PHYS305 Observing Project

Project Summary

This end-of-term project for PHYS305 is designed to familiarize students with the processes involved in astronomical observing. It will involve downloading archival NASA data from the TESS Mission (https://exoplanets.nasa.gov/tess/), conditioning those data, and then applying a numerical model to them. To complete the project, students will need to submit a short write-up of their analysis. Details on all these aspects appear below. The final project write-up is due by Monday, Apr 29 at 12p MT and should be submitted on Canvas.

Data Analysis Process

1. Download and install the Lighkurve python package on your computer - https://docs.lightkurve.org/. You can use the MP301 lab computers, too, if you can't or don't want to use your own computer.

2. Find a hot Jupiter the transit for which you will analyze. Choose from one of the following targets: Kepler-1, TIC 431701493 (aka WASP-10), TIC 292152376 (HAT-P-32), TIC 233948455 (TrES-5), TIC 116264089 (TrES-3), HAT-P-19, TrES-1, Qatar-1, GJ436 (Gliese 436), XO-1, WASP-48, or WASP-3. Look up the planets' parameters using the NASA Exoplanets Archive - https://exoplanetarchive.ipac.caltech.edu/cgi-bin/TblView/nph-tblView?app=ExoTbls&config=PS.

3. To conduct your analysis, use the Jupyter Notebook Observing Project Notebook.ipynb posted on Canvas (and available here - https://github.com/decaelus/PHYS305_Spring2024/blob/main/Observing_Project/Observing%20Project%20Notebook.ipynb). You'll need to change the name of the planet and make a few tweaks throughout the notebook (see notes therein).

4. Be sure to save the figures created by the notebook into your final document.

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?

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?

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?

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 $f = P_{\text{yours}} - P_{\text{theirs}}$, 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?

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.