Detecting Extrasolar Planets with the Transit Method

If an extrasolar planet passes in front of its star, as seen from Earth, then that extrasolar planet will block some of the star's light and prevent that light from reaching Earth, causing the star to appear dimmer. If we observe the star over a long period of time and the star goes through an on-going cycle of appearing bright, then dimmer, then bright again, then astronomers may conclude that there is an extrasolar planet orbiting that star. This technique for finding extrasolar planets is called the **transit method** since it relies on an extrasolar planet transiting (passing in front of) and blocking some of the light of its star.

Figures 1-3 below show the orbits of three extrasolar planets around their stars.

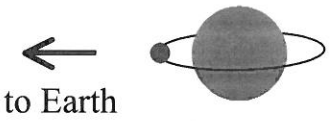


Figure 1

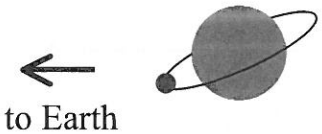


Figure 2

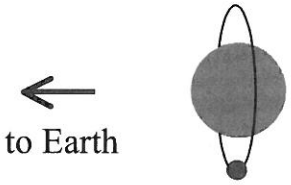
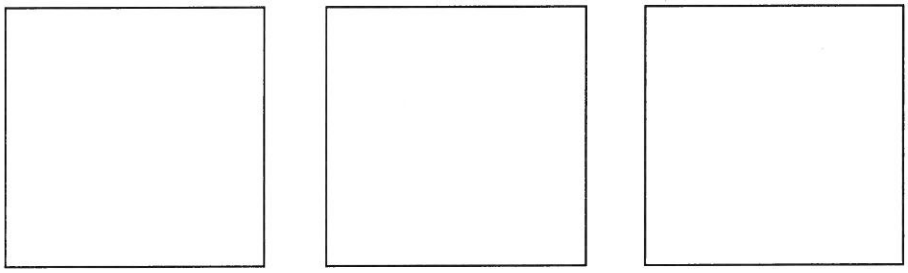


Figure 3

1) Which of the above figures (Figures 1-3) shows a situation in which astronomers on Earth could detect the presence of the extrasolar planet using the transit method? There may be more than one correct answer. Explain your reasoning.

2) Which of the above figures (Figures 1-3) shows a situation in which astronomers on Earth could not detect the presence of the extrasolar planet using the transit method? There may be more than one correct answer. Explain your reasoning.

3) Imagine that you observed a star being orbited by an extrasolar planet. When you begin observing ("Time 1"), the extrasolar planet is in front of the star. A little later ("Time 2"), the extrasolar planet has moved so that only a fraction of its surface is in front of the star. At an even later time ("Time 3"), the planet has moved so that no part of its surface is in front of any part of its star. Imagine you have a telescope that is powerful enough to allow you to see both the star and the extrasolar planet (note that the vast majority of real telescopes are not this powerful). In the space below, draw three sketches showing what the star and extrasolar planet would look like from your view on Earth for each of these three times described above.

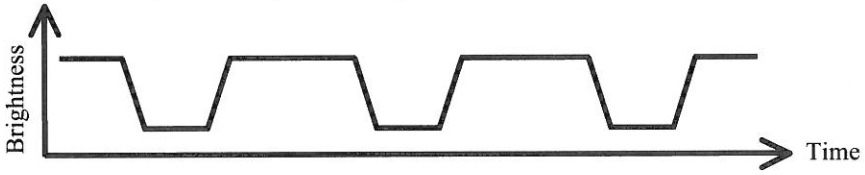


Time 1 Time 2 Time 3

4) At which of the times you drew would you measure the greatest amount of light coming to you from the star? Explain your reasoning.

5) At which of the times you drew would you measure the least amount of light coming to you from the star? Explain your reasoning.

The graph below shows how the amount of light we detect from the star changes over time due to the fact that the star's light is being blocked by the extrasolar planet.



6) Using the letter "A," label the locations on the graph that correspond to the times when the extrasolar planet is completely in front of the star. Explain your reasoning.

7) Using the letter "B," label the locations on the graph that correspond to the times when the extrasolar planet is not in front of the star at all. Explain your reasoning.

8) Using the letter "C," label the locations on the graph that correspond to the times when the extrasolar planet is moving from not being in front of the star at all to being completely in front of the star. Explain your reasoning.

9) Describe what the extrasolar planet is doing when the light we detect from the star begins to increase from the least amount of light to the most amount of light.

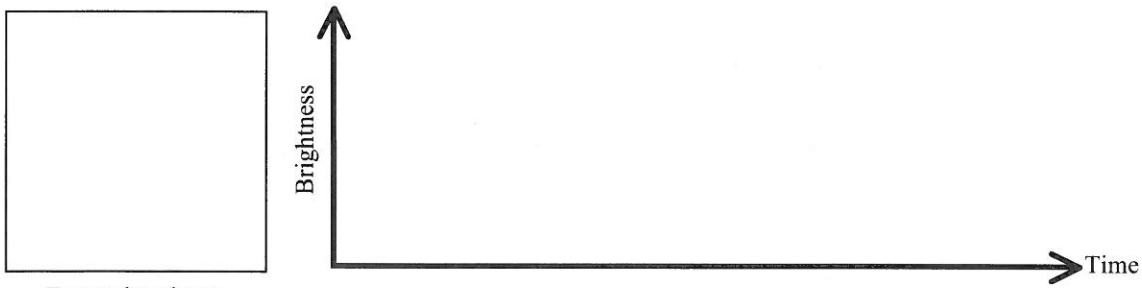
10) Explain why the bottoms of the dips in the graph are horizontal lines rather than points.

11) You observe two identical stars that are each being orbited by an extrasolar planet. Both extrasolar planets orbit at the same distance from their stars, but one planet is bigger than the other. In the appropriate spaces below, draw the extrasolar planets and their stars and sketch the corresponding graphs of the brightnesses of the stars over time.

For the planet that blocks the most light:

Extrasolar planet and star

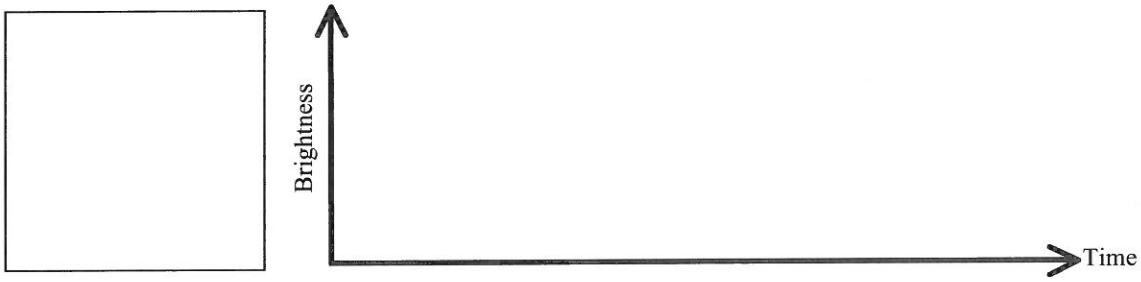
For the planet that blocks the least light:



Extrasolar planet and star

12) You observe two identical stars that are each being orbited by an extrasolar planet. Both extrasolar planets are the same size, but one planet takes longer to orbit its star than the other. In the appropriate spaces below, draw the extrasolar planets and their stars and sketch the corresponding graphs of the brightnesses of the stars over time.

For the planet that has the longest orbit:

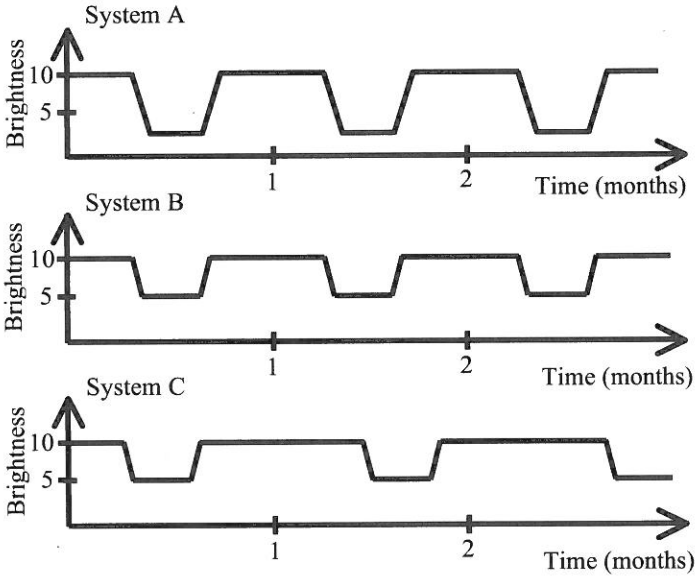


Extrasolar planet and star

For the planet that has the shortest orbit:

Extrasolar planet and star

Below are three graphs that show how much light we detect from three identical stars. Each star is the same distance away from Earth, and each star is orbited by a single extrasolar planet. Use these graphs to answer the following two questions



13) Of the three extrasolar planet-star systems (Systems A-C), which two have extrasolar planets that are the same size? Explain your reasoning.

14) Of the three extrasolar planet-star systems (Systems A-C), which two have extrasolar planets that take the same amount of time to complete an orbit? Explain your reasoning.

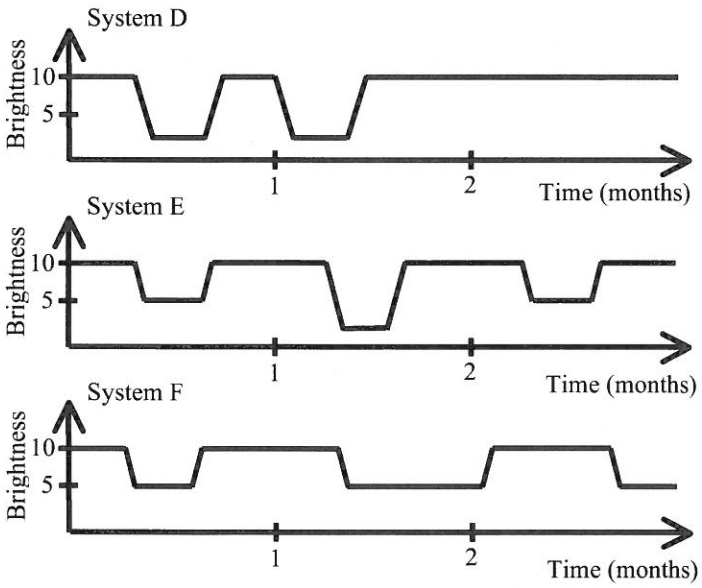
15) Three students are discussing their answers to Question 14:

Student 1: *I think the extrasolar planets in Systems B and C take the same amount of time to complete their orbits. If you look at the dips in the graph, the planets in Systems B and C produce dips that have the same width. This means both must be travelling at the same speed and so they must take the same amount of time to complete their orbits.*

Student 2: *I think the extrasolar planets in Systems A and B take the same amount of time to complete their orbits. If you look at their graphs, you see that about a month passes between when the first dips begin and when the second dips begin for both Systems A and B. The width of the dips depends on the sizes of the planets, not how long they take to complete their orbits.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

16) When an extrasolar planet orbits a star, it makes a pattern of dips in the graph of the brightness of the star over time. The same amount of time passes between each dip and each dip has the same depth. Below are three graphs of the brightness of three identical stars over time. How many of these graphs match what you should see if each star is orbited by a single extrasolar planet? Explain your reasoning.



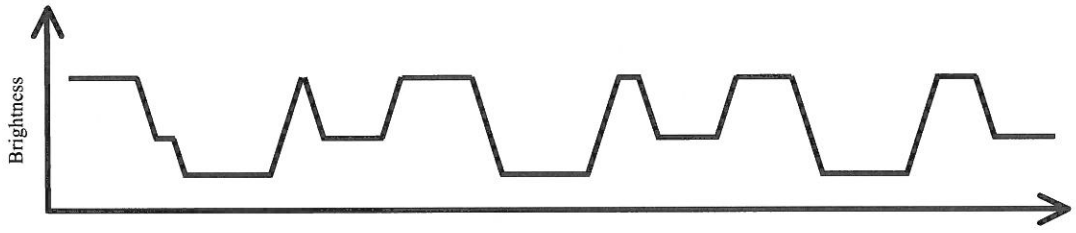
17) Imagine you are an astronomer outside of our solar system. How long would you have to monitor the light from the Sun in order to detect four dips in the Sun's brightness due to Earth? Explain your reasoning.

18) If we move Earth closer to the Sun, would the time it takes to complete an orbit increase, decrease, or stay the same? Explain your reasoning.

19) If you can only observe a star for a limited amount of time (*e.g.*, 6 months), are you more likely to find planets that orbit close to their star or far away from their star? Explain your reasoning.

20) If we move Jupiter so that its orbit is the same size as Earth's and it took as long to orbit the Sun as Earth, then which would be easier to detect from outside the Solar System: Earth or Jupiter? Explain your reasoning.

The graph below shows how much visible light we receive from a star over a period of time. Use this graph to answer the following three questions.

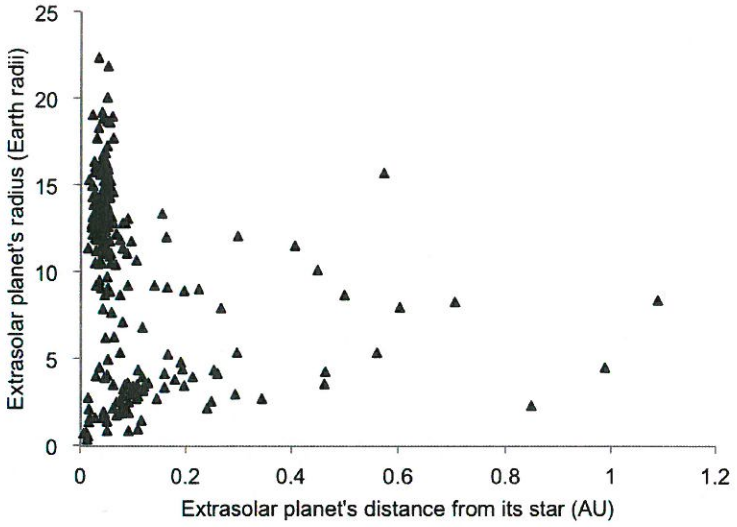


21) How many extrasolar planets orbit this star? Explain your reasoning.

22) How do the periods of the extrasolar planets compare? Explain your reasoning.

23) Which of the planets is bigger and which is smaller? Explain your reasoning.

For extrasolar planets discovered with the transit method, the graph below shows the radius of the discovered extrasolar planets versus the distance of those planets from their stars.



24) Are most of the discovered extrasolar planets bigger than Earth or smaller than Earth?

25) Are most of the discovered extrasolar planets farther from their stars than Earth is from the Sun or are they closer to their stars than Earth is from the Sun?

26) Which of the following best explains the trend we see in the graph above:
   a) Most extrasolar planets in the galaxy are really big and orbit really close to their stars.
   b) Big planets that orbit close to their stars are easier to detect using the transit method than other types of planets.

   Explain your reasoning.