Exoplanet Transits – Sam Hadden

Purpose

The purpose of this lesson is to introduce students to exoplanets and the methods astronomers use to identify and characterize them. Students will also use a computer simulation to collect data and present an analysis of their data to the class.

Overview

- The lesson will begin the teacher leading a discussion to define what a planetary transit is. The class will watch a video of the 2012 transit of Venus.
- The teacher will describe how planets orbiting other stars can be identified by the dimming of their host star's light that occurs when they transit their star. The teacher should define and discuss transit depth, duration, and frequency as measurable features of a planet's transits.
- Students will investigate the influence of the physical properties of a planet and its star on a transit light curve's depth, duration, and frequency. Students should work with the Mathematica simulation to fill out the worksheet table, noting whether or not different planet properties affect the transits' depth duration or frequency and briefly noting the relationship between them. (Students may work in groups or individually, according to available resources.)
- Students will be placed in to groups and each group will be assigned a planet property/transit feature pair to investigate more closely. The group should formulate a claim about the relationship between the variables and collect data by working with the simulation to support or refute their claim. Each group will make a plot from their data and present their findings to the rest of the class.

Student Outcomes

- Students will understand that an exoplanet is a planet that orbits a star other than our Sun and will get a brief overview of the wide variety of planetary systems that have been discovered by astronomers.
- Students will learn what a planetary transit is and be able to describe a transit light curve in terms of the depth, duration, and frequency of the transits.
- Students will know that transits can be used to identify extrasolar planets and understand that physical characteristics of a planet can be deduced from the properties of a transit light curve.
- Students will practice plotting data and interpreting the plot to describe a relationship between an independent and dependent variable.

Standards Addressed

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

(Students will explore the effect of changing a star's mass on the frequency of a planet's transits)

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MS-ESS1-3.: Analyze and interpret data to determine scale properties of objects in the solar system.

(Students will explore the influence of a planet's size on the depth of simulated transits)

CCSS.MATH.CONTENT.8.SP.A.1: Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

Time

Approximately 3 hour-long class periods

Level

8th Grade Physical Science

Materials and Tools

- Projector for showing video of 2012 Venus Transit.
- Computers with the 'Planets.cdf' simulation installed
- Planet Transits Worksheet
- Large sheets of paper and markers for student groups to create plots to present to the class

Preparation

- The teacher should ensure that the simulation is installed and easily accessible for students. The simulation will require installing Mathematica CDF player (http://www.wolfram.com/cdf-player/).
- The teacher should find a video of the transit of Venus to show when introducing the concept of a planetary transit (e.g. http://youtu.be/_7U5VbasKr4).
- A worksheet should be printed for each student.

Prerequisites

- A review of plotting and interpreting recorded data may be beneficial.

Background

The planets of our own solar system are just a few among the billions of planets in our galaxy. Every star you see in the night sky likely has at least one planet orbiting it, just like the planets of our solar system orbit the sun. Planets that orbit other stars are called 'exoplanets'. Astronomers are interested in studying exoplanets to understand how our own solar system fits in among the variety of types of planets and planetary systems in our galaxy and potentially answer the question 'How common are planets that can host life like the Earth?'. Since exoplanets are much smaller and fainter than their host stars, astronomers need special techniques to indirectly search for and characterize them. One technique they use is to search for the dimming of a star's light that happens when a planet passes in front of, or 'transits', its host star. NASA's Kepler mission has discovered thousands of potential planets by looking for such transits, leading to an explosion in our understanding of planets and how our own solar system fits in among the many types of planetary systems observed in our galaxy. By understanding the influence of a planet's physical properties on how and when it dims its host star, we can learn about the physical properties of discovered exoplanets.

Teaching Notes

- The teacher should begin the discussion of what a transit is by drawing an analogy to an eclipse. (A transit is just like an eclipse except the 'eclipsing' object does not appear large enough to entirely block out the sun or transited star.)

- A video of the 2012 transit of Venus should be shown to the class to further illustrate what a transit is. After the video the teacher should explain that just like Venus passed between the Earth and the Sun, a exoplanet can pass between its host star and the Earth. To check for understanding, the teacher should ask the class to if a transit of Mars can be observed from the Earth and to explain why or why not.
- It is important to stress that exoplanets transit in front of their own host stars and **not** the Sun. To assess comprehension, the teacher should ensure that students understand why transits of Earth, viewed from an 'alien' planet would occur once per year. The teacher should explain that, while exoplanets are too far away to be seen directly, like in the video of Venus, the result of their transits as observed from Earth is a temporary dimming of their host star's light. The teacher should show slides illustrating the effect of a transit on the brightness of a star as seen from Earth or use the light-grapher program available at http://kepler.nasa.gov/education/ModelsandSimulations/lightgrapher/# .
- The teacher should define the transit properties explored in the worksheet and demonstrate the simulation, working through one of the table cells as a class example. The class should then work individually, or in small groups to fill out the cells of the table included in the worksheet. In each cell, students should answer whether or not the given physical property of the planet/star system affects the given transit property (frequency, duration, or depth). Students should write a brief description of the observed relationship in cases where the physical property does influence the transit property.
- Once students have completed the table, the teacher should assign small groups of students a specific planet property and transit feature to explore. The group should make a claim about the influence of their assigned planet property on their assigned transit feature. The group will collect data using the simulation and make a plot from their data. The groups will then present their findings to the class and explain how their data supports or refutes their claim.

Assessment

- The worksheet table will allow the teacher to track the progress of students and identify areas where students are struggling.
- The teacher should examine the plots created by each group to discuss the group's findings and provide feedback before they are presented to the class. The teacher may help the group determine the physical basis for the correlation they find (e.g. a bigger planet results in a deeper transit because the larger planet blocks more of the host star's light).

Additional Information

- Note that the effect of the planet's eccentricity will depend on the orientation. It is recommended that the students explore the other properties first and attempt to explore these properties only as time allows
- Example slides with illustrative images and plotting instructions are included.
- Information on exoplanets and the Kepler mission can be found at http://kepler.nasa.gov
- The teacher may wish to have students visit 'planethunters.org', where they can search through Kepler mission data for planet transits as a homework or extra-credit assignment
- The second simulation included in 'Planets.cdf' is not used in this lesson. (The second simulation illustrates the effect of the gravitational interaction of two planets orbiting the same star on the times of the planets' transits). The source Mathematica notebook is included as well.