

Investigation: Transit Tracks

Students will learn

- what a transit is
- under what conditions a transit may be seen
- how a planet's size and distance from its star affect the behavior of transits
- how to interpret graphs of brightness versus time to deduce information about planet-star systems.

Materials and Preparation

- Clip-on lamp with frosted spherically shaped low wattage (25 W maximum) bulb
- 4 beads, various sizes (3-12mm) and colors on threads of various lengths (20-100cm).
- Transit Light Curves (below): one copy per group
- Graph of Kepler's 3rd Law one copy per group
Download from <http://kepler.nasa.gov/ed/lc>
- Blank paper and pencils or pens (1 per student)
- Read account of Jeremiah Horrocks observations of the transit of Venus: Download from:
<http://kepler.nasa.gov/ed/lc/horrocks.html>
- Optional: light sensor and computer with sensor interface and graphing function.

A. What is a transit?

1. **Introduce students to the concept of transits** by reading the account of the transit observation by J. Horrocks.
2. **Demonstrate a transit** by positioning the clip-on lamp at a height between standing eye-level and seated eye-level. Swing the largest bead on a thread in a circle around the lamp, with the lamp at the center in the plane of the orbit. Tell the class that the light bulb represents a star and the bead a planet; the planet is orbiting its star, like the Earth or Venus orbit the Sun.
 - a. With students seated, ask if anyone can see the bead go directly in front of the star. If the lamp is high enough above the floor, none of the students will be able to see the bead go directly in front of the star.
 - b. Ask students to move to where they can see the bead go directly in front of the star--it's OK to stand or crouch. After a show of hands indicates everyone can see that event, confirm that is what we mean by a transit—an event where one body goes in front of another, like a planet crossing in front of a star.

B. How does a planet's size and orbit affect the transit?

To see how a planet's diameter and orbit affect transits, orbit other beads around the light. Make those with shorter threads go in smaller radius orbits with shorter period. Define "period" as the time for one orbit. Ask the students what's different about the planets. They should identify: size, color, period, distance from the star. Ask if there is any relationship between the planet's period and its distance from the light. They should notice that the farther it is from the light, the longer the period.

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C. Interpreting Transit Graphs

1. **Imagine a light sensor.** Have students imagine they have a light meter to measure the brightness of the star (light bulb). Move a large opaque object (e.g. a book) in front of the star so that its light is completely blocked for all the students. Ask, "If we plotted a graph of brightness versus time—with brightness measured by our light sensor—and the book transits the star for 3 seconds, what would the graph look like?" Have volunteers come up and draw their ideas on the board and explain them. We would expect the graph to look like "Fig. 1: Book Transit" (below) with a 100% drop in brightness for 3 sec.
2. **Graph for an orbiting planet.** Ask the students, "What would a graph look like for the orbiting planet, plotting brightness versus time?" Have volunteers draw their ideas on the board, and explain them. If they do not indicate the idea that the dips in brightness would be very narrow and that their depth would depend on the size of the beads/planets, ask them questions about how wide and deep the dips should be. We would expect the graph to look like the one shown in "Fig. 2: Planet Transit" as a horizontal line with dips in brightness to some small percentage less light.
3. **Analyze light curves.** Hand out the *Transit Light Curves* to each group of 2-5 students and have them interpret the graphs. Pose these questions: How big is the planet compared with the star? How big is the planet compared with Earth? (Assume the star has the same mass and area as the Sun; an Earth-size planet would make a 0.01% drop in brightness.) What is/are the period(s) of the planet(s) in Earth years? How far is the planet from its star? (Use graph of Kepler's 3rd Law, which is explained in downloaded activity file.) Lead a class discussion about the graphs, ultimately aiming at answering these questions.
4. **What the graphs can tell us.** Explain that with transit data, it is possible to calculate a planet's diameter and the distance from its star. Ask, "Why do you think those two properties, planet diameter and distance from star, might be important?"

D. Going Further — Optional Activities

1. **Create and Trade Light Curves.** Have students create their own light curves, choosing planet size and orbit radius, then trade graphs with other students/groups to figure out what kind of planetary system they created.
2. **Collect Real Data.** Use a light sensor with computer interface, and graphing software. Aim the light sensor at the light-in the plane of the planet/bead orbit. Collect brightness data and display the computer plot in real time. Let the students comment on what they are observing. You may also use an orrery, a mechanism to model planets orbiting their star. Instructions for building a LEGO™ orrery are at <http://kepler.nasa.gov/ed/lego.html>
3. **Optional: Transit Math.** Have the students compute the planet size (from transit depth) and distance from its star from the transit period and Kepler's 3rd Law. Instructions are at <http://kepler.nasa.gov/ed/lc>

Transit Light Curves

Figure 1: Planet Transit

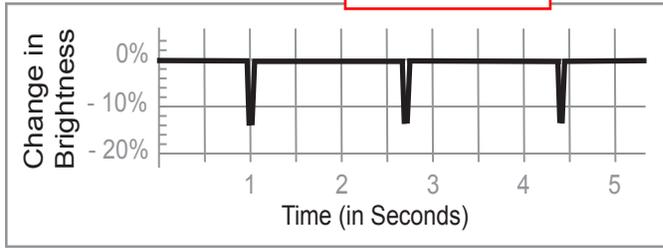
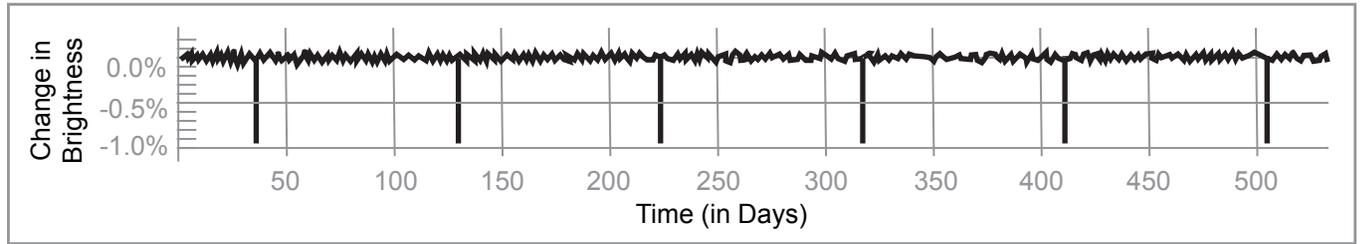


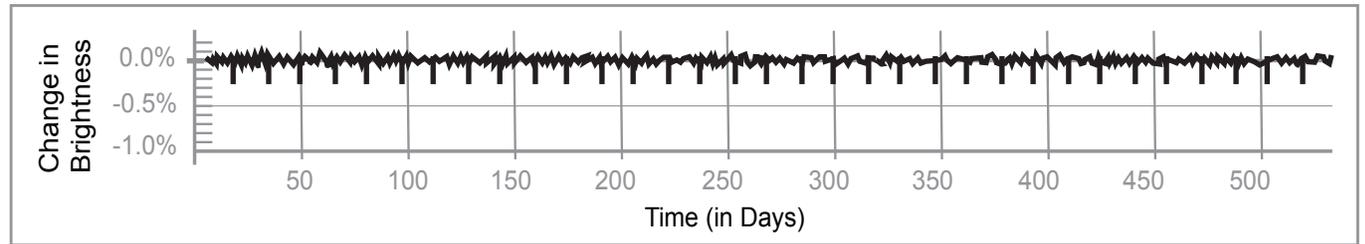
Figure 2: Book Transit



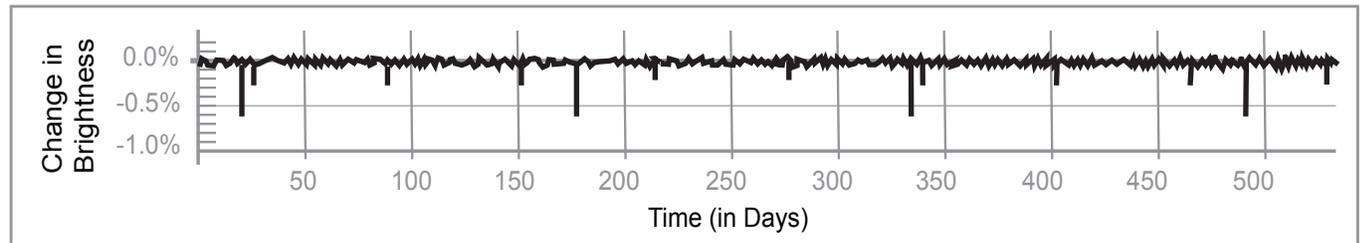
A.



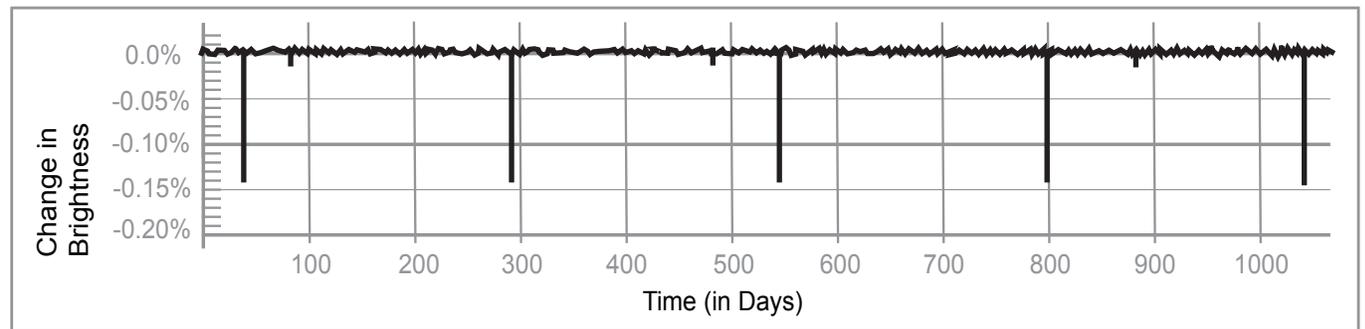
B.



C.



D.



E.

