DETECTING EXTRASOLAR PLANETS

LEARNING GOALS: Detecting planets around other stars is a very challenging task. What is the transiting planet method of detection? What can we learn about extrasolar planets using this method?

EQUIPMENT: Lamp, ruler, Lego™ orrery (with a variety of detachable planets), light sensor, laptop (or other) computer with LoggerLite™ software, modeling clay (available from your lab instructor for the optional section at the end), calipers

In March 6, 2009, the Kepler spacecraft successfully launched and began its 3.5-year mission. The Kepler mission is NASA's first mission capable of finding Earth-size and smaller planets around other stars. In this lab, you will discover how Kepler's instruments work and what we hope to learn about extrasolar planets.

In this lab, you will occasionally be asked to predict (as a real scientist would) the outcome of an experiment before you try it. Make these predictions BEFORE moving on to the experiment itself. You will not be marked down if your predictions are wrong.

Unfortunately, the Lego orrery does not simulate a true solar system since it does not exactly follow Kepler's 3rd Law ($P^2=a^3$). Keep this in mind.

Part I. Setting up your Kepler Simulation

The transit detection method is an *indirect* detection method in that it is not directly detecting the planet itself but rather the planet's interactions with its central star. By detecting a repeating dimming of the star's brightness, scientists can infer that a planet is orbiting around the star and occasionally blocking some of the star's light from the telescope.

In this lab, the light sensor will simulate both Kepler's telescope and its light detecting hardware. The lamp will simulate the star and the Lego orrery will be configured to simulate various planets moving around that star.

The first thing you'll need to do is place the star in the middle of the orrery. Adjust the lamp so the bulb is over the middle shaft of the orrery. Be sure the base of the lamp is not blocking the path to the light sensor.

Next you'll need to align the light sensor so it is pointing directly at the center of the light source. (Make sure none of the planets are between the star and the light sensor during alignment.)

I.1 Using your ruler, measure the height of the star and adjust your light sensor to the same height. Record the height of your star and light sensor: _________________

I.2 Next you'll need to make sure your light sensor is pointed directly at the center of the light source. You could do this by eye (and probably should, in order to get a rough alignment) but can do so much more accurately using the LoggerLite software (if the software is not already running, ask your TA or LA to help start the program). This will also give you a chance to play with the light sensor to see how it works. Explain how you can use the LoggerLite software to align your sensor.

I.3 Record the value for the peak brightness of your lamp: _________ *(The light bulb itself might show some small variability. As long as it's not periodic, this will not effect your measurements. Most real stars actually show some variability.)*

Part II. Measuring the Effect of Planet Size

II.1 Affix a medium-sized planet to the middle arm of the orrery. Try to get the height of the planet to be the same height as the center of your star and your light sensor. Turn on the orrery motor and start the LoggerLite data collection. Describe the results.

II.2 (a) Suppose that your planet was ½ the diameter of your star. What percent of the star's light would you *predict* that planet would block?

(b) As seen from a distance, planets and stars look like circles. Draw a planet and a star on top of each other below with the planet having a diameter that is ½ the diameter of the star (use circles, don't do a 3-dimensional drawing). To help make the point even clearer, temporarily pretend the star and planet are squares, with the smaller one ½ the width of the larger (start the square "planet" in the corner of the square "star").

Star & Planet Star & Planet (drawn as a squares)

(c) Based on your drawing, how does the *area* of the star compare to the area of the planet? (You should be able to give actual numbers here, not just bigger or smaller).

II.3 (a) Using the clamps provided, measure <u>your</u> star (in the orrery) and record its size here (be careful not to break your bulb!): ____________

(b) Now measure <u>your</u> planet and record its size here:_______________

(c) What is the ratio of the diameters?________________

II.4 What percent of the star's light do you predict the planet will block? *Record your calculations below*.

II.5 (a) Use the experimental setup to measure the percentage of the light that is actually blocked. *Show your work*. (You can use the "Examine" button in LoggerLite to get the exact y-value at any point on your graph. Be sure to run your orrery for *at least* two complete orbits of the planet.)

(b) How well does your result agree with your predictions?

(c) What might be the cause(s) of any differences? <u>Show your prediction and result to your TA or LA before you proceed.</u>

II.6 Replace the medium planet with a different sized planet, run the orrery, and describe the results. Compare your results to those you found in the previous question.

Part III. Measuring the Effect of Planet Distance

III.1 Predict the effect of changing the orbital distance of the planet and record your prediction. Be as specific as possible.

III.2 Move the planet to a different position, run the orrery for at least two orbits, and describe your results.

III.3 How well do your results agree with your prediction? If they disagree, what might be the cause(s) of any differences?

Part IV. Measuring a Complex Planetary System

Split your lab group into two teams. Each team will take one turn acting as the extrasolar system creators and one turn acting as the Kepler Science Team. Fill in the appropriate sections when it is your turn to act as that team.

Extrasolar System Creators: Place the cardboard divider between your teams so the Kepler Science Team cannot see the orrery. Using the various planet choices, create a solar system consisting of up to three planets. You don't *have* to use all three but try to make it challenging! It is up to you to decide which planets to use and how to make them.

IV.1 Record the sizes for the three planets you chose in the table below.

Planet	Size
1st Planet (closest to star)	
2nd Planet	
3rd Planet	

IV.2 In the space below, draw your *prediction* for what the Kepler light curve will look like. Explain, in words, your prediction.

When you are ready, turn on the orrery and tell the Kepler Science Team to begin their analysis.

Kepler Science Team: Your job will be to act as the scientists analyzing Kepler's data here on Earth. Without seeing the orrery, you will need to determine what kind of solar system the Kepler satellite has discovered.

IV.3 In the space below, make a sketch of the detected light curve. You might need a few minutes of data to recognize the full pattern. (If you want, you can print out your light curve and attach it to your lab write-up.)

IV.4 Based on the detected light curve, what are the sizes and distances of the planets around the system you've detected? Be as specific as possible (i.e. can you guess exact sizes?) Explain your reasoning.

IV.5 Once you've completed your analysis. Check with the other team to see what actual planets were used. Was your analysis correct? If not, why not?

Now switch roles with the others; create a new solar system, and let the others analyze it. If you were the Kepler astronomers, you are now the creators, and should go back and fill in IV.1 and IV.2.

Part V. Summary

V.1 What are the difficulties that might be associated with detecting planets using the transit method? There are several answers to this question; you should list at least two for full credit.

V.2 For what types of extrasolar planets would the transit method work best? Large planets or small planets? Planets close to their host star or far from their host star? Highly eccentric orbits or circular orbits? Stars close to Earth or far away? Explain your reasoning.

V.3 If you had a spectrograph instead of a light sensor, how could this method be used to tell if a transiting planet had an atmosphere?

Part VI. Detecting Earth-size Planets

VI.1 Earth's radius is ~6000 km and the Sun's radius is ~700,000 km. Using the reasoning you came up with in II.5, calculate the percentage of the Sun's light that Earth would block during a transit.

VI.2 The Kepler spacecraft will monitor the brightness of more than 100,000 stars over a period of 3.5 years and be able to measure brightness changes of as little as .002%! How successful do you think Kepler will be in detecting Earth-size planets? Explain your answer. *(Note: This question is not asking if Kepler is capable of detecting Earth-size planets… the designing scientists made sure of that! This question is asking if you, personally, think the mission will be a success.)*

If you wish to explore the concepts a little further, your TA has modeling clay available. Create your own planets and predict what the light curve will look like. Some outcomes may surprise you! Please clean up your lab station before you leave.

For more information on the Kepler Mission, see http://www.nasa.gov/kepler (or follow the Kepler mission on twitter at http://twitter.com/NASAKepler).