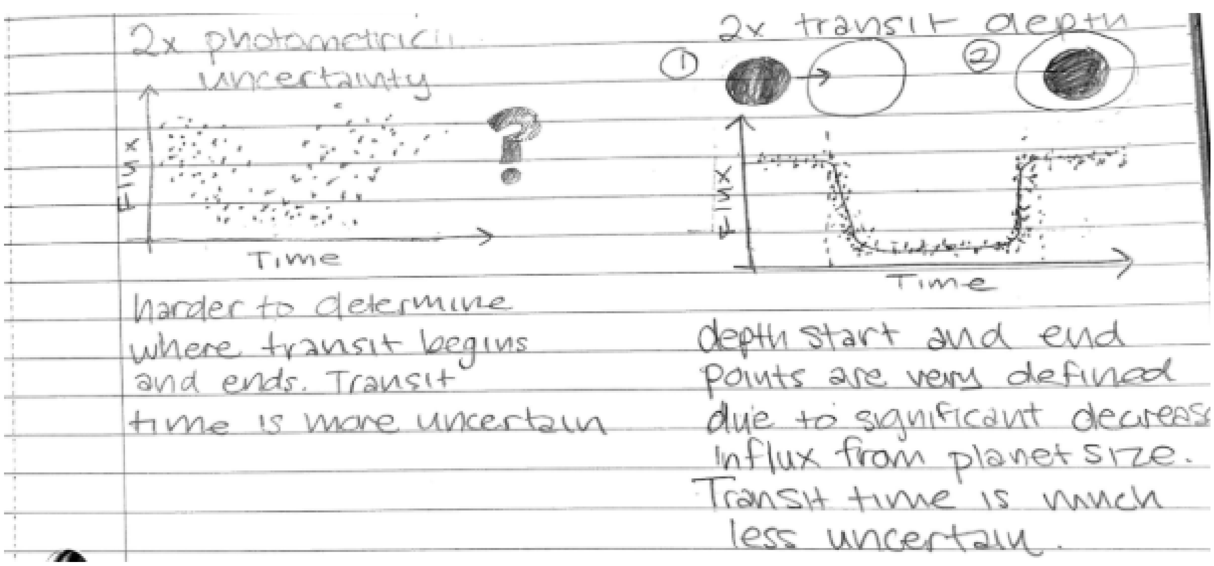
$$\frac{\sigma_2}{\sigma_1} = (\frac{F_2}{F_1})^{1/2} \Rightarrow \frac{\sigma_2}{\sigma_1} = (10^{(m_2 - m_1)/2.5})^{1/2}$$

Where $m_2 - m_1 = 2.5$

$$\frac{\sigma_2}{\sigma_1} = (10^{(2.5)/2.5})^{1/2} = (10)^{1/2} = \sqrt{10} \simeq 3$$

We can now determine that σ increases by a factor of $\sqrt{10}$

3) If you doubled the photometric uncertainty, then the uncertainty of the transit time would increase. This is because if the uncertainty of the photometric data points increased, then it would be harder to see the actual transit depth within the flux vs time graph. This causes the transit time uncertainty to increase because it is uncertain of where the transit begins and ends. Now, if you were to double the transit depth instead, meaning the planet was big compared to the star, the transit time uncertainty would decrease significantly. Since the planet is so large compared to its host star, it will block out much more light from the star and create a very defined dip within the flux vs time graph, meaning the transit depth is deeper, more defined, and easier to determine the start and end times of the transit.



4) My period value is $2.143626 \pm 1.2749 \times 10^{-5} days/orbit$ while the value reported on the [Exoplanet Archive] is $2.143630 \pm 0.000003\ days/orbit$. We can determine the uncertainty for the function $f = P_{yours} - P_{theirs}$ through the following calculations.

$$f = P_{mine} - P_{theirs} \Rightarrow f = (2.143626) - (2.143630) = -4 \times 10^{-6}$$

$$\sigma_f^{\ 2} = \sum_i^N \left(\frac{\partial f}{\partial f_i}\right)^2 \sigma_i^{\ 2} \Rightarrow (1)^2 (\sigma_{mine})^2 + (-1)^2 \sigma_{theirs}$$

$$\Rightarrow \sigma_f^{\ 2} = \sigma_{mine}^{\ \ 2} + \sigma_{theirs}^{\ \ 2} \Rightarrow \sigma_f = \sqrt{\sigma_{mine}^{\ \ 2} + \sigma_{theirs}^{\ \ 2}}$$

$$\Rightarrow \sigma_f = \sqrt{\sigma_{mine}^{\ \ 2} + \sigma_{theirs}^{\ \ 2}} \Rightarrow \sigma_f = \sqrt{(1.2749 \times 10^{-5})^2 + (0.000003)^2} = 1.31 \times 10^{-5}$$

$$\frac{|f|}{\sigma_F} = \frac{|-4\times10^{-6}|}{1.31\times10^{-5}} = 0.31$$

$$\frac{|f|}{\sigma_f} \leq 3 \Rightarrow 0.31 \leq 3$$

We can see that the values are consistent and my value agrees with the archives value.

5) The next time WASP-48 is visible according to Stellarium is April 29th, 2024 around 06:00 UTC. In Julian Date, this is 2460430.39927JD. We can find out the next time Wasp-48b will be visible through the following calculations:

$$T_0 = 0.078208 \rightarrow Julian\ Date\ T_0 = 2457000.078\,JD$$

$$P = 2.14363\ days/orbit$$

$$t_0 = 2460430.39927\,JD$$

$$t_0 = T_0 + PE \Rightarrow E = \frac{t_0 - T_0}{P}$$

$$E = \frac{(2460430.399\,JD) - (2457000.078\,JD)}{2.14363\ days/orbit} = 1600.2 \Rightarrow 1601\ orbits$$

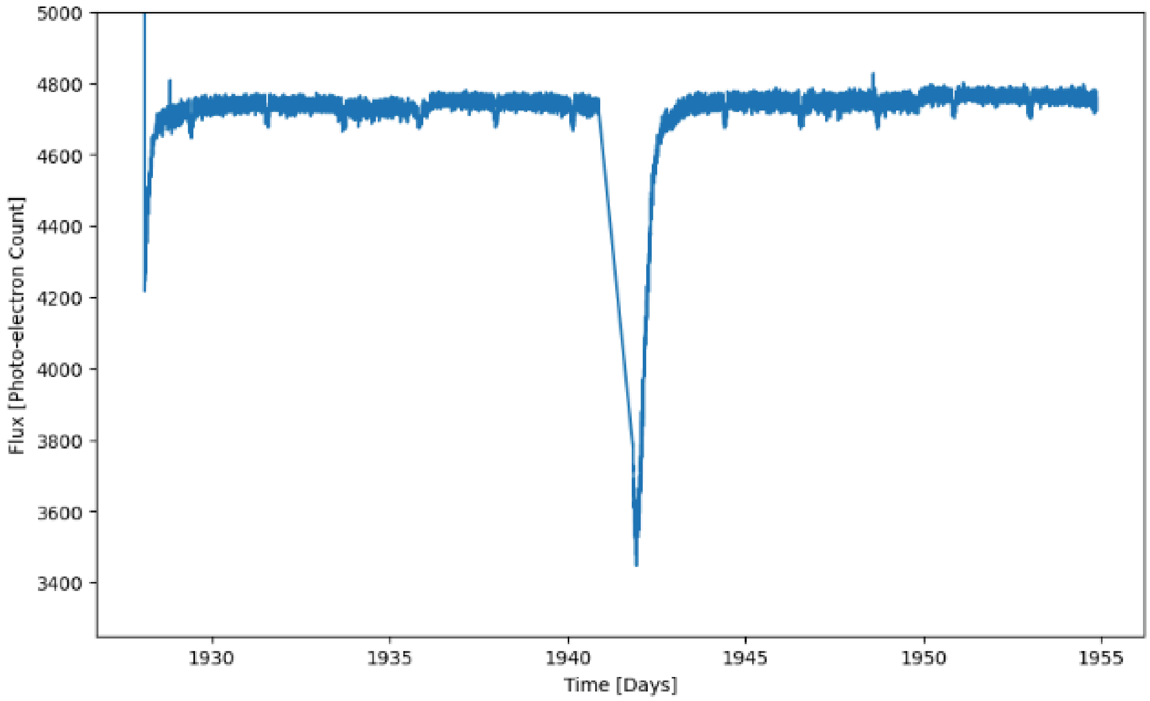
You can't have a partial orbit so we need to round up.

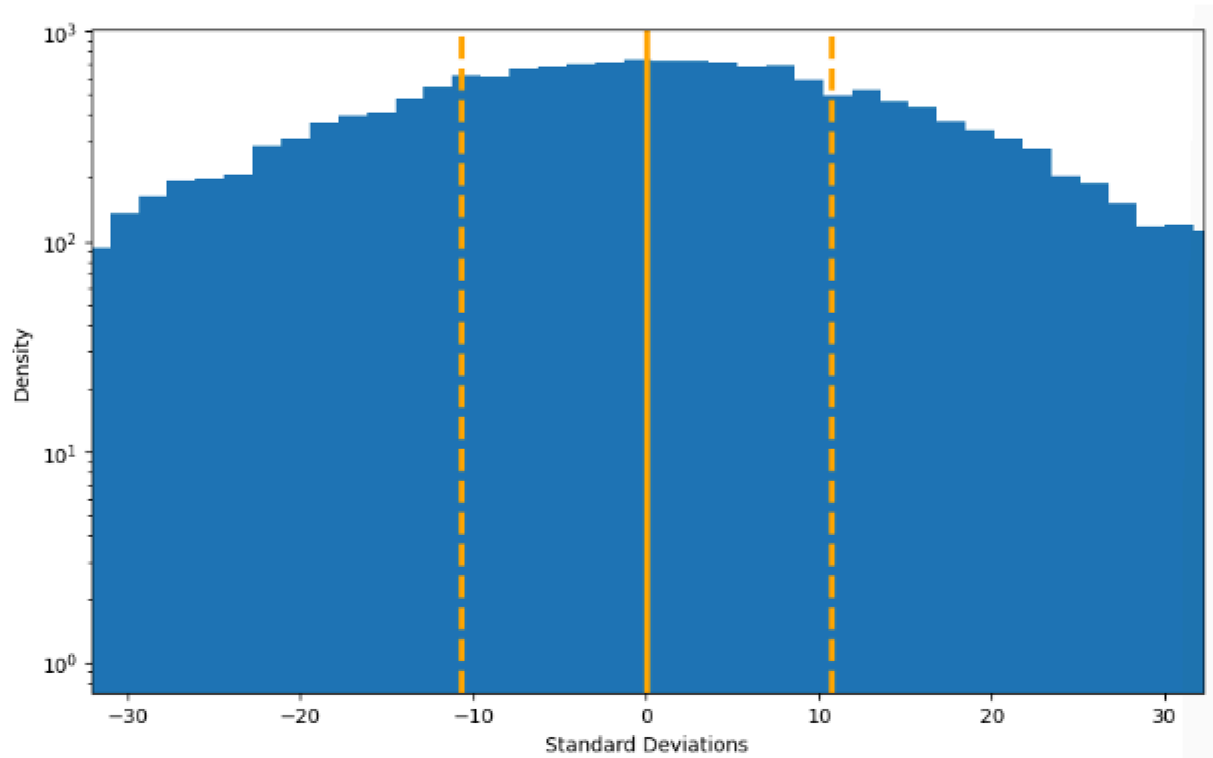
$$t_0 = T_0 + PE$$

$$\Rightarrow t_0 = (2457000.078\,JD) + (2.14363\ days/orbit)(1601\ orbits) = 2460432.03\,JD$$

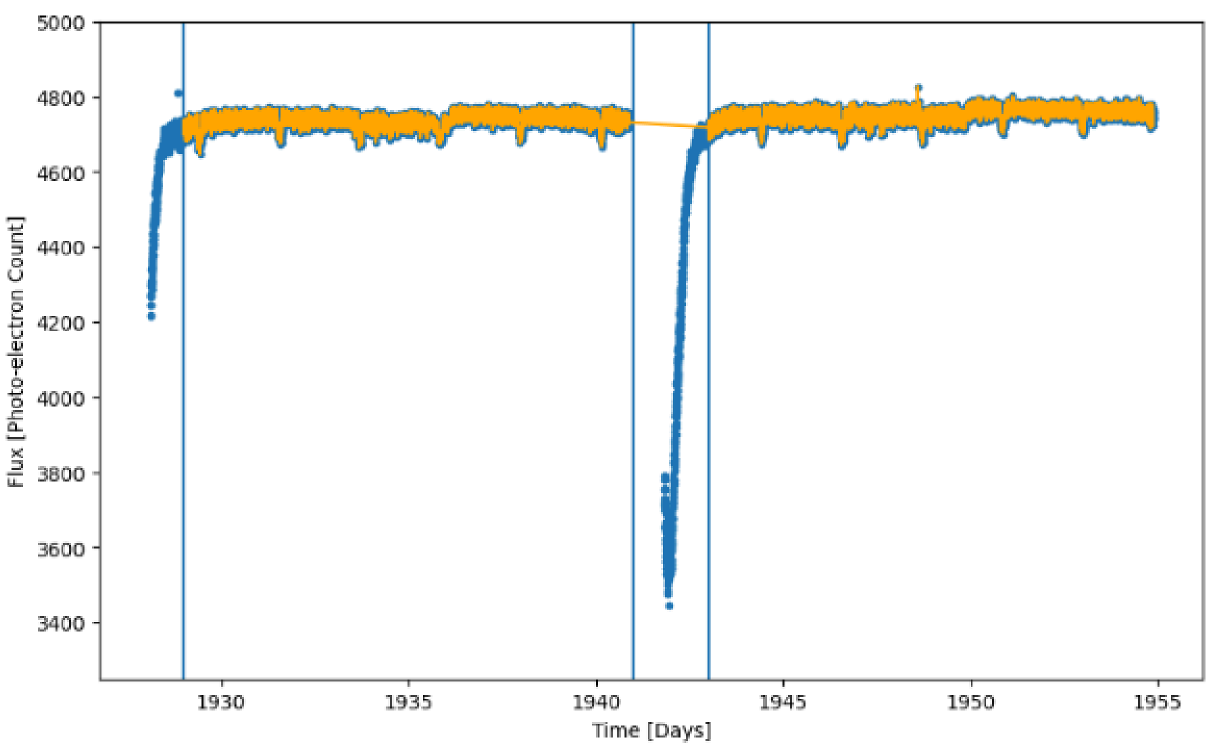
The next time Wasp-48b will be visible is at 2460432.03 JD or May 1st, 2024 at 12:43:12.00 UT.

Figures from Analysis

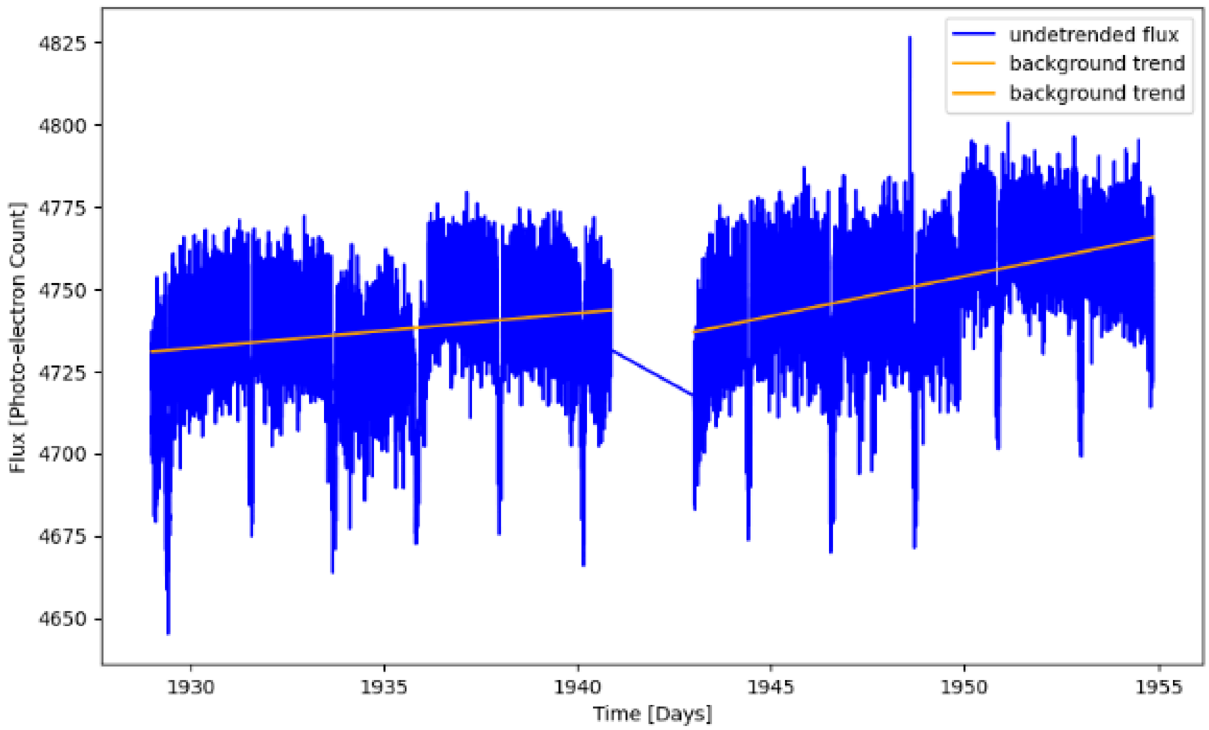


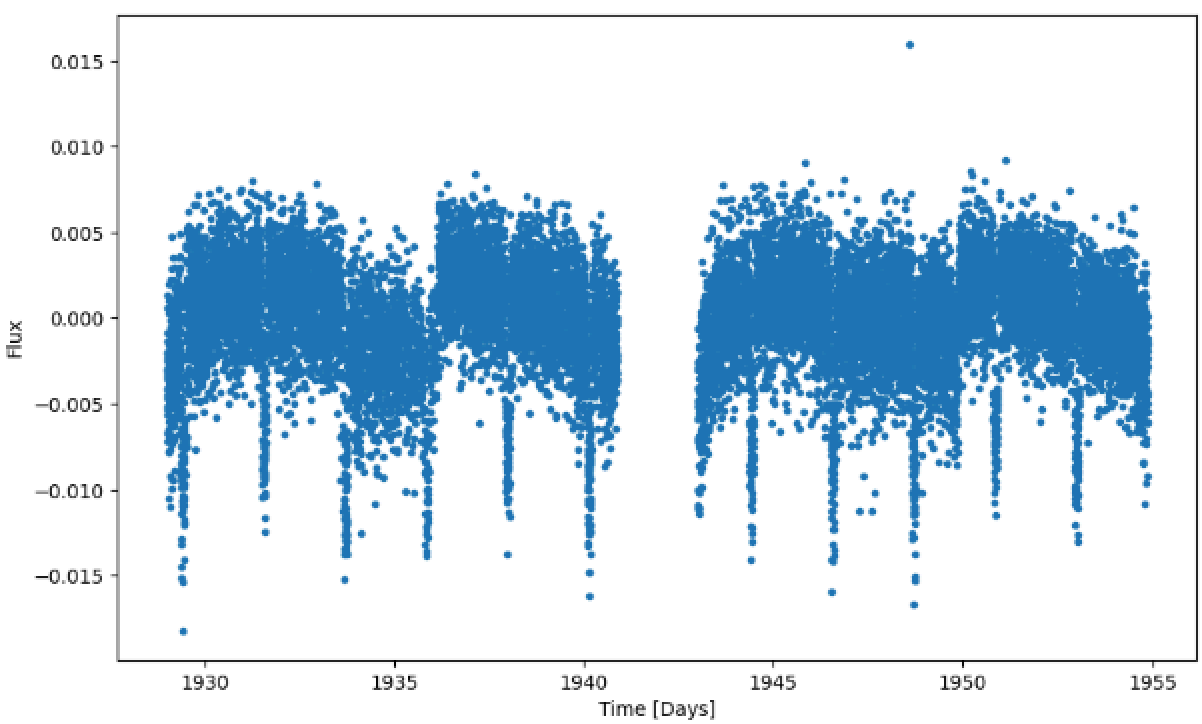


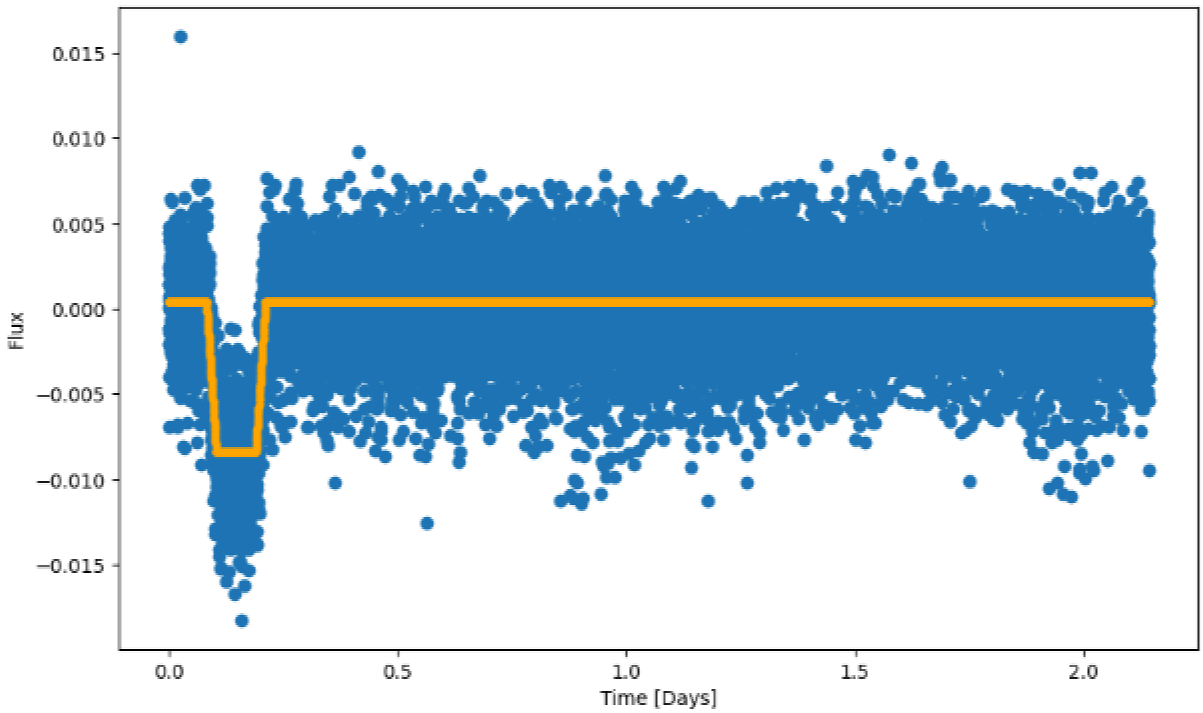
Density
Standard Deviations



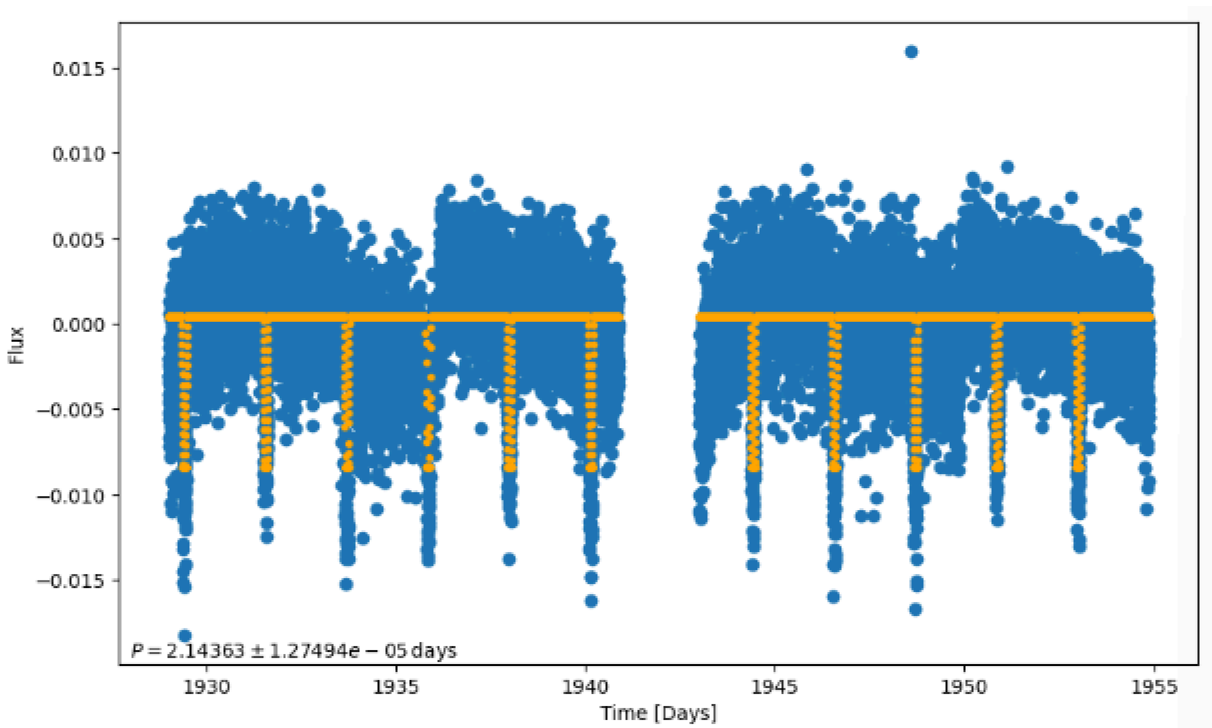
Flux [Photo-electron Count]
Time [Days]


undetrended flux
background trend
background trend
Flux [Photo-electron Count]
Time [Days]


Flux
Time [Days]



0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
Flux
0.0
0.5
1.0
1.5
2.0
Time [Days]



0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
Flux
$P = 2.14363 \pm 1.27494e-05$ days
1930
1935
1940
1945
1950
1955
Time [Days]