Star Light, Star Bright? Finding Remote Atmospheres

Middle School Grades

Lesson Summary

In this activity, students explore stellar occultation events to determine if an imaginary dwarf planet "Snorkzat" has an atmosphere.

Prior Knowledge & Skills

- Understand that graphs are used to represent physical data

AAAS Science Benchmarks

The Nature of Mathematics

Patterns and Relationships

The Physical Setting

The Universe

NSES Science Standards

- **Science as Inquiry:** Understandings about Scientific Inquiry
- **Unifying Concepts and Processes:** Evidence, models, and explanation

NCTM Mathematics Standards

- **Principles and Standards for School Mathematics:** Representation Standard

Suggested background reading

Mike Brown's Planets blog:

http://www.mikebrownsplanets.com/

View: The shadowy hand of Eris

Teaching Time: One to two 50-minute periods

Materials

Each Student Needs:

- Student directions

To Share with the Class:

- Access to a computer and projector
- Transparency or projection of Geometry of a Stellar Occultation
- Transparency or projection of Apparent Stellar Motion

Advanced Planning

Preparation Time: 20 minutes

1. Make copies of the student pages.
2. Prepare to project the computer and set-up the "Occultations demonstration" from the website: http://lasp.colorado.edu/spectra
3. Make transparencies of Geometry of a Stellar Occultation and Apparent Stellar Motion

Why Do We Care?

Some planetary bodies are too far away to explore easily and are too dim to get much information from the reflected sunlight. How do we know they have an atmosphere? One way to find out is through stellar occultations explored in this activity.

Adapted from: "Stellar Illumination," Johns Hopkins Applied Physics Laboratory, "New Horizons: To Pluto and Beyond"
http://pluto.jhuapl.edu/education/educators_eduGuide.php

Grade Level 6-9

Activity Dependency none

Group Size 1-4

Expendable Cost per Group $0.50

Engineering Connection Occultation events throughout history have lead to science questions about distant objects. As a result of these events, engineers have built spacecraft and spacecraft instrumentation that visit and explore the planets and other bodies. We still have a long way to go, questions still exist, and there are many planets and objects we have yet to visit. In 2015, the New Horizons mission visits Pluto and the Kuiper belt to give us new information about some of the distant bodies in our Solar System.

Pre-Requisite Knowledge

Students should:

- Understand that graphs are used to represent physical data.

Learning Objectives

After this lesson, students should be able to:

- Explain an occultation event
- Plot occultation events and interpret data
- Demonstrate how an occultation event can be used to determine whether a planet or body has an atmosphere

Introduction / Motivation

You are an astronomer on Earth. You have a 1-meter diameter telescope in New Mexico with a sensitive camera. You have discovered a new object in our Solar System, which you have named Snorkzat. On [give future date] you calculate that Snorkzat will appear to pass in front of a distant star. Snorkzat is in the Kuiper Belt of the Solar System and very little is known about it. You think this event could give you new information about Snorkzat. First, you will hypothesize about what will happen during the event before making your observations [hand out Part 1].

Vocabulary / Definitions

Word	Definition
Occultation event	When an astronomical body crosses the line of sight between an observer and another astronomical body.
Apparent Motion (Also: Apparent Path)	When an object appears to be moving relative to an observer (i.e. the sun appears to move across the sky when it is actually stationary and the Earth is rotating).
Brightness (Also: Apparent Brightness)	The brightness of a star as it appears to our eyes.
Dwarf planet	A nearly round object orbiting the sun which has not cleared its orbit of other objects.
Kuiper Belt Object (Kye-per) (Also: KBO)	Objects that orbit the Sun beyond the orbit of Neptune, which includes comets and other small bodies. Pluto is a Kuiper Belt Object.
Charon	Pluto's largest moon.
Spacecraft	A human made craft that does not orbit Earth.

Procedure

[Adapted from the lesson "Stellar Illumination," part of the suite of "New Horizons: To Pluto and Beyond" lessons, created at the Johns Hopkins Applied Physics Laboratory. See "References."]

The following resources will prove helpful to you and your students:

http://www.teachersdomain.org/resource/hew06.sci.ess.eiu.planetdefine/

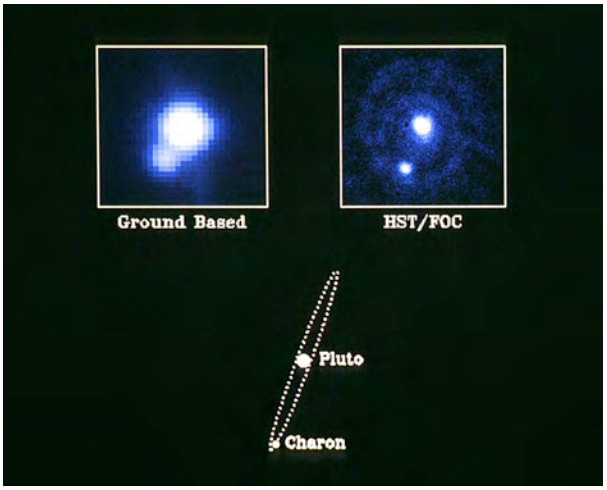
http://www.windows2universe.org/our_solar_system/dwarf_planets/dwarf_planets.html&edu=mid

http://www.universetoday.com/13573/why-pluto-is-no-longer-a-planet/

Background

Stellar occultation is one observing method that enables us to learn about the atmospheres of distant bodies. A stellar occultation occurs when a nearby solar system body passes in front of a distant background star (See Image 2). The intensity of the starlight is recorded as time goes by, beginning before and stopping after the occultation. These data are displayed as a light curve, which is a graph of intensity versus time. From light curves, scientists can determine the density profile of an atmosphere, and the width of the planet or body along the apparent path of the star (See Image 2). If the occulting planet or solar system body has an atmosphere, the intensity of the light is absorbed and refracted by the atmosphere. When the star is behind the planet, only the light reflected by the planet (from the Sun) is recorded in the light curve (See Image 2).

Image 1

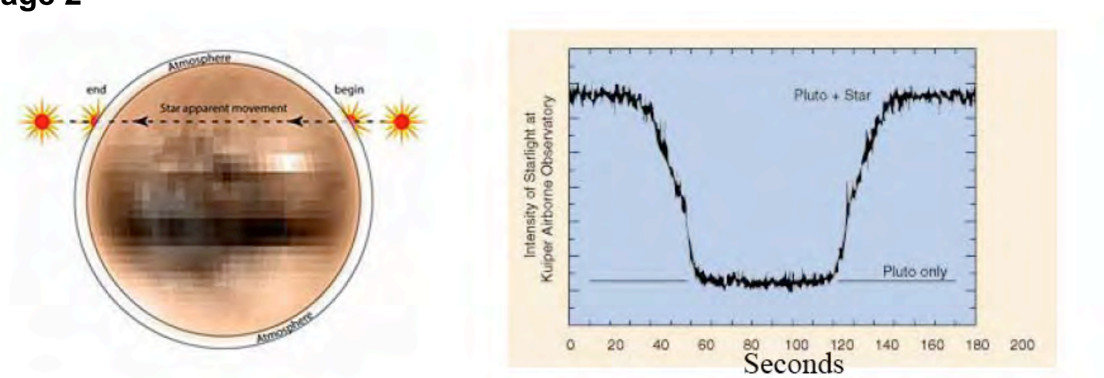


Kuiper Belt Objects (KBOs) are so far away that many Earth-based instruments and techniques are not able to probe the atmospheres or determine accurate sizes of these distant bodies. Left: A ground-based image of the dwarf planet system, Pluto and Charon. Right: A Hubble Space Telescope (HST) image of Pluto and Charon. Even though the HST image is clearer, not much detail can be seen in the image.
Source/Rights: Image courtesy of NASA/HST

Image 2 illustrates the geometry of a stellar occultation. While it is not indicated in the Figure, the dwarf planet is also moving during the occultation, albeit at a much slower orbital velocity than our own. Based on this geometry, it appears to the Earth-based observer that the star passes from right to left behind the occulting planet.

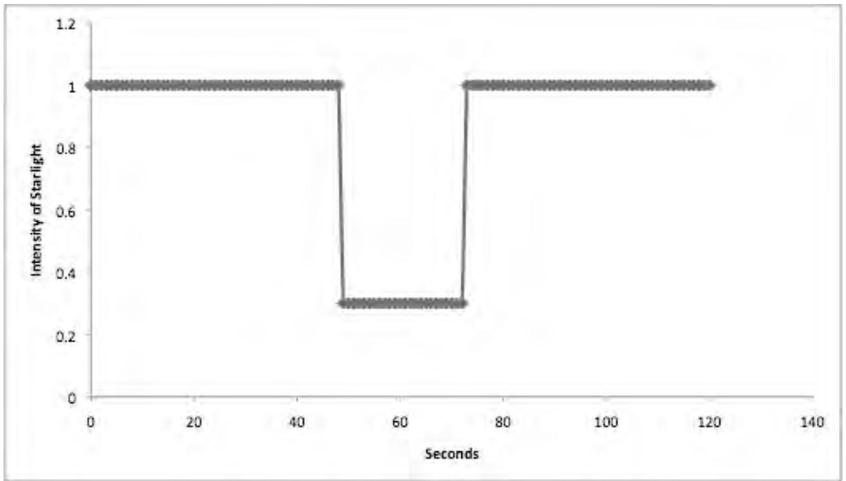
(The star isn't actually moving, but it appears to move along a path as indicated in Image 3).

Image 2



Left: Pluto and what the apparent motion of the star looked like during the occultation on June 9, 1988. Right: The light curve from that occultation. Notice how the light from the star dims over about 30 seconds, which indicates that Pluto has an atmosphere. Also, the slope of the line appears to change as the star is almost behind or just emerging from behind Pluto indicating some structure in Pluto's atmosphere, perhaps due to a temperature change, a haze layer or maybe both.
Source/Rights: JHU/APL

Image 3



This example light curve represents an object without an atmosphere. Notice that it has a sharp decent when the body obscures the star. A light curve from Charon, Pluto's moon, would look similar to this since Charon lacks an atmosphere.
Source/Rights: LASP

In this lesson, we consider a stellar occultation event behind a KBO as seen from an Earth-based telescope, however occultation events are used to probe many distant objects' atmospheres and can be done from spacecraft. In the lesson, "Enceladus, I Barely Knew You," students will explore how the Cassini Spacecraft's orbit enabled it to view a stellar occultation behind the moon Enceladus.

Before the Activity

1. Gather materials and make copies as indicated in the Materials section.
2. Create a transparency of the Geometry of a Stellar Occultation and the Apparent Stellar Motion teacher sheets if you use an overhead projector or prepare to project from a computer.
3. Prepare to project the "Occultations" computer demonstration tool, or prepare to have students go to a computer lab to use the tool independently.
4. Explore the "Occultations" computer demonstration tool prior to class.

With the Students

1. Hand out student sheet Part 1.
2. Allow students to work in small groups to complete Part 1 before explaining stellar occultation events. The section should take about 10 minutes to complete.
3. Ask the class to compare and contrast a planet or body with an atmosphere and one without an atmosphere. Enable students to come to the conclusion that a plot (light curve) can be used to help us understand whether or not a body has an atmosphere, and that the slope of the line will be more gradual if the body has an atmosphere (see teacher answer key).
4. Distribute Part 2 of the Stellar Occultation student data sheet. For this section, you may either demonstrate using the "Occultation event" computer demonstration tool or bring students to a computer lab for independent exploration of the "Occultation event" computer demonstration tool. For each occultation, you can hit pause and compare and contrast the different planets and their plots. You can also step-through the occultation event to show how the event matches the corresponding plot. All planets can be dragged with the mouse.
5. Ask students to review their plots from Part 1. Using the computer demonstration tool, have students compare and contrast their plots against the plots seen in the demonstration.
6. After students compare their Pre-lab plots to the actual plots, have students move on and view the Snorkzat tab of the simulation.
7. Return to the classroom and display *Geometry of a Stellar Occultation* and *Apparent Stellar Motion* images provided. Discuss stellar occultations as a class and the student responses to the questions from Part 3. Allow this to be a student-led discussion. You may want to point out that it is actually mostly the movement of Earth along its orbit that causes the dwarf planet to appear to move in front of the very distant star. Example questions to ask students:
    - Do you think Snorkzat has an atmosphere? Why? Answer: No. The light did not dim as the planet passed in front of the star.
    - How do we know if a planet's atmosphere has denser regions? Answer: More light from the star will be obscured in the dense areas.
    - What other ways can we explore an atmosphere? Answer: Sending spacecraft to the planet, sending a probe through the atmosphere of the planet, looking at only the outside portion of the atmosphere using spectroscopic lines and reflected sunlight etc.

Troubleshooting Tips

- Snorkzat is not a real dwarf planet.
- If you are not able to project images, make copies for students or draw figures on the board.
- If you are not able to view the "Occultations" computer demonstration, play the movie "Occultation Demo" provided on our website: http://lasp.colorado.edu/spectra
- If the simulation does not allow you to drag the planets, re-start your browser.

For students with vision impairment: [Adapted from the lesson "Stellar Illumination," part of the suite of "New Horizons: To Pluto and Beyond" lessons, created at the Johns Hopkins Applied Physics Laboratory. See "References."]

- Demonstrate a stellar occultation using sound intensity instead of light intensity. Download this free tone generator: http://www.nch.com.au/tonegen/index.html (click on 'download'. You can purchase this software for more options, but you can download just one tone for free). Limit the sound output from your computer to just one speaker by disconnecting any additional speakers. Position the blind or visually impaired student near the speaker of the computer. Start the tone by clicking "Play". Move a pillow (or other sound-absorbing material) slowly in front of the computer speaker, cover the speaker, and then move the pillow away slowly in a similar motion to that of the mock-planet and the light source. Experiment with different sound-dampening materials to try to create changes in the tone similar to the planets with larger atmospheres, smaller atmospheres, no atmosphere, etc. in the Stellar Occultation demonstration.
- Print one of the "brightness versus time" graphs from the Stellar Occultation student data sheet using a swell form machine. Ask students to graph the relative tone (rather than brightness) with time using pushpins on the graph paper. You will need to read out time for them every few seconds. Then they can connect the points along the graph using string or yarn by looping it around each of the pushpins to create a "sound curve" (rather than light curve).
- Print the actual light curve from Pluto using a swell form machine so they can interpret the light curves and answer questions about the atmospheres of these bodies.

Assessment

Pre-Activity Assessment

Pre-lab: Use the Pre-lab, Part 1, to assess student understanding.

Activity Embedded Assessment

Observing plots: In Part 2, assess student understanding by observing the plots they make for your demonstration of stellar occultation events.

Activity Summary Assessment and Extension Activity

Demonstrating to peers: Provide students materials to create their own planet. Include materials such as Styrofoam balls, construction paper, craft sticks, vellum paper, bubble wrap, clear wrapping paper, Mylar, etc. Each student will create his or her own planet (or dwarf planet). Students should not reveal what their planet's atmosphere contains with anyone. After completion of the planets, have students work in small groups of 2-5 students and provide a light source (LED). Students will demonstrate a stellar occultation to their peers. The other members of the group can guess the materials the student used to create their planet. Walk around the room during the demonstrations, listen to student conversations, ask leading questions, and correct misconceptions.

Activity Extensions

Continue the spectroscopy unit by completing the associated activities, "Solving a Mixed Up Problem" and "Enceladus, I Barely Knew You".

References

"Stellar Illumination," Johns Hopkins Applied Physics Laboratory, "New Horizons: To Pluto and Beyond" lessons, http://pluto.jhuapl.edu/education/educators_eduGuide.php

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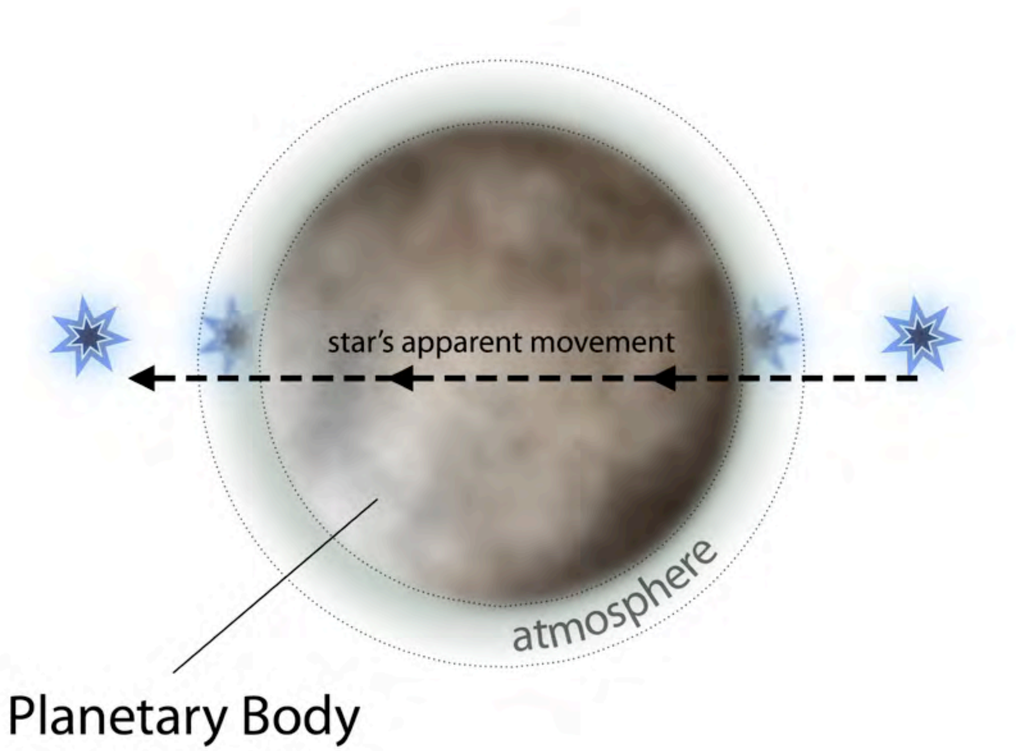
Apparent Stellar Motion



Geometry of a Stellar Occultation

Stellar Occultation: Teacher Answers

Part 1: Pre Lab

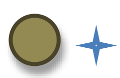
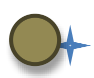
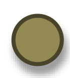
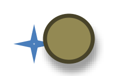
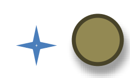
To be completed independently.

Later, you will be observing the object, Snorkzat, which will pass in front of a distant star this evening. Since you are an astronomer, your plan is to observe this through a 1-meter diameter telescope in New Mexico and take a picture every second. Before you make your observations, hypothesize about what you will see as the star appears to pass behind object:

The object: 

The star: 

Hypothesis Table:

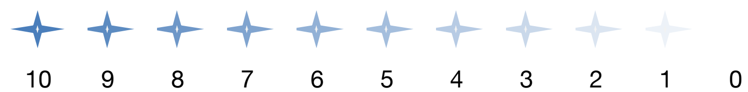
Dwarf Planet and Star position					
Time (seconds)	**0**	**3**	**6**	**9**	**12**
Hypothesis: If Snorkzat has no atmosphere, I will see…	*A dwarf planet with a star nearby*	*A dwarf planet with a star right next to it.*	*Only the dwarf planet and no star.*	*A dwarf planet with a star right next to it.*	*A dwarf planet with a star nearby.*
Hypothesis: If Snorkzat has an atmosphere, I will see…	*A dwarf planet with a star nearby.*	*A dwarf planet with a star dimmed by the atmosphere right next to it.*	*Only the dwarf planet and no star.*	*A dwarf planet with a star dimmed by the atmosphere right next to it.*	*A dwarf planet with a star nearby.*

Project SPECTRA!

Star Light, Star Bright? Finding Remote Atmospheres

Your telescope measures the brightness of the objects you are viewing. The star you will be observing tonight has a brightness of 10. In the next section, complete the tables below and graph your hypothesis of the brightness of the star versus time. Do not connect the dots. *Note: Student answers will vary when the star is behind the atmosphere (at 3 seconds and 9 seconds). The star will dim, but how to classify how much dimmer will be up to the student. The idea to get across is that the graphs are different depending on whether or not the object has an atmosphere.*

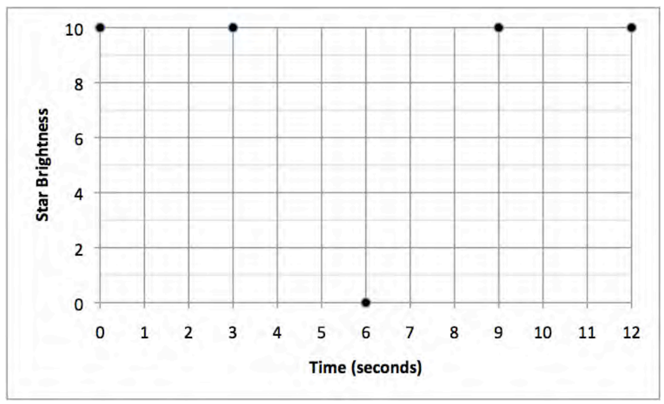
Scale



Hypothesis:
If Snorkzat has no atmosphere…

Time (seconds)	Star Brightness (10= bright, 0=dim)
0	*10*
3	*10*
6	*0*
9	*10*
12	*10*

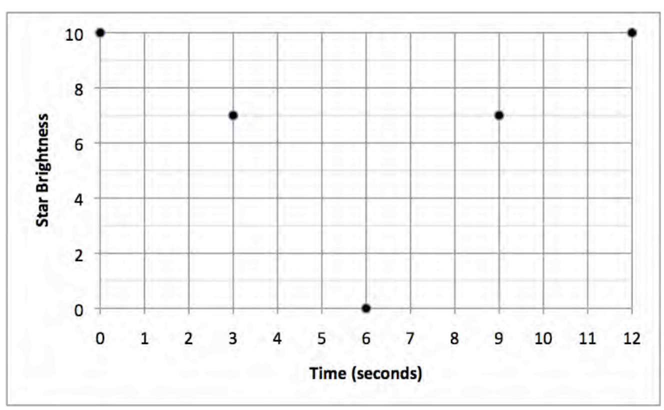
Graph: If Snorkzat has no atmosphere…



Hypothesis:
If Snorkzat has an atmosphere…

Time (seconds)	Star Brightness (10= bright, 0=dim)
0	*10*
3	*7*
6	*0*
9	*7*
12	*10*

Graph: If Snorkzat has an atmosphere…



Teacher Answers

Part 2: Exploring occultation events

Following instructions from your teacher, you will explore different occultation events. Compare these events below and note the time for your observation in the description. The first one is done for you.

Object type	Description of event
No Atmosphere	**At 2 seconds, the star was bright. A little after 2 seconds, the star disappeared behind the object. A little after 10 seconds, the star reappeared, and was just as bright as it was at zero seconds.**
Thin Atmosphere	At 1 second, the star was bright. Just before 2 seconds, the star dimmed just a tiny bit. A little after 2 seconds, the star disappeared behind the object. A little after 10 seconds, the star reappeared, but was a little dim, and at 11 seconds, the star was bright again.
Thick Atmosphere	At 1 second, the star was bright. Just before 2 seconds, the star dimmed just a tiny bit. At 2 seconds, the star was even dimmer. A little after 2 seconds, the star disappeared behind the object. A little after 10 seconds, the star reappeared, but was dim, and at 11 seconds, the star was a little less dim. Shortly after 11 seconds, the star was bright again.

Part 3: Viewing Snorkzat

Following instruction from your teacher, you will be viewing the Snorkzat occultation event.

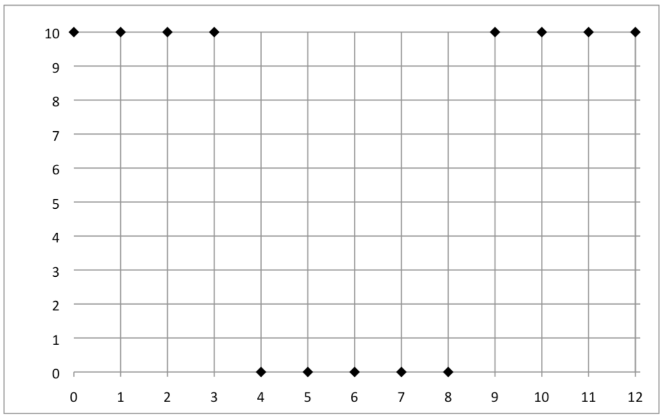
Describe the event as you did in Part 2:

The star was bright at 3 seconds. At 4 seconds, the star disappeared behind Snorkzat. At 9 seconds, the star reappeared and was just as bright as it was at 3 seconds.

Record the stellar brightness in the table below, and then plot your results on the next page.

At time (in seconds)	Earth Observer sees a stellar brightness of….
0	10
1	10
2	10
3	10
4	0
5	0
6	0
7	0
8	0
9	10
10	10
11	10
12	10

Graph the brightness of the star recorded during your observations. Do not connect the dots! *Students should not connect the dots since they are likely to have it slope down and up when the star disappears at 4 seconds and reappears at 9 seconds. The plot should not slope down, since that would imply a gradual decent to zero, and gradual dimming. They can compare this plot to their predicted results from the pre-lab.*



For each of the questions, below, explain your answer. Use an additional page if needed.

1. Does Snorkzat have an atmosphere?
   Answer: No, Snorkzat does not have an atmosphere because the light from the star did not dim when it neared the star. The plot we made is similar to our hypothesis plot from Part 1 where the object has no atmosphere.

2. Would you describe Snorkzat as a planet, dwarf planet, asteroid, or comet? Why?
   Answer: Snorkzat would be classified as a dwarf planet in this case because it is round and is located in the Kuiper Belt, so it has not "cleared its orbit" from other objects as a planet has. It will not be classified as an asteroid because it has enough gravity to pull itself into a round shape. It is not considered a comet unless it comes close enough to the Sun to form a tail, however, comets do come from the Kuiper Belt. Accept a variety of reasonable answers. The question could lead into a Kuiper Belt research project.

Stellar Occultation: Student Handout

Part 1: Pre Lab

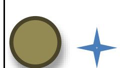
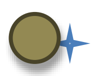
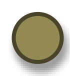
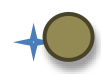
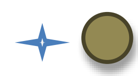
To be completed independently

Later, you will be observing the dwarf planet, Snorkzat, which will pass in front of a distant star this evening. Since you are an astronomer, your plan is to observe this through a 1-meter diameter telescope in New Mexico and take a picture every second. Before you make your observations, hypothesize about what you will see as the star appears to pass behind the dwarf planet:

The planet: 

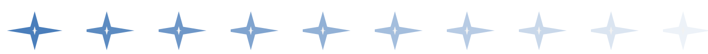
The star: 

Hypothesis Table:

Dwarf Planet and Star position					
Time (seconds)	**0**	**3**	**6**	**9**	**12**
Hypothesis: If Snorkzat has no atmosphere, I will see…					
Hypothesis: If Snorkzat has an atmosphere, I will see…					

Your telescope measures the brightness of the objects you are viewing. The star you will be observing tonight has a brightness of 10. In the next section, complete the tables below and graph your hypothesis of the brightness of the star versus time. Do not connect the dots.

Scale

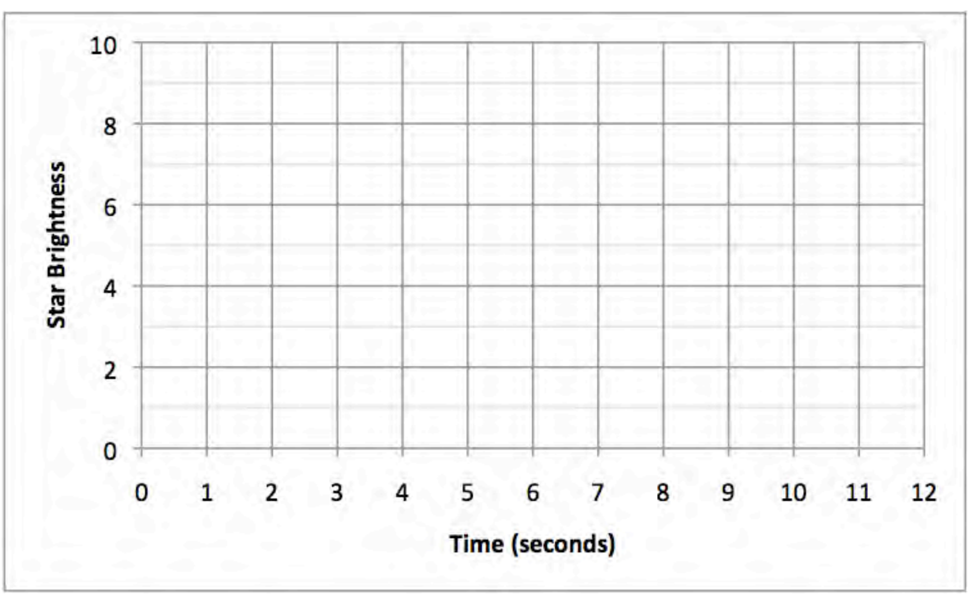


10 9 8 7 6 5 4 3 2 1 0

Hypothesis: If Snorkzat has no atmosphere…

Time (seconds)	Star Brightness (10= bright, 0=dim)
0	
3	
6	
9	
12	

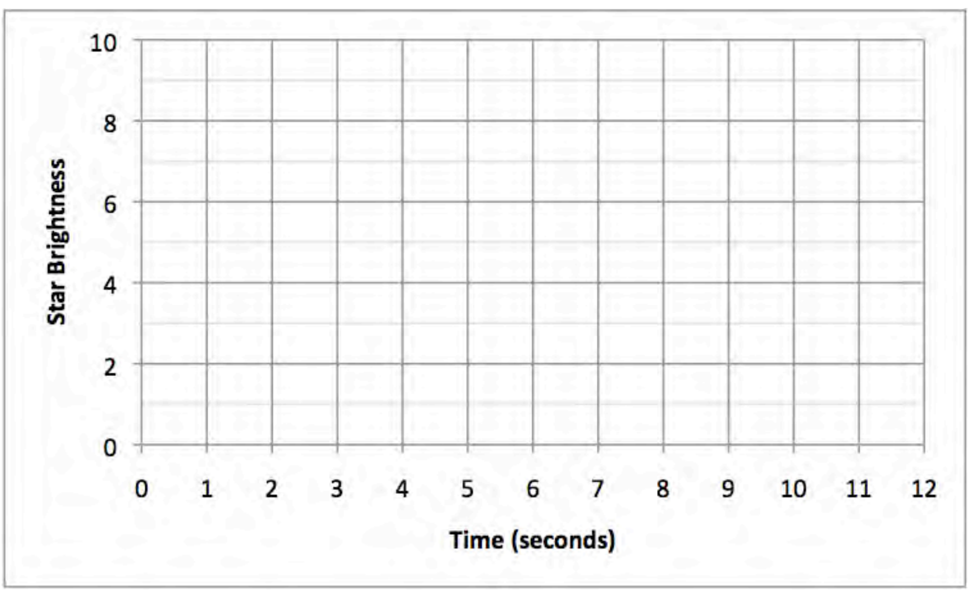
Graph: If Snorkzat has no atmosphere…



Hypothesis: If Snorkzat has an atmosphere…

Time (seconds)	Star Brightness (10= bright, 0=dim)
0	
3	
6	
9	
12	

Graph: If Snorkzat has an atmosphere…



Part 2: Exploring occultation events

Following instructions from your teacher, you will explore different occultation events. Compare these events below and note the time for your observation in the description. The first one is done for you.

Object type	Description of event
No Atmosphere	**At 2 seconds, the star was bright. A little after 2 seconds, the star disappeared behind the object. A little after 10 seconds, the star reappeared, and was just as bright as it was at zero seconds.**
Thin Atmosphere	
Thick Atmosphere	

Part 3: Viewing Snorkzat

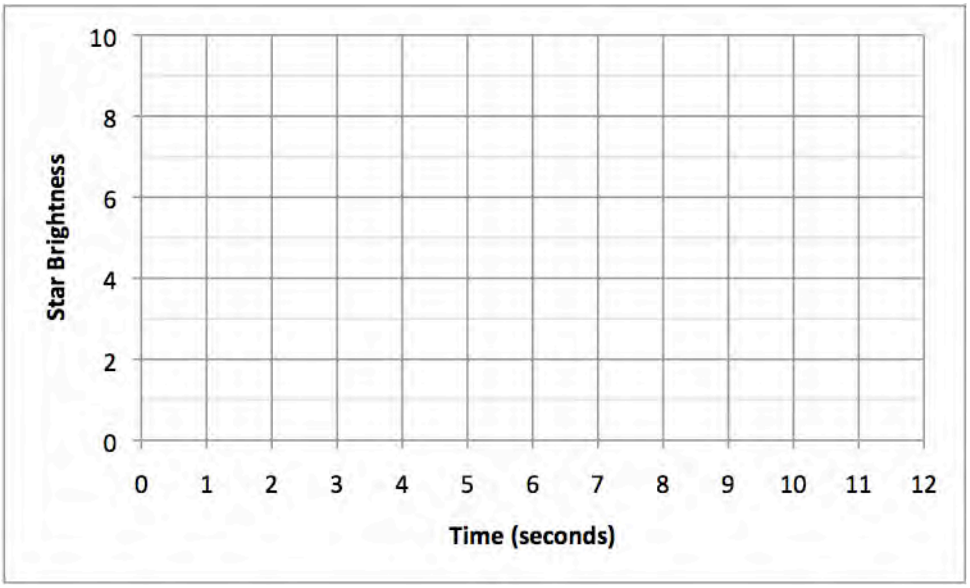
Following instruction from your teacher, you will be viewing the Snorkzat occultation event.

Describe the event as you did in Part 2:

Record the stellar brightness in the table below, and then plot your results on the next page.

At time (in seconds)	Earth Observer sees a stellar brightness of….
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Graph the brightness of the star recorded during your observations. Do not connect the dots!



For each of the questions, below, explain your answer. Use an additional page if needed.

1. Does Snorkzat have an atmosphere?

2. Would you describe Snorkzat as a planet, dwarf planet, asteroid, or comet? Why?