Project 1: Searching for Exoplanets with The Transit Method

Start Assignment

Due Feb 17 by 11:59p.m. **Submitting** a file upload **File Types** pdf
Available Jan 30 at 9a.m. p.m.

For nearly 20 years, astronomers have been monitoring the brightness of distant stars in an attempt to determine whether or not any of them host a planetary system. A measure of a star's brightness as a function of time is known as a light curve. Periodic fluctuations within a star's light curve are an indication that planetary transits *may* be occurring, where a planet is periodically passing between Earth and the distant star causing a temporary decrease in its brightness (although fluctuations can be caused by other astrophysical phenomena as well!). Over 5000 confirmed exoplanets have been detected via this Transit Method, mostly due to the Kepler Space Satellite and the Transit Exoplanet Survey Satellite.

In Project 1, you will be provided with simulated light curves that are comparable to those studied by astronomers today. Through an analysis of these light curves, you will determine whether or not your target star has any planets orbiting around it and what some of their properties are. You will also be asked to infer what other properties the planet(s) may have. Both course materials and independent sources will have to be consulted in order to complete this project.

Materials

Each student will be provided with three independently generated light curves named C1, C2, and C3. Please note that each set of light curves will be unique to each student. Your specific dataset can be found at the below link, within a folder named after your UTORID

https://www.astro.utoronto.ca/~ast251/AST251_2023_Project1/ (https://www.astro.utoronto.ca/~ast251/AST251_2023_Project1/)

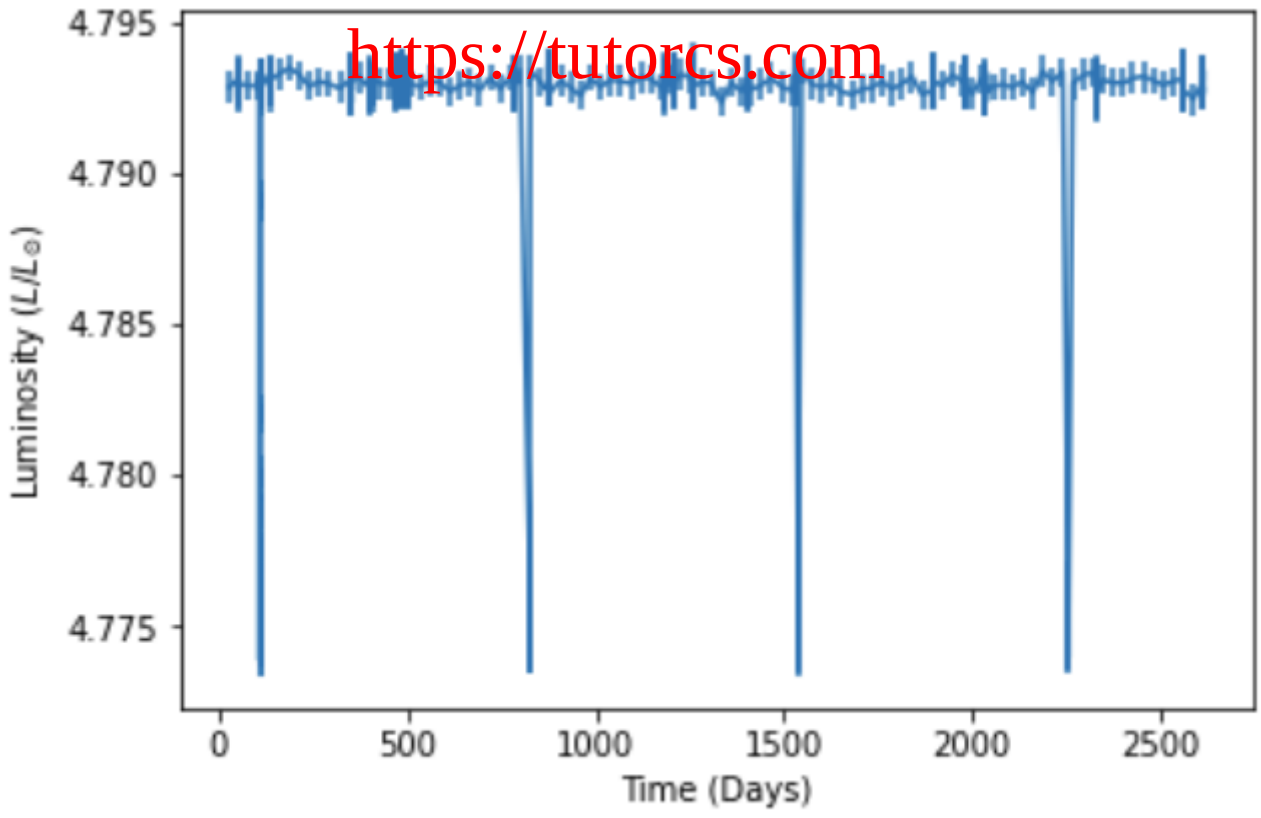
Each of the three files should be downloaded right away and inspected on your personal computer. If you don't have experience with comma separated values (csv) files, note that they can be opened with Microsoft Excel. However you may use any software program that you wish (e.g. Google Sheets, TOPCAT). As indicated in the below image, each file contains measurements of the star's light curve, the star's mass, and the star's radius. The first three columns mark the time of a brightness measurement (in days), the star's brightness (in solar luminosities), and the uncertainty in the star's brightness (in solar luminosities). The sixth column notes the star's mass (in solar masses) and the star's radius (in solar radii). Remember that solar units are units that are relative to the Sun. A star that is 0.8 solar luminosities is 80% as bright as the Sun. A star that is 1.5 solar radii has a radius that is 1.5 times the radius of the Sun.

	A	B	C	D	E	F
1	Time (Days)	Brightness (solar luminosities)	Brightness uncertainty (solar luminosities)		Star Mass (solar masses)	1.48
2	26.68207	4.79286705	5.00E-04		Star Radius (solar radii)	1.448
3	48.99635	4.79310812	4.40E-04			
4	49.00787	4.79293852	5.00E-04			
5	49.0194	4.79336767	5.40E-04			
6	49.03093	4.79300197	4.80E-04			
7	49.04246	4.79317541	4.50E-04			
8	49.05398		4.50E-04			
9	49.06551		4.70E-04			
10	49.07704		4.80E-04			
11	49.08857		4.90E-04			
12	49.10009		5.30E-04			
13	49.11162		4.90E-04			
14	49.12315		4.70E-04			
15	49.13468		5.20E-04			

For a given dataset, the star you are studying may have anywhere between 0 and 4 planets orbiting around it. While these light curves are artificial, state-of-the-art models have been used to generate them in order to include the effects that we discuss in class (limb darkening, variable impact parameter, secondary eclipses, stellar variability, and stellar activity). However, it should be noted that these effects are not always clear on a given light curve as their magnitudes are variable (analogous to studies of real light curves).

Analysis

The first part of your analysis will be to simply plot all three of the light curves, with time on the x-axis and brightness on the y-axis. The uncertainties in brightness should be included in the graph. An example of such a plot would be:



Once you have examined all three light curves, select two that you wish to analyze and use for submission. The third light curve can be ignored, as we will only grade two submitted light

curves.

For the two light curves that you have elected to analyze:

- determine the number of planets orbiting the star
- note the times at which each planet's primary transit occurs
- measure each planet's orbital period
- estimate each planet's

Project Questions

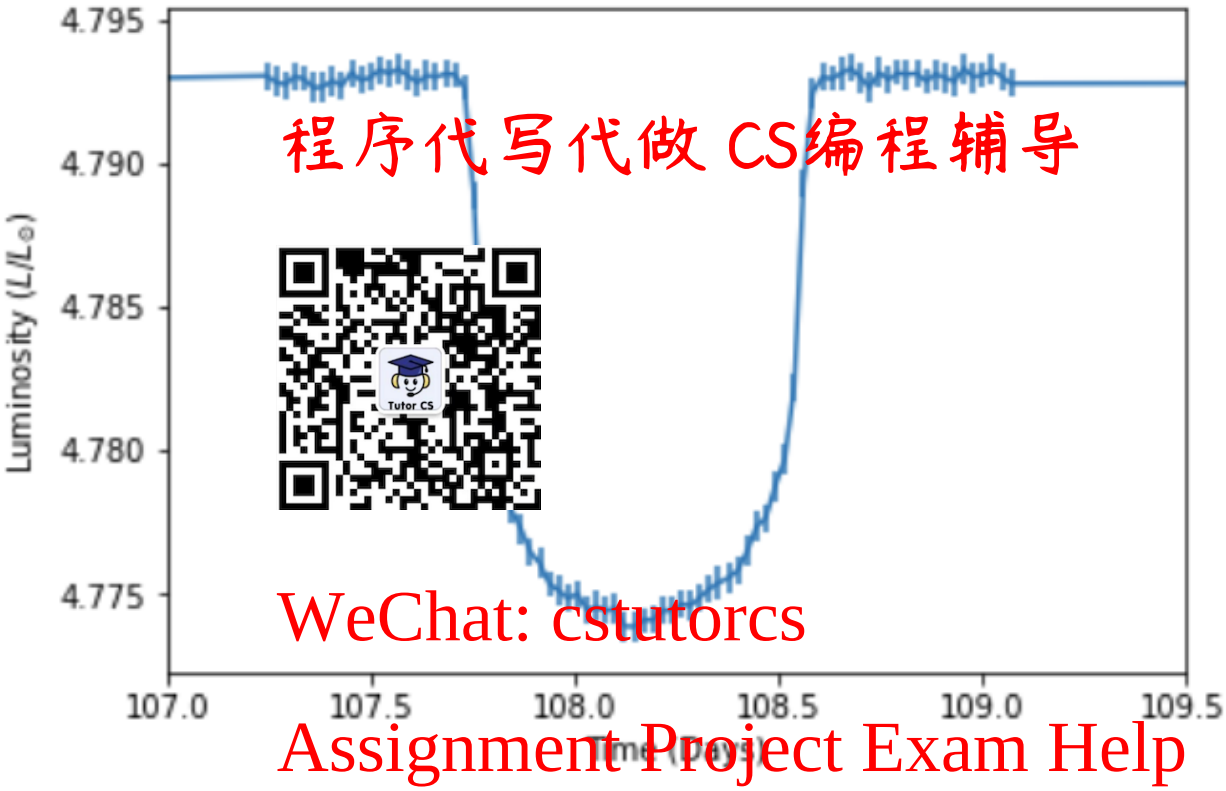
Given your light curves, yo following questions:

- What properties of these planets can you derive from the information given, other than their orbital periods and radii?
- What evidence supports your claim about the type of each planet? Cite evidence from your light curve as well as independent research to support your claim.
- What can you say about the habitability of this planet to life-like-us based on the evidence alone?
- How confident are you in your conclusions? What information would you need to increase your confidence. Be specific!

Submission

Please submit the following by Friday February 17th at 11:59 pm:

- A graph of each light curve, in its entirety, with the transits of each planet clearly labeled. Please label the planets based on the star they're orbiting and the order in which they undergo their first transit. So the first transiting planet in the C1 dataset should be labeled C1/Planet 1, the second transiting planet in the C1 dataset should be labeled as C1/Planet 2, and so on. The labels should be in different colours. If a given planet undergoes more than 3 transits, just label the first 3.
- A zoomed-in graph of one of each planet's primary transit. It is important that you choose a well-resolved primary transit such that the detailed shape of the transit can be seen. Several transits may only have a few datapoints, which would make them poor choices to show for your zoomed-in transit. An example of a zoomed-in transit would be:

- 

- A table that lists the properties of each planet that you believe to be orbiting around your two stars. The table should include each planet's orbital period (in years), its radius (in Earth radii), and a note regarding the type of planet you think it is as per the questions above.
- Answers to the project questions:
- A list of references used by you in the completion of the project. Sources should also be cited **in-line** in your answers and table. Your references must be high-quality sources that have been peer-reviewed or edited by an expert in the field (i.e. not somebody's lecture slides, wikipedia, blog post, or twitter feed). You may use any citation style that you like, please just be consistent. See the University of Toronto's **Citation Guide (https://guides.library.utoronto.ca/c.php?g=251103&p=1673071)** for some help with proper citations. For web-based references, you must include the full URL in your citation.

Your complete submission should be a single PDF that contains no more than 3 pages of analysis and 4 pages of figures and tables. The bibliography has no page limit, as there is no limit to the number of sources used in the project. Be sure to include a sample calculation for any calculations made throughout the analysis with all of the steps. **Remember that you only need to submit an analysis for 2 out of the 3 datasets. If more than two are submitted, the third dataset will be ignored.**

Additional Notes

- When working to estimate the type of planet you have discovered, be aware that there are no formal rules on how to define planet type. There have been many attempts to establish some fixed criteria (i.e a planet of size X, mass Y, and orbital period Z is a Hot Jupiter), but these are generalizations based on the growing number of planet detections. There are no official rules. So you are encouraged simply to focus on the evidence at hand, take into consideration the properties of each star and the planets that you detected, and come to an evidence-based

conclusion regarding the planet type. You should not make assumptions about the planet's unknown properties.

- Due to the uniqueness of each dataset, some questions may be difficult to answer for a given light curve. If you find that your dataset does not allow you to answer one of the Project Questions above, be sure to explain what it is about the dataset that makes it difficult and discuss what you would need to be improved in order to answer the question accurately.
- You are all encouraged to discuss the project amongst yourselves, but the submitted work must be done by you and you alone. Collaborating on another student's analysis is an academic offense.

Support

In addition to the AST 251 Team being available to answer questions after class or during office hours, there will be a dedicated Project 1 drop-in help session on Monday February 13th from 10:00 am - 12:00 pm in AB-88.

Project 1			
Criteria	**Ratings**		**Pts**
Image Quality	**6 pts** **Full Marks** All graphs are clearly plotted with axis labels. Transits are clearly labelled following the planet naming convention. The zoomed-in graphs clearly resolve a transit.	**0 pts** **No Marks**	6 pts
Table	**6 pts** **Full Marks** All planets are listed in the table, each property is calculated correctly, notes for each planet's type are included.	**0 pts** **No Marks**	6 pts
Project Questions	**8 pts** **Full Marks** Each question is answered clearly and with sufficient detail (2 marks per question)	**0 pts** **No Marks**	8 pts
References / Sample Calculations	**4 pts** **Full Marks** In-line citations are provided throughout the submission, with a complete list of citations attached at the end as a bibliography. All citations are appropriate (peer reviewed, edited, etc.) Sample calculations are provided for each calculation made in the assignment.	**0 pts** **No Marks**	4 pts
		Total Points: 24	