Transiting Planet Experiment; Instructors Guide

Created by Anil Seth and Andrew West, updated Feb. 11, 2011

Summary and context:

In this activity, the instructor simulates planetary transit observations, and students record data and make transit plots. Following data taking, students split into small groups to address the discussion questions designed to help them understand what can be learned from planetary transits.

The only background required is knowledge of Kepler's laws and a basic concept of light. This activity was done in our introductory planets/astrobiology courses the day before the NASA Kepler mission's Feb. 1, 2011 data release. After the press release, we discussed the Kepler 11 system (Lissauer+, 2011), applying what we'd learned from this activity.

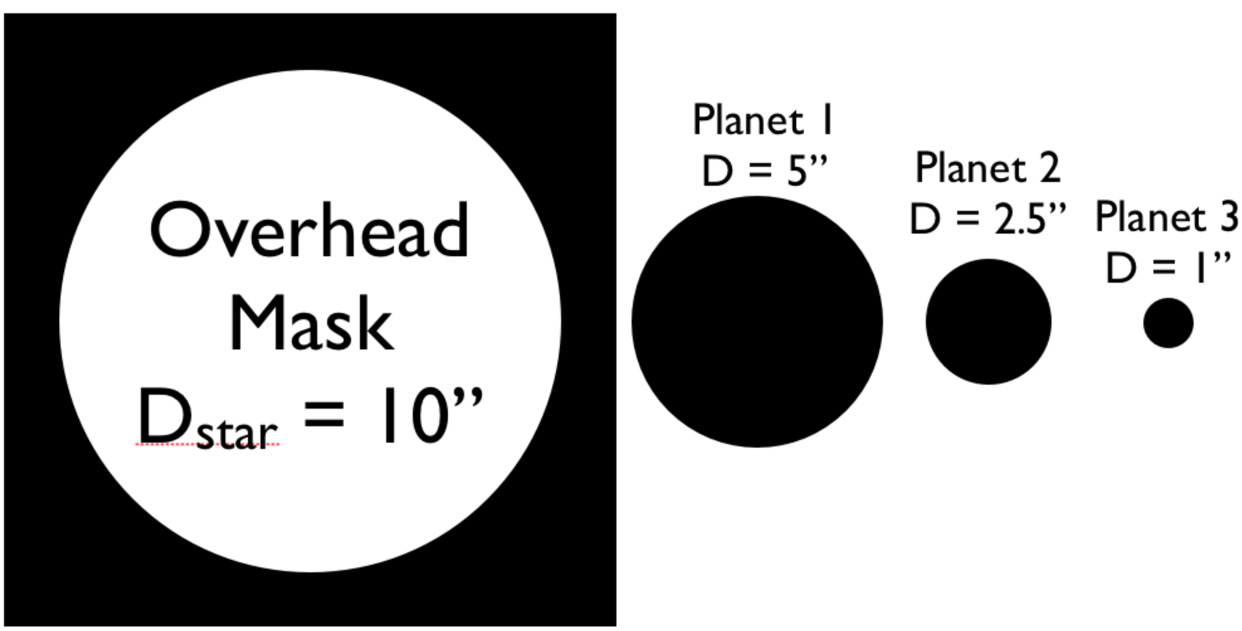
Goals:

The goals of this activity are to have students understand the following:

- The depth of a transit indicates the size of a planet.
- The length of a transit indicates the speed of the planet in its orbit, and by Kepler's Third Law, the distance from the star.
- The geometry of transiting planets and that not all planets will be detected.
- The difficulty of detecting small planets, and distant planets that transit less frequently.

Materials:

- The student worksheet, for recording and plotting results.
- An overhead projector.
- A light meter (we used a BK Precision 615) with the detector placed at a fixed position pointed at the screen. Note that it was helpful to have a baffle to block light from reaching the light detector directly from the overhead projector.
- Black foam board star and planet cutouts, as shown below.



Procedure:
Before starting the experiment, give a brief introduction on Kepler and transiting planets, being sure to define what a transit is. Then explain that:

- the projection of the circle on the screen is our star
- the light meter is our telescope
- you will be observing 5 stars (A through E) like the sun (same radius, temperature and luminosity)
- the observations will consist of 10 measurements of the stars brightness separated by 4 hours. [NB: typical Kepler transits take from a few hours to a day; the Earth's of the Sun transit would take about a day].

After explaining what you will be doing, choose one person from class to read out the light meter and another to record the numbers on the board (it would work even better if you had many light meters and groups could each make their own measurements!). The observations are made by moving the different planets across the stars as follows:

A) Planet 1; Steps 1-2=off, 3=half on, 4-7=on, 8=half on, 9-10=off
B) no transit (can just say that all measurements are equal)
C) Planet 2; Steps 1-2=off, 3=half on, 4-7=on, 8=half on, 9-10=off
D) Planet 2; Steps 1-3=off, 4=half on, 5-6=on, 7=half on, 8-10=off
E) Planet 3; Steps 1-2=off, 3=half on, 4-7=on, 8=half on, 9-10=off

After taking the data, have the students split into groups of 3-4. Then have them calculate the fractions (to speed things up, have the groups split up the calculations) and plot the data. Draw a sample plot on the board.

Discussion Questions:
For the discussion questions, display each on a separate slide, and have the students talk about the questions in groups followed by a class discussion on each one to teach the finer points. Show the first slide as the students are finishing up their plotting. Notes about each discussion question are in italics below.

1) Draw the orbit of a planet transiting a star. What orientation of the planet, star, and telescope do you need to produce planetary transits? Do you expect this orientation to be common? Are there some planets that you wouldn't see?
This was surprisingly difficult for the students, and required some interaction with individual groups to get all to understand. After everyone got it, I mentioned that for earth like planets, Kepler will detect less than 1% of all planets assuming random orientations.

2) What can we learn about the physical properties of the planets from transits?
Most students understood that you could measure how big the transit was. Some also understood that the duration of the planet told us about its orbit. Some even suggested taking a spectrum while the planet was transiting to measure the planet's atmospheric composition. In the class discussion cover the difference between mass and size, and make sure that they understand why slower transits are due to more distant planets.

3) What is the difference between the planets around Star A and Star C (be as quantitative as possible)?

Most students understood that the planet around star A was larger. And many of them said the planet around star A was 4× bigger than the planet around Star C. After their group discussion, I drew the planets on the board and showed them that the planet around star A had a 4× larger **area**, *and thus had a 2× larger radius.*

4) The Earth's radius is about 100 times smaller than the sun? How sensitive would our light meter have to be to detect its transit?
Similar to the last question, but the ratio is between the star's and planet's radius. Show that the sensitivity would have to be 0.01%. Discuss error in the measurements.

5) What is the difference between the planets around Star C and Star D?
The planet around Star D is closer. Emphasize the link between Kepler's 3rd law and the length of transit. One could make this discussion quantitative (but I didn't).

6) What is the deal with B? Why didnt we observe a transit? *The students were able to come up with many reasons including: there is no planet there, the planet is too small to detect, it is not orbiting in the right plane, or we just didn't observe for long enough. Conclude the activity with a discussion of how long we need to observe to detect Earth or the outer planets and why we haven't yet found an earthlike planet.*