DETECTING PLANET TRANSITS

When we are able to observe a planet move in front of a star, the event is called a *transit* of the planet in front of the star. NASA's Kepler mission is designed to detect habitable Earth-size planets by detecting transits of those planets. In this activity we model Kepler observations of planetary transits by standing in a circle with model star (light bulb) in the center, and observing, through rolled up paper viewing tubes, a marble planet orbiting the star.

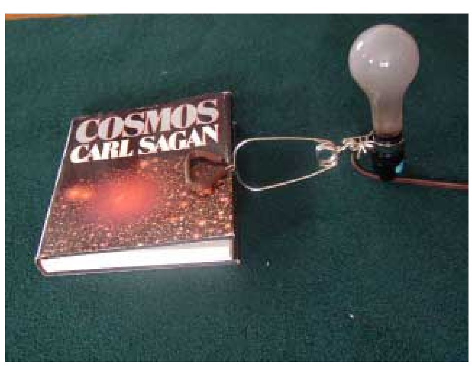
Materials

For the whole group/class:
1 Light bulb (frosted, low wattage, like 25-40W) on table lamp or clamp-on socket
1 Marble
1 Piece of thread (or very light string), as long as the distance from the ceiling to the floor
1 Push pin, thumb tack, or T-pin
1 Ladder or step stool or long stick
1 stop watch or wall clock with a second hand
Optional: A few rolls of clear tape or masking tape

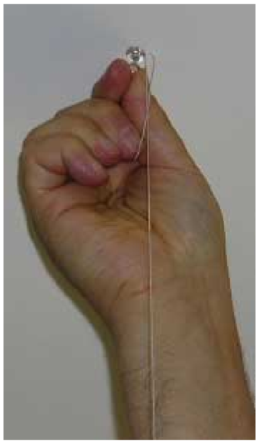
For each person:
1 sheet of paper, 8 1/2" x 11"

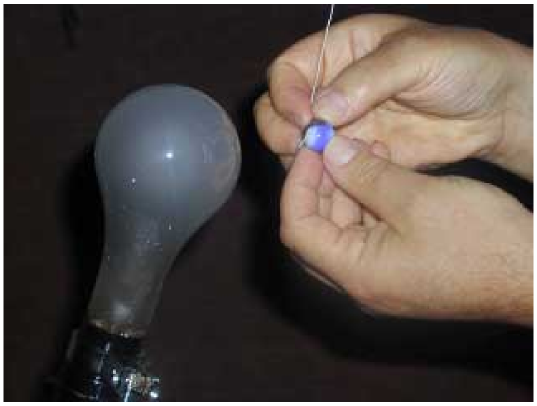
Preparation

1. Set up the light either in the center of the room or at least a couple of meters (6') away from a wall. If you have a table lamp, this can just sit on a table, as long as it is not higher than your shortest student. A tall lamp can just stand on the floor. If you are a using clamp-on socket,the simplest thing to do is to clamp it onto the back of a chair, but two other methods are illustrated here:
    a. Fill a box with books (oriented vertically), tape a meter stick or yard stick onto one of the books and clamp the light onto the stick.
    b. Clamp the light onto the cover of a sturdy hard copy book, and place it on a table.



2. Tie one end of the thread to a push pin, tack or T-pin and stick it into the ceiling directly over the light bulb setup. This may require a step stool or ladder, but can also be done by loosely taping the pin or tack to the top of a stick (e.g. a pointer stick or broom stick), and then carefully pushing it into the ceiling. This may take some practice—the trick is that the pin must be at right angle to the ceiling before you apply pressure. Once it goes in, the loosely attached tape will come off when you lower the stick. See photo (right): Putting push pin in ceiling.





3. Tape the marble to a spot on the thread, such that the marble will hang beside the bulb at a height about even with the bottom of the round part of the light bulb. See photo (left): taping marble.

4. Optional: prepare pieces of tape, two per person, stuck on the edge of a table chalk board or white board, ready for people to get for securing their rolled up paper viewing tubes.

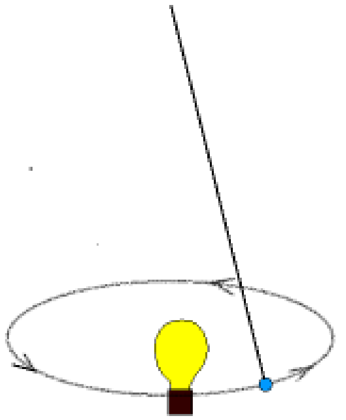
➔Go

1. Tell students that finding planets around other stars is tough. Ask "Why might it be difficult to detect a planet going around a star other than the Sun?" [Possible answers include "The planets are too small to be seen." "The stars are too far away and the planets too small." "The star is to bright and the planet too dim." "The planet is lost in the glare of the starlight."]

2. Define transit as a planet going in front of its star and blocking some of its light. Tell the group that they will observe a simulated transit: a model planet (marble) moving across a model star (light bulb). You can do observations with the light bulb either on or off.

3. Start the marble in orbit around the light bulb by holding it about a meter away from the light and giving it a sharp push in the direction perpendicular to the line connecting the marble and the light. Have students raise their hands if they see the planet go directly in front the light—not above it or below it, but actually blocking the light. Ask students, "What do you have to do to see a transit? [Students are different heights. To see a transit, your eye has to be directly in line with the planet and star.]

4. Explain that NASA's Kepler mission is designed to detect habitable planets. Explain that it's possible to detect a drop in brightness of the light from a star when a planet transits the star. For very large (Jupiter-size) planets it's possible to measure the drop in brightness using a telescope on Earth. It's even possible to detect Earth-size planets by observing transits, but that requires a telescope in



space, not on Earth. The NASA Kepler mission is just that: a telescope in space that will detect planet transits.

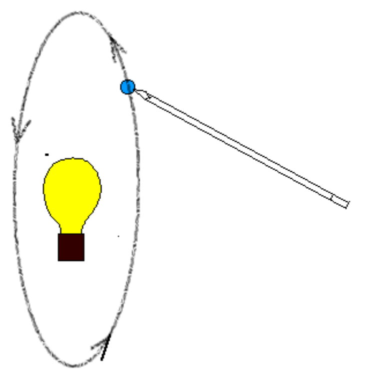
5. Simulate observing through a telescope. Have each person roll up a sheet of paper into a tube to look through as a simulated telescope (see photo, below). This limits the view to only the "star" and the region immediately around it. Repeat the observations in step 2, but this time everyone looks through their "telescope." Just for fun, have them say "Transit" every time they see a transit.

The Kepler telescope must be in space because ground-based observing has two intrinsic limitations:

(1) The motions in the atmosphere are constantly bending the rays of light from each star into different directions changing the apparent brightness by more than 50%. This is why stars appear to twinkle. Planet transits cause change in brightness of less than a 1/10 of a percent.

(2) To detect a planetary transit as short as 2 hours out of a year requires measuring the brightness of the stars continuously. You can't blink! Earth-based telescopes can only do observations at night and when there is no bad weather.

6. Point out that orbit angle is crucial. Emphasize that we would not be able see transits in all planetary systems, tape the marble to a pencil and move it in a *vertical* orbit around the light bulb. Ask students to raise their hands if they see a transit. Ask, "Why do so few people see transits now?" [Probably only two people will see them—those people who are in the plane of the orbit.] Ask, "Would we be able to see transits of planets in all planetary systems?" [No.] Why not? [We can only see transits of those planets that have orbits that are lined up with us.]



7. Planet period is the time it takes the planet to orbit. Pick one person to be the Kepler satellite—others may be seated. Give one student a stopwatch or have all students watch a clock with a second hand to time the simulated orbit period.

8. Assume that the model planet system is also in an accelerated time model: 1 second = 1 month. The "Kepler satellite" person must call out "transit!" when they see a transit.

9. Time the orbit period. Remove the marble from the pencil and let it hang again from the string. Start it in orbit as before and when the Kepler person calls out "transit" stop and ask, "Do we know the period of the planet's orbit now?" Discuss the question until the everyone realizes that observing one transit cannot give us the period.

10. Ask, "What do we have to do to know the period of the planet?" [Observe 2 or more transits and measure time BETWEEN transits.] Go ahead and model that, timing and recording intervals between transits. Find out how many days (months or years) the period is using 1 sec = 1 month. Explain that a planet's period can give us the size of the planet's orbit—how far the planet is from its star, which is a critical piece of information in determining if the planet might be habitable.

OPTIONAL

Some students may ask how knowing the planet's period can tell us the distance of the planet from its star. Distance from the star can be computed using Kepler's 3rd law, which relates the period of a planet's orbit, with the diameter of the planet's orbit. . There can be a whole other activity that teaches Kepler's 3rd law, but the essence of Kepler's 3rd Law is expressed mathematically by

$$\frac{D^3}{P^2} = \text{Constant}$$

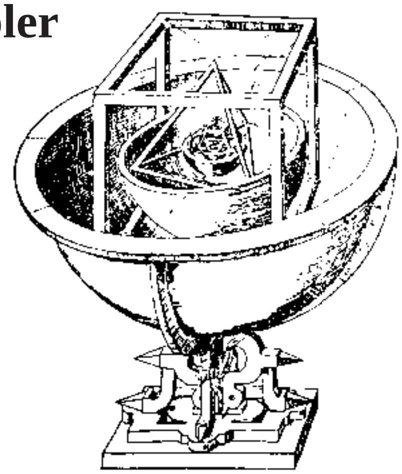
Where
P = Period in Earth years
D = Orbit diameter in Earth orbit diameters (AU)
[One Earth orbit diameter = one Astronomical Unit = 1 AU]

The constant is actually 1 $AU^3/year^2$.

So for Earth:

$$\frac{(1\ AU)^3}{(1\ year)^2} = 1\ (AU^3/year^2)$$

Johannes Kepler



Going Further
1. An algebra activity about Kepler's Law can be done with the solar system as a model. Make a chart showing the planets in our solar system and their respective orbit periods and orbit radii. Students try to find a formula to relate period and orbit radius. Groups may try different formulae by making tables. Excel can make this very easy.

2. Measure the transit drop in brightness of a model planet. Using a model star (light bulb) and some different size model planets (disks of cardboard or heavy paper), see if you can detect a drop in brightness using some sort of light meter or brightness measuring device. Professional light meters can cost hundreds of dollars, but you can use a solar cell and multimeter for under $20 from an electronics store.

Sample Trial formula: D/P = Constant? [No.]

Solar System Data

	Orbit radius AU	Period (P) (years)	D/P AU/P
Mercury	0.4	0.2	1.625
Venus	0.7	0.6	1.1613
Earth	1.0	1.0	1
Mars	1.5	1.9	0.8085
Jupiter	5.2	11.9	0.4384
Saturn	9.5	29.5	0.3238
Uranus	19.2	84.0	0.2286
Neptune	30.1	165.0	0.1824
Pluto	39.4	248.0	0.1589

