ScienceNews

Activity Guide for Students: The Hunt for Other Worlds

Directions:
During this activity, you will pretend to be astronomers studying an exoplanet orbiting the star GSC 00522-01199 to confirm its presence and determine information about it. Your team has collected data by the transit method, using a 0.8-meter reflecting telescope pointed toward the star, which lies in the constellation Delphinus. The attached data sheet shows the processed data, which you will use to create a light curve.

This activity could take place in the classroom or in a virtual environment. If the activity takes place virtually, your teacher will make arrangements for you to participate in classroom discussions and share your data. Follow your teacher's instructions for getting set up to discuss and share remotely.

Homework reading and questions for students
Before studying the data, you need to understand what an exoplanet is and how it can be detected. Start by reading information at the following websites:

NASA Exoplanet Exploration, including 5 Ways to Find a Planet
What are exoplanets?, from EarthSky
Your Guide to Exoplanets, from The Planetary Society

You can also search for information from reputable sources such as NASA, as well as *Science News* and *Sciences News for Students*, to answer the following questions before class to gather some background information about exoplanets.

Then use the knowledge you have gathered to apply to the dataset of the exoplanet.

1.What is an exoplanet?

2. What was the first exoplanet to be discovered? When and how was it discovered?

3. Describe the four main methods of exoplanet detection.

4. To date, approximately how many exoplanets have been discovered? You may notice different numbers such as "confirmed" or "candidates." What is the difference between them?

5. About how many exoplanets have been discovered by each detection method?

6. What is the approximate range in mass of confirmed exoplanets?

7. What are the nearest and farthest discovered exoplanets? What method(s) were used in their discovery?

8. What is the habitable zone around a star? Is it the same for each star?

9. Have any exoplanets been found in the habitable zone of their host stars?

10. During class you will act like an astronomer who has gathered data while studying a potential exoplanet You will use this data to create a graph showing how the amount of light measured changes over time. Which value will go on the x-axis and which will go on the y-axis? How do you know?

Group discussion about exoplanets

Your teacher will lead your class or small groups in discussions about what you learned from your research about exoplanets. Share any insights that you have about exoplanets.

1.Which of these detection methods has been the most successful for discovering exoplanets? Why do you think that is?

2. In addition to studying the target stars that might host an exoplanet, astronomers also use several nearby stars to gather comparison data. Why do they do this?

3. Most of the exoplanets discovered early were very large, including some that are several times the mass and radius of Jupiter. Why do you think the larger exoplanets were discovered first?

Detecting exoplanets
Many astronomers rely on automatic surveys of the sky to alert them to potential targets of interest. For example, NASA's Kepler mission focused on a single patch of sky for its first four years. When the gyroscopes that kept the telescope steadily focused on that patch of sky began to fail, the NASA team had to make adjustments. The result was that the Kepler's focus had to be widened, and it could no longer "stare" for such long periods of time. But the mission continued to discover objects. Data from the Kepler space telescope's nine years of operation were used to discover more than 2,800 transiting exoplanet candidates, over 2,600 of which have been confirmed.

Other land-based telescope surveys study the sky and alert astronomers to slight anomalies that could indicate an exoplanet. Follow-up observations are then taken with other telescopes. Images may be taken a few seconds to several minutes apart. Each image is then studied and compared with others in the dataset to find the anomalies and determine if the anomaly could indicate an exoplanet. The amount of light measured from a host star is called the "flux," which is the rate of the amount of energy reaching the telescope instruments per unit of time and is dependent on the luminosity of the star and its distance from Earth.

For this part of the activity, you will pretend that you are an astronomer who has collected data about an exoplanet transiting the star GSC 00522-01199 in the constellation Delphinus using a 0.8-meter reflecting telescope. Your transit data were then processed to take into account comparison stars and the changing atmospheric conditions. The data have also been normalized, meaning that the average brightness of the target star was given a value of 1, while complete darkness was given a value of 0.

You will use these data to create a graph, which you will then use to confirm the presence of an exoplanet. Your graph and answers to the questions on the Detecting Exoplanets worksheet, found below, will help you gather information about the exoplanet, including its movement through its star system.

Detecting Exoplanets worksheet

1. What do you expect will happen to the normalized flux from a transiting exoplanet as the exoplanet passes in front of its star? What will the plot look like?

2. If the normalized flux dipped from 1 to 0.5, what does that suggest about the light from the star?

3. Why does the data table include a column for "error?" What does "error" mean in scientific data?

4. Plot the data points from the data sheet to create a light curve by copying and pasting the data into Google Sheets, Excel or a similar graphing program or by plotting on graph paper. Make sure that the independent variable is graphed on the x-axis and the dependent variable is on the y-axis. Include a title for your graph, labels for the x-axis and the y-axis and units as needed. Insert a screenshot or photo of your light curve below.

5. Based on what you have learned about exoplanet detection methods, does your graph of the data support the presence of an exoplanet? Explain your reasoning.

6.This type of data is normalized so that the average brightness of the target star is 1 and complete darkness is 0. However, when you look at the data points on the y-axis, what do you notice? What do you think this indicates?

7. If you wanted to include the error column's data in your graph, how would you represent it? What could have caused these errors?

8. What are your observations of your light curve? Are your observations in line with what you thought you would see in your light curve?

9. The "depth" of transit is the amount of light from the star that is blocked by its exoplanet when the exoplanet is between the star and Earth. What is the approximate depth of transit (as a percentage) for your exoplanet?

10. The approximate size of the planet can be found using the equation:
R_planet = R_star $\sqrt{(\textit{depth of transit})}$
If the radius of the star is 0.834 solar radii (0.834 times the radius of our sun), what is the radius of the planet?

11. How does the size of the exoplanet compare with a planet within our own solar system?

12. What points on your light curve could you use to calculate the time it takes the exoplanet to complete its transit? Why?

13. Based on your graph, how long does the exoplanet take to transit its star using your defined points from the previous question?

14. Multiple, consecutive light curves are needed to calculate an exoplanet's orbital period (year). (An exoplanet's year is the time it takes to orbit its star once.)
Kepler's third law $P^2 = \frac{4\pi^2}{G(M_1+M_2)}a^3$ allows us to calculate the distance (a) between a star and its orbiting planet, if we know the masses of the star and planet and the planet's orbital period. When the mass of the planet (M_2) is very tiny compared with the mass of its star (M_1), we can assume that the sum of the two ($M_1 + M_2$) will be about the same as the mass of the star alone (M_{star}).

If the orbital period (P) of your exoplanet is 51.7 hours, and the mass of the star (M_1) is 0.84 solar masses (0.84 times the mass of our sun), what is the distance (a) between the exoplanet and its star in kilometers? Note that *G* is the gravitational constant, which is equal to 6.673×10^{-11} $m^3kg^{-1}s^{-2}$.

15. Not all information about an exoplanet can be determined from a single light curve. What additional information would you need to calculate further details about the exoplanet?

Possible extension
As a supplemental activity, your teacher may have you create a model of the exoplanet. Use the data, light curves and calculations to help you create your models. Be sure to explain what properties of the exoplanet and exoplanet star system you cannot model based on the information provided, what other information you would need to find those properties and how to find that information. If time allows, your teacher may ask you to present your model to the class.

Data sheet for GSC 00522-01199

This is the data you collected on the exoplanet orbiting the star GSC 00522-01199 in the constellation Delphinus using a 0.8-meter reflecting telescope.

Timestamp (hh:mm)	Normalized flux	Error (+/-)
4:55	1.0014745	0.001357
5:02	1.0009931	0.0013506
5:13	1.0002007	0.001361
5:22	1.0002247	0.0017181
5:29	0.9974525	0.0017975
5:35	0.9929189	0.0013696
5:42	0.9892178	0.0015124
5:52	0.9872619	0.0014387
6:02	0.9848948	0.0016819
6:08	0.9836611	0.0014069
6:15	0.9847644	0.0014103
6:21	0.9844735	0.0014168
6:31	0.9839419	0.0014278
6:38	0.9875026	0.0014305
6:44	0.9860282	0.0014283
6:53	0.988646	0.0014293
6:57	0.9939921	0.0014285
7:01	0.9944936	0.0014264
7:07	1.0003166	0.0014347
7:13	0.9988466	0.0014309
7:26	0.9991576	0.0014514
7:36	1.001447	0.0014657
7:45	1.0003812	0.0014951
7:50	0.9989369	0.0015045
8:00	1.0002748	0.0015589
8:15	0.9991748	0.0015569

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