Extreme Planets

Planetarium Show – Teacher's Guide

PROGRAM OUTLINE

Description: *Extreme Planets* immerses audiences in the cutting-edge science of finding planets orbit around stars other than our Sun ("exoplanets").The show features a look at real exoplanets discovered in the last 15 years and discusses the instruments and techniques that astronomers have used to find these unique worlds.

Activities: The transit method, exploring distant solar systems, the chemistry of life.

LEARNING OBJECTIVES

- There is a wide diversity of planets and astronomers are continually discovering new worlds.
- Extrasolar planets generally do not resemble Earth – these extrasolar planets are typically hotter in temperature, larger in size, and closer to their host star than the Earth.
- Astronomers use several techniques for finding extrasolar planets.

Process Skills Focus: Inquiry, observation and communication.

Topics: Exoplanets, life in the Universe, cosmic distances.

OREGON STANDARDS

Scientific Inquiry Standards:

- K.3S.1   Explore questions about living and non-living things and events in the natural world.

- K.3S.2   Make observations about the natural world.
- 1.3S.2   Record observations with pictures, numbers, or written statements.
- 1.3S.3   Describe why recording accurate observations is important in science.
- 2.3S.2   Make predictions about living and non-living things and events in the environment based on observed patterns.

Engineering Design Standards:

- 1.4D.3   Show how tools are used to complete tasks every day.
- 2.4D.3   Describe an engineering design that is used to solve a problem or address a need.

Earth and Space Science Content Standards:

- K.2E.1   Identify changes in things seen in the sky.
- H.2E.3   Describe how the universe, galaxies, stars, and planets evolve over time.

Physical Science Content Standards:

- K.2P.1   Examine the different ways things move.

NEXT GENERATION SCIENCE STANDARDS

Practices
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
7. Engaging in argument from evidence

Crosscutting Concepts
1. Patterns
2. Cause and effect
4. Systems and system models

DCIs

	Disciplinary Core Idea	K	1	2	3	4	5	MS	HS
Physical Science									
PS1	Matter and Its Interaction	n/a	n/a		n/a	n/a			
PS2	Motion and Stability: Forces and Interactions		n/a	n/a		n/a			
PS3	Energy		n/a	n/a	n/a				
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	n/a		n/a		

	Life Science								
LS1	From molecules to organisms: Structures and processes			n/a					
LS2	Ecosystems: Interactions, Energy, and Dynamics	n/a	n/a			n/a			
LS3	Heredity: Inheritance and Variation of Traits	n/a		n/a		n/a	n/a		
LS4	Biological Evolution: Unity and Diversity	n/a	n/a			n/a	n/a		
	Earth & Space Science								
ESS1	Earth's Place in the Universe	n/a			n/a		✔	✔	
ESS2	Earth's Systems		n/a						
ESS3	Earth and Human Activity		n/a	n/a					
	Engineering, Technology, and Applications of Science								
ETS1	Engineering Design								

DCI Grade Band Endpoints

ESS1.A   *The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (By end of grade 5).*

Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (By end of grade 8).

Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (By end of grade 8).

ESS1.B   *The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (By end of grade 8).*

Performance Expectations

5-ESS1-1.   *Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.*

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

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

GLOSSARY

51 Peg: The first extrasolar planet was discovered in 1995 around the star 51 Peg.

Accretion disk: A flat disk of matter that orbits an object such as a young star, black hole, or neutron star. Over time, gravity causes the material to spiral in toward the central object. Planets form from accretion disks.

Direct detection: A method of detecting exoplanets by directly imaging them. The first images of a planet beyond our Sun were obtained by the Hubble Space Telescope 2008.

Earth-like planet: Planets that resemble our world in size, composition and temperature, where liquid water can exist.

Eccentricity: A measure of how much an orbit differs from a perfect circle. An orbit with a small eccentricity is close to circular, while an orbit with a large eccentricity is elongated, like an oval.

Elliptical orbit: The path of an object that forms an ellipse. Most objects in orbit around another object have elliptical orbits. The degree of difference from a perfectly circular orbit is measured as the eccentricity.

Exoplanet: See *extrasolar planet.*

Extrasolar planet: A planet beyond our Solar System, orbiting a star other than our Sun. Also known as an "exoplanet".

Globular cluster: Groups of tens of thousands or hundreds of thousands of old stars that are tightly bound by mutual gravitational attraction. One of the best examples of a globular cluster is the Hercules cluster located in the constellation of Hercules the Hero.

Habitable zone: The region around a star in which temperatures are such that water can exist in liquid form. Earth-like planets will reside in the habitable zone.

Neutron star: The immensely dense remains of a star after a supernova explosion blows off the outer layers of the star. Neutron stars rotate very quickly and may emit jets of particles from their magnetic poles.

Photosphere: The part of a star's atmosphere where light is radiated.

Radial velocity: A method of detecting exoplanets by measuring their gravitational effect on their host star. A planet exerts a small gravitational tug on its star, creating a tiny wobble in the star's motion. By measuring this wobble using Doppler shifts towards or away from our perspective on Earth, astronomers can deduce the presence of a planet, as well as its mass and orbit.

Red dwarf star: A small, cool star less massive than our Sun. Red dwarfs are the most common of all stars, comprising roughly three quarters of all stars in our galaxy.

Satellite: A body orbiting a planet. A synonym for satellite is "moon".

Supernova: The explosion of a massive star.

Transit method: A method of detecting exoplanets by measuring the decrease in brightness of a star as a planet passes directly in front of it.

Check your comprehension of the planetarium show!

1) ***Fill in one blank with "close to" and one blank with "far from".***
   Our own Solar System is a special place. The rocky planets are located _____the Sun while the gas giant and icy planets are located _____ the Sun.

2) **True or false: All planets in our Solar System orbit the Sun in the same direction. _____**

3) **The exoplanet orbiting the star 51 Peg is only 5 million miles from its host star – that's approximately _____ times closer than the Earth is to the Sun!**

4) **Why are planets so dim compared to the bright stars that they orbit?**

5) **What makes a planet "Earth-like"?**

6) **If two stars are close together, a planet can orbit around both stars. Draw this arrangement:**

7) **Choose the correct statement:**
   a. **Oxygen exists naturally in planetary atmospheres.**

   b. **Oxygen does not exist naturally in planetary atmospheres. If oxygen is observed, that might imply the presence of plants that are releasing oxygen.**

8) **Life cannot exist on stars, but life can exist on planets and on _____ that orbit around planets.**

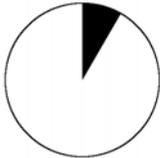9) **Develop a message that you would send to another civilization on another planet.**

The Transit Method

Description: In this activity, students will investigate using the transit method to find extrasolar planets.

TIME REQUIRED
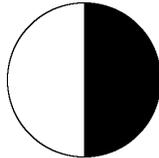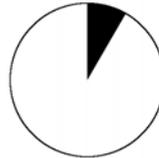
Advance Preparation

5 minutes

Activity

30 minutes

Clean Up

5 minutes

SUPPLIES

- Transit method worksheets (reproduced below)
- Projector for showing images on paper or images from a computer

ADVANCE PREPARATION

- Print a copy of the transit method worksheet for each student.

ACTIVITY

- Discuss with the students that a transit occurs when one body passes in front of a larger body. Show the image of the transit of Venus against the disk of the Sun that occurred in June 2012 (image shown at the end of this activity).

- Ask students to predict what will happen to the light of a star when a planet or other object passes in front of it. They'll likely arrive at the correct

answer – the amount of starlight will appear to dim. Astronomers use this method of find exoplanets.

- Hand out the transit method worksheets to each student. Explain to the students the concept of a "light curve". A light curve is simply a plot showing the brightness of a star as a function of time. A light curve is shown below, beneath the drawing of the star:
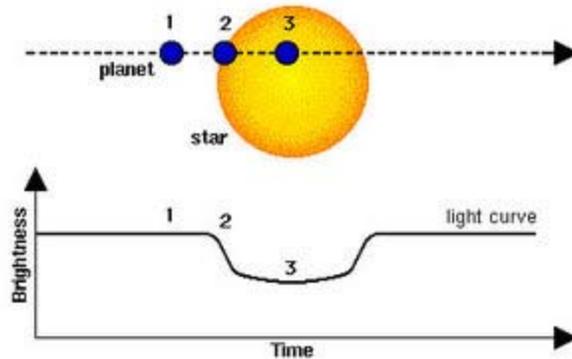

- Ask the students to pick a brightness level for their star. Before the planet passes in front of the star, the star's brightness will be constant. Instruct the students to draw a flat line to indicate the star's constant brightness.

- Ask the students to predict the shape of the light curve for the time steps marked #2 and #3. They should approximately reproduce the light curve that you see above. Have the students draw the light curve on their worksheets. (Remember that the light curve won't show zero brightness at time step #3, since there's still light from the star!)

- Now tell the students that it's possible to calculate the relative size of the planet and the star, given the information from the light curve. Let's assume that the brightness at time step #1 is 100% and that the brightness at time step #3 is 99%. Write these numbers on the whiteboard. Astronomers say that there a 1% drop in the light.

- Introduce the idea that this drop in brightness tells astronomers about the relative sizes of the planet and star:

$$\text{Drop in the light} \; = \; \frac{\text{Area(planet)}}{\text{Area(star)}}$$

So, the area of the planet is 1% of the area of the star! Let's say that astronomers look at another star and find a 0.01% drop in the light. What is the ratio of the planet's area to the area of the star?

- Emphasize to students that the transit method is a powerful way of finding exoplanets. Furthermore, this technique can be used to find out information about the size of the planet relative to the size of the star.
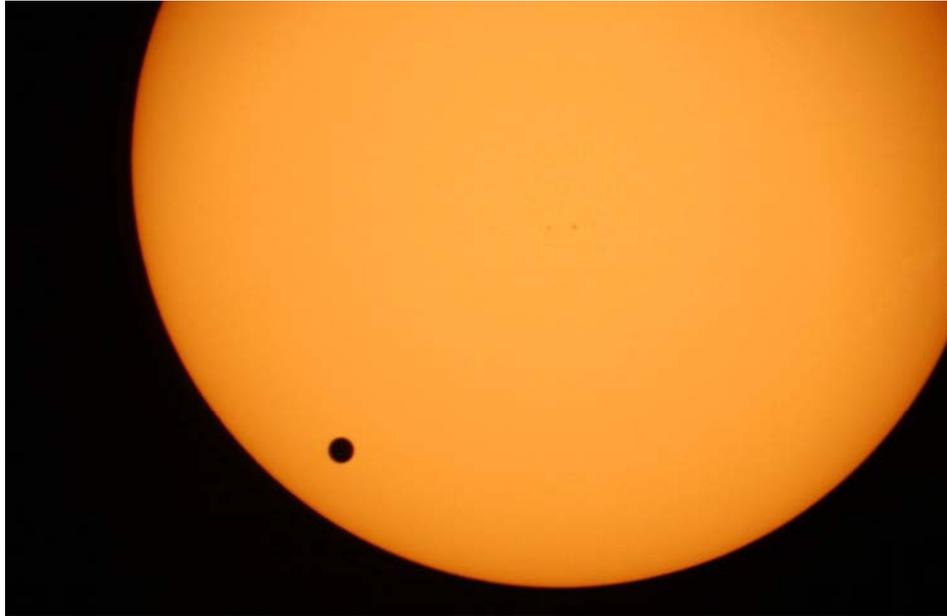
Transit Method Worksheet

We are going to investigate what happens when planets pass in front of stars. We'll use a "light curve", which is a plot of a star's brightness as a function of time. A blank light curve is shown below – you'll get to fill it in! Listen for your teachers' instructions.
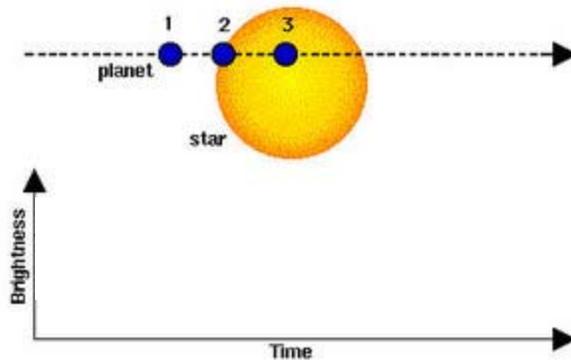
Now we're going to use your graph to figure out how big the planet is compared to the star.

Let's say that the planet blocks 1% of the star's light. So, the star emits 100% of its light when the planet is not in front of it and 99% of its light when the planet is in front of it. Astronomers say that there's a 1% drop in the light.

We can set up a <u>ratio</u> to relate this brightness information to the size of the planet:

$$\text{Drop in the light} \quad = \quad \frac{\text{Area(planet)}}{\text{Area(star)}}$$

So, the area of the planet is 1% of the area of the star!

Let's say that astronomers look at another star and find a 0.01% drop in the light. What is the ratio of the planet's area to the area of the star?

Weird Solar Systems

Description: Students will compare the positions of planets in our own Solar System with the positions of exoplanets around their host stars.
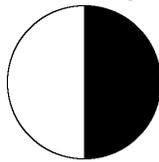
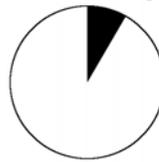## TIME REQUIRED

Advance Preparation
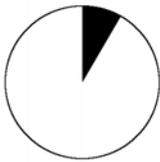
5 minutes

Activity

30 minutes

**Clean Up**

5 minutes

SUPPLIES

- Whiteboard markers in different colors
- "Imagine a Planet" worksheet for each student (worksheet below)

ADVANCE PREPARATION

- Make a copy of the worksheet for each student.

ACTIVITY

- Draw a line on the whiteboard. One end will represent the Sun and the units of the line will be in Astronomical Units (AU). One AU is equal to the average distance between the Sun and the Earth (93 million miles). Your line should look like this:

5	10	15	20
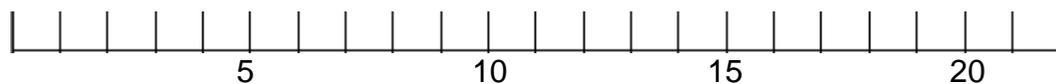
Distance from the Sun (AU)

- Call on students to place a mark on the line representing Mercury, Venus, Earth, Mars, Jupiter, Saturn, and Uranus. The distance between each planet and the Sun is listed below:

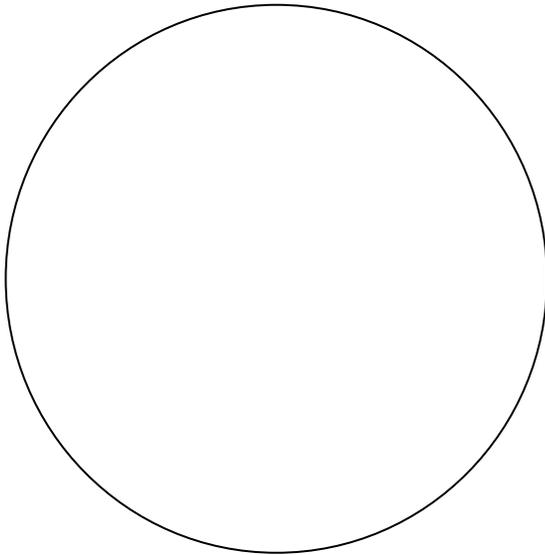| Planet	Distance (AU)
Mercury	0.39
Venus	0.72
Earth	1.00
Mars	1.52
Jupiter	5.20
Saturn	9.54
Uranus	19.18

- The exoplanets that have been found orbiting around other stars are not arranged in the same ways as the planets in our Solar System. Challenge students to note the differences after plotting the following exoplanets on the same line:

Planet	Distance (AU)
55 Cancri e	0.026
51 Peg b	0.46
Kepler 22 b	0.85
HAT P-9 b	0.053

- The students will likely remark that the exoplanets are all much closer to their stars than our planets are to the Sun. Brainstorm some ideas to explain this remarkable result.

- One simple explanation has nothing to do with the properties of the planets themselves but rather has to do with <u>observational bias.</u> Observational bias means that planets closer to their stars are easier to observe, so astronomers will preferentially find more of them! Let's investigate why it's easier to observe planets close to their stars.

- One technique for finding planets relies on measuring how the gravity of a planet tugs on the host star and causes the star to move slightly in its orbit. If a planet is closer to its host star, then it exerts more gravity and the star moves more. Since it's the movement of the star that astronomers measure, it's easier to find planets that are closer to their host stars.

- Instruct your students to imagine their own extrasolar planet and record their ideas on the "Imagine a Planet" worksheet.

Imagine a Planet

Draw your planet:

How far is your planet from its host star? The Earth is 93 million miles from the Sun – this distance is equal to 1 Astronomical Unit.

My planet is _____ miles from its star. This

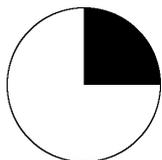distance is equal to _____ Astronomical Units.

Is there life on your planet? Describe the life forms that live there:

The Chemistry of Life

Description: Students study the chemistry here on Earth and learn that no other planet or moon in our Solar System is as good a place for humans!
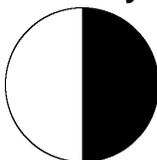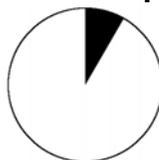
TIME REQUIRED

Advance Preparation

15 minutes

Activity

30 minutes

Clean Up

5 minutes

SUPPLIES

- Small glass beads ("seed beads") in red, orange, green, blue, black, brown, and yellow colors, approximately a thimble's worth for each student.
- Pieces of paper labeled Human, Mars, Jupiter, and The Sun (one set for each student).

ADVANCE PREPARATION

- Write the color key of the elements on a whiteboard:

Red = Hydrogen
Orange = Helium
Green = Oxygen
Blue = Carbon
Brown = Iron
Yellow = Nitrogen
Black = Silicon

- Prepare paper labels for each student

- Explain that the students will be investigating the chemistry of the Earth and the chemistry of other moons and planets in the Solar System. The goal is to determine if there are other places that would be good for hosting life.

- Hand out a small assortment of beads (approximately a thimble's worth) to each student.

- Ask the students to brainstorm elements that are needed for human life. We'll focus on oxygen, carbon, hydrogen, and nitrogen here. Ask the students to identify which colors represent these atoms (green, blue, red, and yellow).

- Have the students pick out six oxygen beads, two carbon beads, one hydrogen bead, and one nitrogen bead and place these in the pile next to a piece of paper labeled "Human". The different numbers of beads represent the approximate ratios of oxygen, carbon, hydrogen, and nitrogen in the human body.

- Mars is composed primarily of silicon, oxygen, and iron. Instruct students to pick out three silicon beads, three oxygen beads, and one iron bead and place these in a pile next to a piece of paper labeled "Mars".

- Jupiter is composed primarily of hydrogen, helium, oxygen, and carbon. Instruct students to pick out five hydrogen beads, three helium beads, one oxygen bead, and one carbon bead and place these in a pile next to a piece of paper labeled "Jupiter".

- The Sun is composed primarily of hydrogen and helium. Instruct students to pick out eight hydrogen beads and two helium beads and place these in a pile next to a piece of paper labeled "The Sun".

- Discuss with the students the chemical differences among humans, Mars, Jupiter, and the Sun. If humans want to be able to live in different environments like Mars, how will it be necessary to change Mars's chemistry?

RESOURCES

NASA Education
http://www.nasa.gov/offices/education/about/index.html

NASA Kepler Mission
http://kepler.nasa.gov/

NASA Planet Quest
http://planetquest.jpl.nasa.gov/