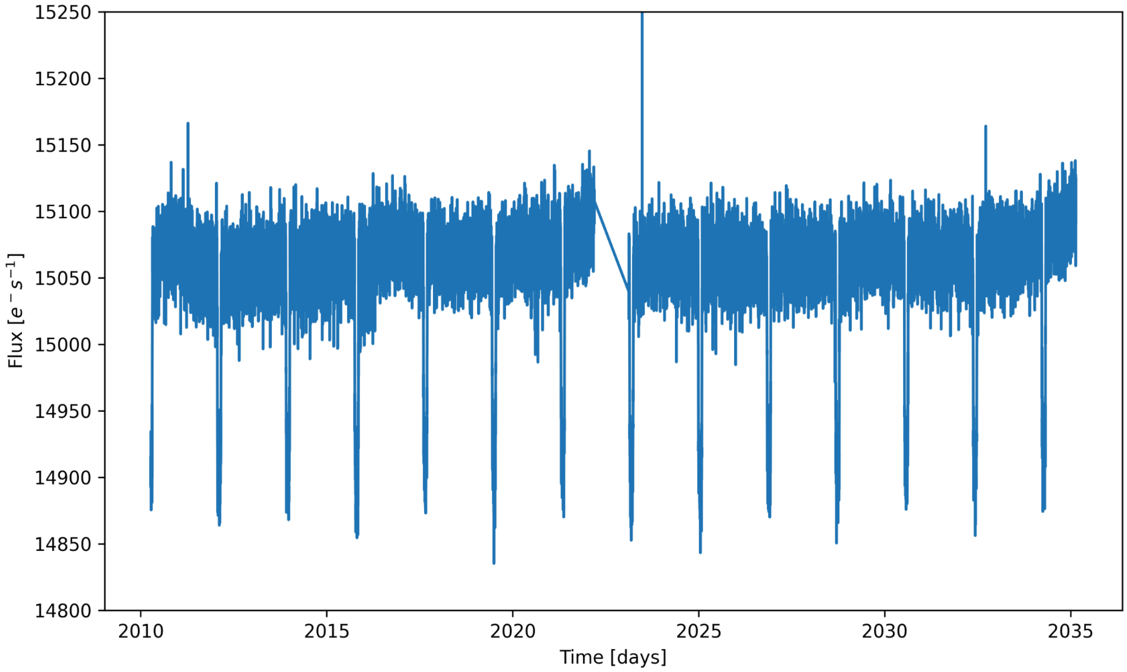
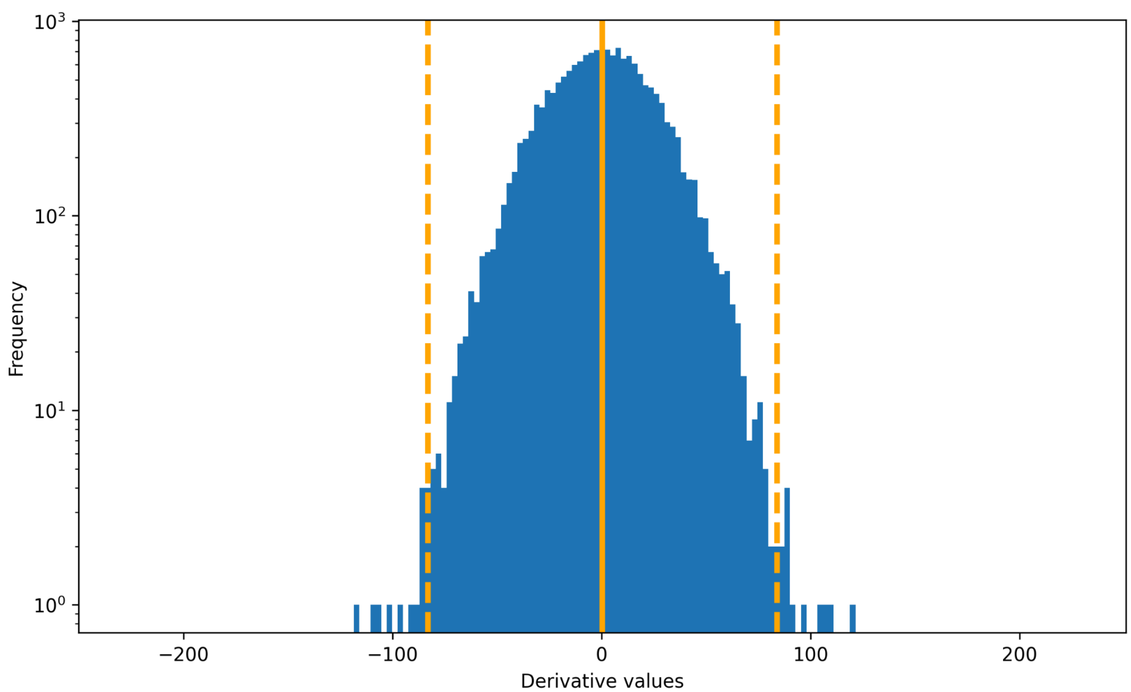
Joey Migchelbrink
PHYS 305 Observing Project

Planet: **WASP-3 b**

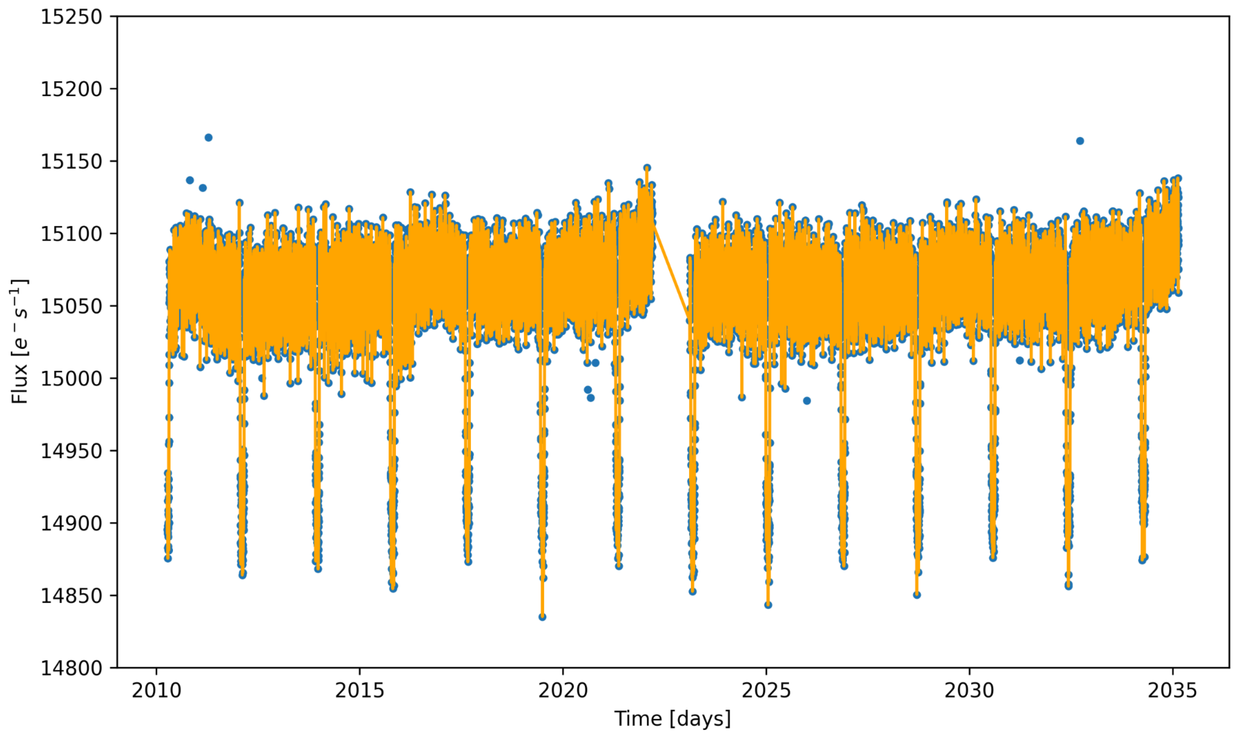
Initial Transit Data



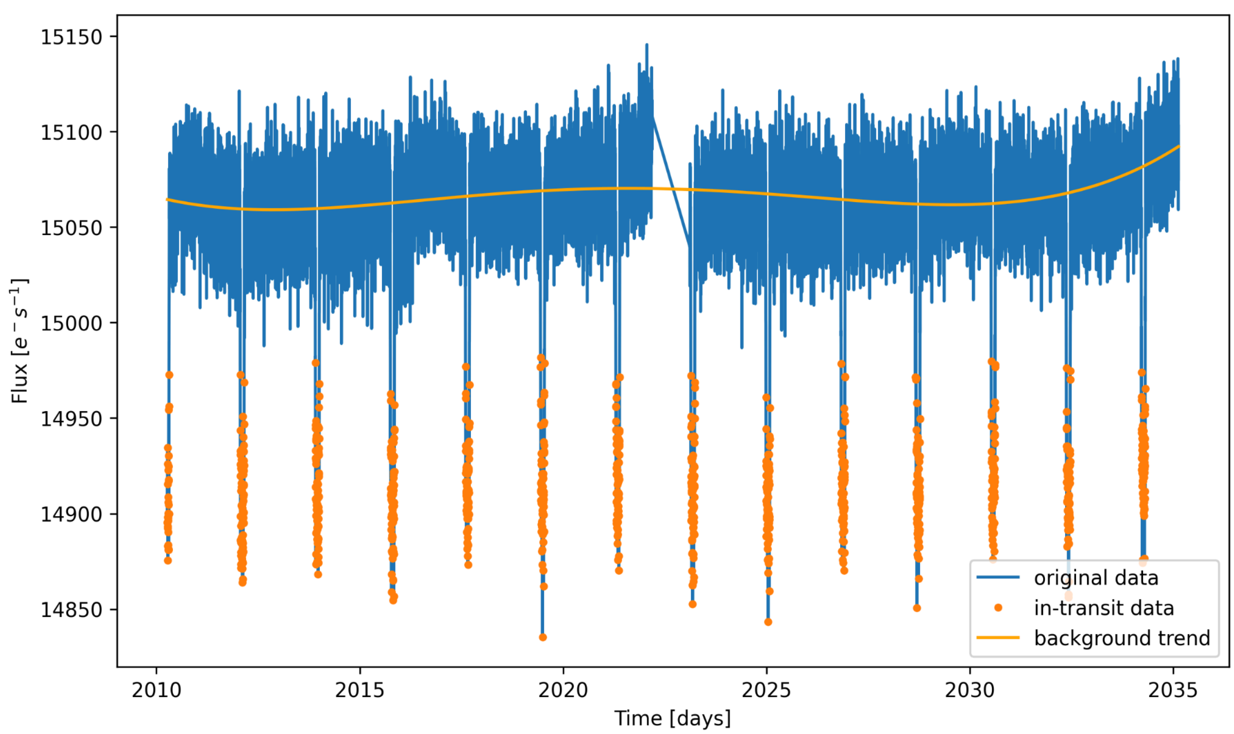
Gaussian Distribution of Derivatives



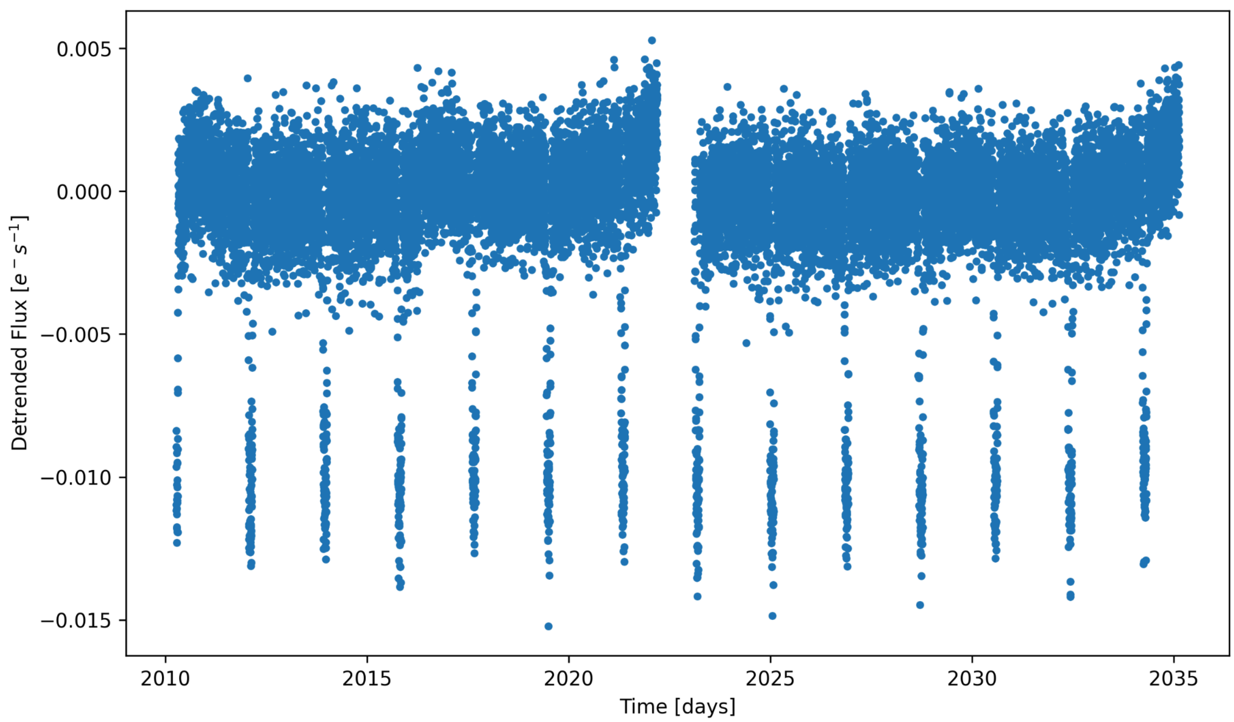
Transit Data with Outliers Removed



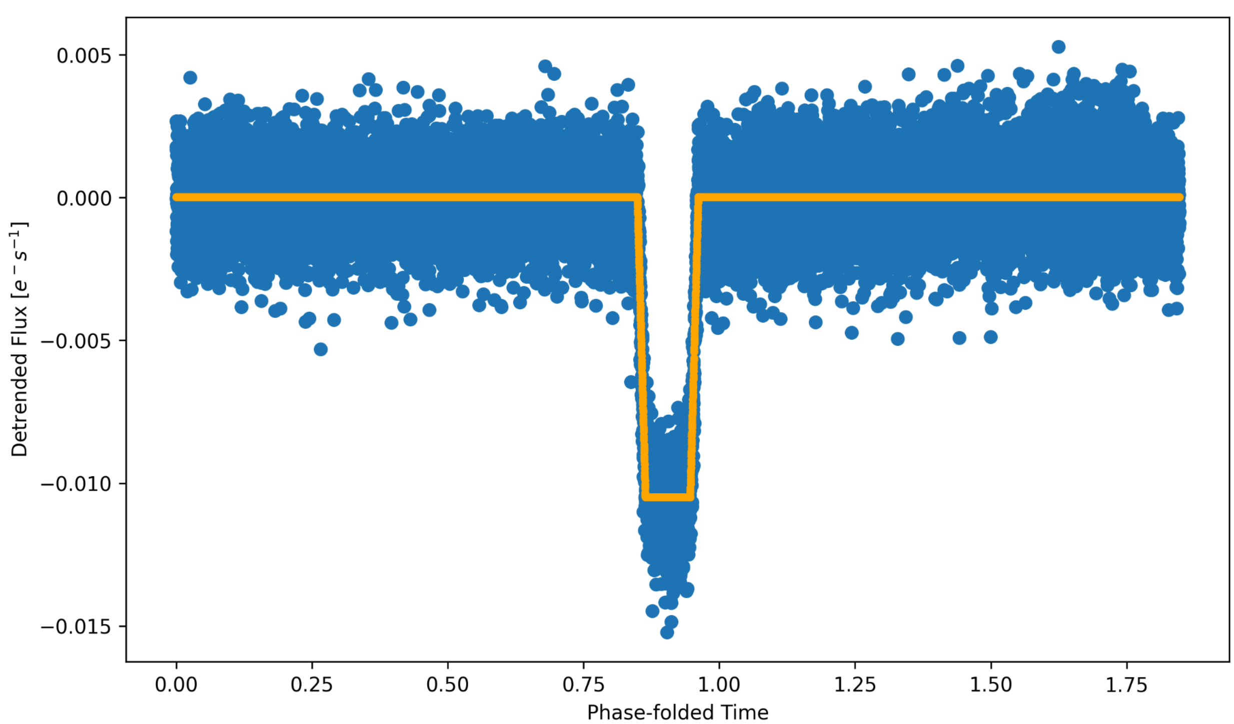
High Pass Filter
num_sigma = 6, polynomial_degree = 4



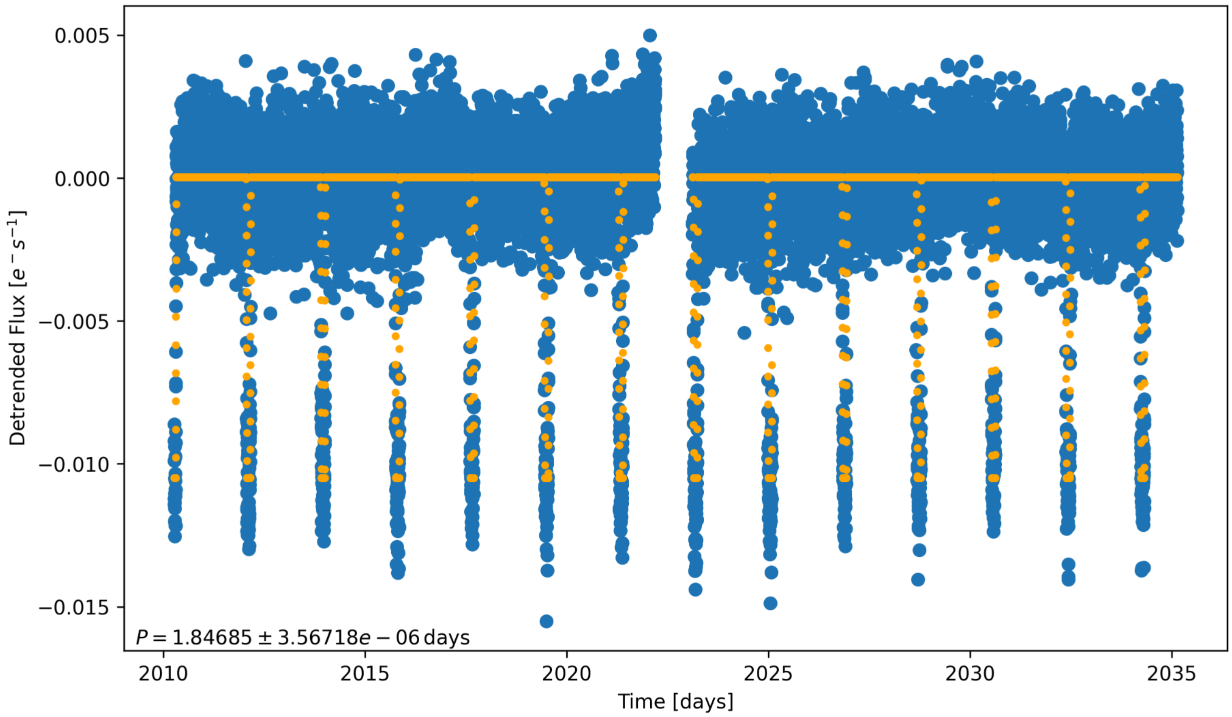
Detrended Flux



Phase Folded Time



Fitted Transit Ephemeris Overlay



1. The per-point uncertainty can be estimated using the median absolute deviation (MAD). The MAD is calculated as $MAD(y_i) = median(|y_i - \tilde{y}_i|)$ where $\tilde{y}_i$ is the median of y_i. From there, the per-point uncertainty can be calculated as $\sigma_i = 1.4826 \cdot MAD$.

```
median_flux = np.median(detrended_flux)
MAD = np.median(np.abs(detrended_flux - median_flux))
per_point_uncertainty = 1.4826 * MAD

print("Per-point uncertainty:", per_point_uncertainty)
```

```
Per-point uncertainty: 0.001310954854655373
```

Using my own transit data for WASP-3 b, I calculated the per-point uncertainty with the MAD as $\sigma = 0.00131$. Anomalously outlying data points will not affect my estimate using the MAD because it utilizes the median instead of the mean. If I were to calculate the standard deviation as $\sigma = \sqrt{< y_i^2 > - < y_i >^2}$, my per-point uncertainty would be sensitive to outliers because this method utilizes the mean of the points. The MAD naturally mitigates the effects of outliers, so there is no need to implement any techniques to help the per-point uncertainty estimation. If I was using other methods to calculate the uncertainty, I would remove outliers from my dataset before calculating the uncertainty. I did this, as shown in plot 3 above, by removing points outside $\pm\ 5\sigma$ from the Gaussian distribution.

2. The magnitude of a star is calculated as $m = -\ 2.5log(\frac{F}{F_0})$ where F is the observed flux of the star and F_0 is the reference flux. To find the change in uncertainty between my observed star (WASP-3) and a star 2.5 magnitudes brighter, I would first need to find the change in fluxes by calculating the difference between the magnitudes $m - m'$ where m' is the magnitude of the star 2.5 magnitudes brighter than WASP-3.
$m = -\ 2.5log(\frac{F}{F_0})$
$m - m' = 2.5$
$-\ 2.5log(\frac{F}{F_0}) - (-\ 2.5)log(\frac{F'}{F_0}) = -\ 2.5log(\frac{F}{F'}) = 2.5$
$(\frac{F'}{F}) = 10$
Every 2.5 magnitudes changes the flux by a factor of 10.
Number of photons:
$N = F \cdot A \cdot \tau$
$N' = F' \cdot A \cdot \tau$
$\frac{N'}{N} = \frac{F'}{F} = 10$
Uncertainty:
$\sigma = \sqrt{N}$
$\frac{\sigma'}{\sigma} = \frac{\sqrt{N'}}{\sqrt{N}} = \sqrt{\frac{N'}{N}} \simeq \sqrt{10} \simeq 3$
So, a star 2.5 magnitudes brighter would increase σ by a factor of 3.

3. According to the equation $\sigma_{t_c} = \sqrt{\frac{\tau}{2\Gamma}}\frac{\sigma}{\delta}$ – where σ_{t_c} is the uncertainty on the transit time, τ is the ingress or egress duration, Γ is the sampling rate for the data, σ is the per-point photometric uncertainty, and δ is the transit depth – if the photometric uncertainty were doubled, the uncertainty on the transit time would double. This makes sense because a greater photometric uncertainty means there are more fluctuations in the measured flux, meaning it is more difficult to interpret the exact transit time, therefore the uncertainty in transit time is greater. Doubling the transit depth would decrease the uncertainty of the transit time. This makes sense because a larger depth would make the transit more pronounced and easier to detect, therefore the uncertainty in transit time would be less. Changing different factors such as the photometric uncertainty and the transit depth changes the appearance of the signal, either introducing more noise or more clarity, which directly affects the uncertainty in the transit time.

4. The period of WASP-3 b, according to the NASA Exoplanet Archive, is 1.846835 days with an uncertainty of $\pm\ 2.0E - 6$. My period value for WASP-3 b is 1.84685 days with an uncertainty of $\pm\ 3.56718E - 6$. The difference between the periods is found using the function $f = P_{mine} - P_{NASA}$ which gives a value of $f = 1.84685 - 1.846835 = 1.5E - 5$. The uncertainty can be found with the equation $\sigma_f^{\ 2} = \sum(\frac{\partial f}{\partial P})^2\sigma_P^{\ 2}$ which is reduced to $\sigma_f = \sqrt{\sigma_{mine}^{\ \ 2} + \sigma_{NASA}^{\ \ 2}}$. Using the uncertainty values, the uncertainties in quadrature is $\sigma_f = \sqrt{(3.56718E - 6)^2 + (2.0E - 6)^2} \approx 3.66785E - 6$. My results do not exactly agree with the values from the archive, but they are close enough that any differences in values are barely noticeable. Possible errors in my data could be the result of noise in the signal that was not properly accounted for in my analysis. Overall, my results are fairly accurate compared to the archive data.

5. WASP-3 next visibility:
   Calendar date: 2024-04-28 22:00:00
   Julian date: 2460429.41667

   $T_0 = 0.4525617986194887$
   $P = 1.846835$
   $T_{0,JD} = 0.4525617986194887 + 2457000 = 2457000.4525617986194887$
   $t_c = T_0 + PE$
   $2460429.41667 \leq 2457000.4525617986194887 + 1.846835 \cdot E$
   Where E is the minimum integer value that makes this relationship true
   $E = 1857$
   Next date when WASP-3 b can be observed transiting:
   $t_c = 2457000.4525617986194887 + 1.846835 \cdot 1857$
   $t_c = 2460430.0251567983$
   This Julian date translates to the calendar date 2024-04-29 12:36:13.55. However, this is during the day, and the next closest E for which the transit could be observed at night is 1858 which gives a Julian date of 2460431.8719917983 or a calendar date of 2024-05-01 8:55:40.09. Although this is shortly after sunset, it allows for enough time to observe the entire transit which lasts 5h 48m according to Stellarium.