Is there life in space?
Activity 1: The Vastness of Space

Overview

This first activity sets the stage for the rest of the investigation. Students are introduced to the unanswered question about the possibility of life outside of Earth. Students will watch a video (from NOVA scienceNOW (“The Hunt for Alien Earths”)) that introduces scientists in the field of planet hunting. After watching the video, students are asked to reflect on the immense scale of the universe and the basic requirements for life. Finally, they are asked to speculate on the likelihood of finding planets or moons that can support life.

Learning Objectives

Students will be able to

• engage with the “unknown question” guiding the unit.
• explain how scientists use light from distant stars to find planets.
• explore the probability of scientists finding a habitable planet.
• describe the factors that scientists look for to determine if life could be possible on distant planets.

Lesson Plan

1. Estimated Time

This activity should take approximately 45 minutes.

2. Introduce the Activity

In this activity, your students will explore the question “Does life—any form of life—exist on another planet or moon, in our own galaxy or the countless others that exist?” The video clip from NOVA scienceNOW introduces the complexity and methods for finding planets in a vast universe. You may want to project this video (it runs approximately 12 minutes) for the entire class to view at once and then engage in a discussion.

This activity asks students to begin to think about the probability of finding life. There is still uncertainty about the outcome of finding life. Talk to them about the probability of finding life; students' thoughts on this will vary. Don't try to persuade students into
thinking one way or another. Rather, take the time to discuss what might influence the outcome. Encourage all ideas. Use the questions below to encourage discussion.

3. **Discuss the Activity**

Possible discussion questions:

**Search for life in a vast universe**

- What is the probability of finding a habitable planet or moon?
- Does the vast number of stars and moons increase the probability of finding life?
- What makes for a habitable planet?
- What are the requirements for life?
- What are the different ways scientists are searching for planets?
- Why do scientists have to use indirect measurements to find planets? Why can’t they detect planets directly?
- How does the “walking a dog” analogy from the video apply to finding planets?

4. **Answers to Questions**

**Section 1: A Lot of Stars…**

Page 1: Are We Alone?

Q. How do planet hunters use light from distant stars to find planets? Give two examples from the video.
A. *Planet hunters use the light from distant stars in two different ways: 1) they can look at the movement of the light towards and away from Earth to find a wobble in the star’s orbit and 2) they can look for dimming of the light from the star.*

Q. Why is finding other planets difficult?
A. *It is impossible to see the planets directly because they don’t give off light, so scientists have to rely on indirect evidence to find planets.*

Q. Scientists are looking for Earth-like planets. Not every planet is friendly to life as we know it. According to the video, what makes a planet suitable for life?
A. *The planet needs to have liquid water, so the planet needs to be close enough to its star to be warmed (not an ice-ball), but not too close so as to have its water evaporated off. It needs to be a “Goldilocks” planet.*

Page 2: The Vastness of Space

Q. Do you think that it is probable that scientists will find a habitable planet in your lifetime?
A. Student answers will vary.

Q. Explain your choice.
A. Student answers will vary. Answers should include a full explanation of the “yes” or “no” in the previous question.

Q. Are you certain about your answer about the probability of finding a habitable planet outside of Earth?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Answers should explain the areas of certainty and uncertainty.

Page 3: Evidence of Life

Q. What is the first thing that scientists need to look for to find life outside of Earth?
A. Scientists should look for water. Living things need liquid water to survive. This means that scientists should be looking for planets that fall into the habitable range—not too close to their stars and not too far away from their stars for liquid water to exist. Students may give other answers, such it must be a rocky planet, or that it needs to have an energy source. These are reasonable, if their reasoning supports their answers.

Q. Explain your reasoning.
A. Student answers will vary. Students should include evidence from the video and from the text.
Is there life in space?
Activity 2: Moving Stars and Their Planets

Overview

In this activity, students are introduced to the wobble-method of detecting planets. The activity starts with an introduction to Newton’s Third Law of Motion. Students use a model to explore the effects of a planet’s mass on the star’s motion. Students then explore how the wavelength of light that a star emits is apparently changed as the star moves toward and away from a telescope. Students use a model to discover the influence of orbiting angle on the ability to detect a planet with the wobble method. Students then use an integrated model to explore the effects of planetary mass and orbiting angle concurrently. Finally, students learn about telescope precision and noise in the data.

Learning Objectives

Students will be able to

- explore the effect of planetary mass on a star’s wobble.
- explain how wavelength can describe the motion of a star.
- demonstrate how a planet’s angle of orbit determines whether or not the planet might be found.
- explain how planets are found using the wobble method.

Lesson Plan

1. Estimated Time

This activity should take approximately 45 minutes.

2. Introduce the Activity

In this activity, students will explore how the motion of planets can influence the motion of stars. Using models, they will experiment with different types of planets, different sizes of planets, and different planetary orbits and learn how to interpret shifting wavelengths of light coming from stars.

Please note: there are short videos about how to use the models on several pages. You should be sure to look at them prior to using this activity in class. These models get more complex as the activity progresses.
Please note the following:

- A rocky planet is denser than a gaseous planet, so the mass of the rocky planet will be higher than a gaseous planet of the same size.
- The “graph-time-window” slider introduced on page 3 allows students to increase or decrease the amount of data they see in the velocity graph.
- There is a new control added on page 4 that allows students to magnify the y-axis with the slider, allowing them to see very small or very large curves within the graph window.
- On page 4, students can also create their own custom planets. To do this, they need to turn on the “custom-planet” switch, choose a rocky or gaseous planet, and set the planet’s diameter with the slider. To set the planet’s velocity, they will need to move the arrow (vector) of the planet. To start the simulation, students must turn off the “custom-planet” switch. The model must be running (with the “Run/Pause” button) before any of these features will work.
- The “Distance-to-star” button zooms the view in and out.

You may want to project the models to demonstrate how to use the controls on the more complex models.

**Section Highlights**

*Section 1: Finding Planets Using Star Motion*—This section is divided into seven pages. Students will begin by exploring how the mass of a planet is related to the movement of a star. They then explore how the wavelength of light emitted by the star changes as it moves toward or away from Earth. It is important that you make sure students understand that *the color of the light emitted by the star does not change as the star moves*; the wavelength detected by the telescope changes because the star is either moving closer (compressing the waves) or moving farther away (decompressing the waves).

Students will then explore how the mass of a planet and the angle of its orbit affect a scientist’s ability to detect the planet’s presence based on a star’s wobble. Students will use a model to experiment with changing a planet’s orbit and the mass to explore this phenomenon. Students will interpret graphs representing the change in the velocity of light emitted by the star.

Finally, students will explore the concept of noise in data by setting up the model so that a planet is detectible with a perfect telescope and then altering the models “precision” to see how noise might obscure the signal.
1. **Discuss the Activity**

Possible discussion questions:

**Using light to find planets**

- How do scientists use light from distant stars to measure stars’ movements?
- What do scientists know about the motion of a star from the color of its wavelength? How is a star moving if its wavelength is shifted towards the red end of the spectrum? How is a star moving if its wavelength is shifted towards the blue end of the spectrum?

**“Wobbling” stars**

- What is meant by the term “star wobble?” Is Earth’s star (the Sun) wobbling?
- How does the model help to explain star wobble?
- How does a planet’s angle of orbit affect the ability of scientists to detect it?
- What would the velocity graph look like if there were multiple planets orbiting the star?

**Finding planets with indirect evidence**

- The graphs represent the velocity of the star, not the velocity of the planet. Why do scientists focus on a star’s motion?
- How can scientists be sure that they have found a new planet?
- How do technological innovations influence the process of science?

4. **Answers to Questions**

Section 1: Finding Planets Using Star Motion

Page 1: Gravity and Orbits

Q. The motion of a star caused by an orbiting planet is referred to as a “wobble.” Why does the star wobble when it has an orbiting planet?
A. *The star is pulled towards the planet by the planet's gravitational force. The pull on the star results in the star moving, or wobbling, as the planet orbits.*

Q. What happens to the wobble motion of the star when the planet has a very low mass?
A. *The star continues to wobble.*
Q. Explain your answer in the previous question.
A. Even if the planet is small, it still exerts a gravitational force on the star. The wobble may be undetectable by telescopes, but it still exists.

Q. Are you certain about your explanation in the previous question?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Q. Based on your observations, what is the relationship between movement of the star and the mass of the planet?
A. As the planet gets more massive, the star wobbles more. When there is a smaller planet, the wobble is less.

Page 2: The Doppler Effect

Q. Take a snapshot of the model that shows both short and long wavelengths in the same picture. Insert your snapshot here. Add notes that show which wavelengths are short and which wavelengths are long.
A. Student answers will vary.

Q. You observe a star through a telescope. What happens to the apparent wavelength of the star's light as it moves toward you?
A. It gets shorter.

Q. Explain your answer.
A. As the star moves closer, the waves get compressed so the wavelength appears shorter.
Q. Are you certain about your answer and explanation?
A. Student answers will vary. Students should be fairly certain of their answers because they can test the scenario with the model.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Q. A scientist observes that the light from a star seems to be shifted toward the red end of the visible spectrum. How is the star moving?
A. The star is moving away from the telescope.

Q. Explain your answer in the previous question.
A. If the visible light is shifted toward the red, then the wavelengths are getting longer, which means that they are being stretched out. This indicates that the star is moving farther from the telescope.

Q. Are you certain about your answer and explanation?
A. Student answers will vary. Students should be fairly certain because they can test the scenario with the model.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Page 3: The Importance of Angle

Q. Which orbital angle prevents you from seeing the motion of a star that does have an orbiting planet?
A. 90 degrees

Q. Explain your choice in the last question.
A. When the planet's orbital tilt is at 90 degrees, the star is not moving towards and away from the telescope. Only forward and back motion is detected with the telescope.

Q. Are you certain about your answer and explanation?
A. Student answers will vary. Students should be fairly certain because they can test it with the model.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Q. A scientist looks for planets by studying the light from a newly discovered star. The velocity graph of the star's motion (based on shifting wavelengths) indicates no motion of the star toward or away from Earth. The scientist decides that the star doesn't have any planets. Do you agree with the scientist?
A. Student answers will vary.
Q. Explain your choice.
A. Answers should include the possibility that any planets are orbiting at a 90 degree tilt or that planets may be too small to affect the motion of the star.

Q. Are you certain about your explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Answers should include the unknowns about planet size and orbital angle.

Page 4: The Importance of Both Mass and Angle

Q. Insert a snapshot that shows a very large, very heavy planet that creates a velocity graph similar to the one shown above.
A.

Q. Explain how different combinations of planetary mass and orbital angle can create similar velocity graphs.
A. If the planet is very big and orbiting at a high orbital angle, it can give the same appearance as a much smaller planet orbiting at a low orbital angle. If a smaller planet were orbiting at a high orbital angle, it might not be detected because it wouldn't exert enough gravitational force on the star to move it very much.

Q. This velocity graph was recorded by pointing a telescope at a nearby star. A scientist determines that the star must have a very large planet orbiting around it. Do you agree with the scientist's conclusion?
A. Student answers will vary.
Q. Explain your answer.
A. Student answers will vary. Students should note that it is not possible to determine the size of the planet based on the velocity graph, since a very large planet at a high tilt could produce the same velocity graph as a much smaller planet at a low tilt.

Q. Are you certain about your explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Page 5: Limitations of Noise

Q. Does this graph show a planet orbiting a star? What is your prediction?
A. There is definitely a planet shown there.

Page 6: Impact of Noise on Angle of Orbit

Q. Most of the planets that have been discovered orbit their stars at a tilt closer to 0 degrees than to 90 degrees. Why?
A. The signal is more evident when the tilt is lower. The telescopes are not perfect, so they can only detect star motions that are very large. The largest motions occur when the tilt is closer to 0 degrees.

Q. Why might a scientist, using modern telescopes, be unsure about having discovered a planet?
A. Telescopes are not precise enough so that a small signal can be reliably detected. The velocity graph may indicate that there is a planet present, but it may also be just the noise of the telescope.

Page 7: Impact of Noise on Planet Discovery via Star Motion

Q. Most of the planets that have been discovered so far have been very massive. Why?
A. The signal is more evident when the planet is more massive. The telescopes are not perfect, so they can only detect star motions that are very large. The largest motions occur when the planets are massive.

Q. This velocity graph was recorded by pointing a telescope at a nearby star. Based on the velocity graph, shown above, could there be a planet orbiting this star?
A. Student answers will vary.

Q. Explain your answer.
A. Answers should include the appearance of an undulating curve in the data, as well as the large amount of noise.
Q. Are you certain about your answer and explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.
Is there life in space?  
**Activity 3: Hunting for Planets**

In this activity, students are introduced to the transit method of finding planets. Students experiment with a moveable planet to see the dimming effect—as shown in a “light intensity graph”—that a transiting planet has on its star. Students experiment with planet diameter to discover the effect of a planet’s size on star dimming. Then students use another model to investigate the effect of a planet’s orbiting angle on its ability to be detected through the transit method. Students explore the role of telescope precision and noise on data interpretation.

**Learning Objectives**

Students will be able to

- explain how planets can be detected using the transit method.
- describe the effect of a planet’s diameter on its ability to be detected using the transit method.
- describe the effect of orbiting angle on a planet’s ability to be detected using the transit method.
- explain how technological advances can result in new scientific discoveries.

**Lesson Plan**

1. **Estimated Time**

This activity should take approximately 45 minutes.

2. **Introduce the Activity**

In this activity, your students will explore how differently sized planets can change the intensity of light coming from the star. You may want to replay the clip from the NOVA scienceNOW video that explains the transit method as a planet-hunting tool. Begin the activity by talking about eclipses.

**Section Highlights**

Section 1: Finding Planets Using Star Motion—This section is divided into five pages. Using the models on the first page, students are quickly able to explore how the size of
different planets transiting in front of a star can affect the amount of light detected by a telescope. The model on the second page asks students to change the tilt of a planet’s orbit to observe how that affects the star’s light intensity graph. When a planet transits a star in this model, the model goes into a "super slow-motion" mode and a pop-up window shows the transit of the dark planet in front of the star. This visualization is similar to the one in the first model in this activity. It is important to spend time analyzing the graph with your students so that they can explain the dips in the light intensity graph and how it relates to the transit of the planet. If students do not see a drop in the star’s light intensity, have them explore whether angle of planet orbit, size of the planet, or the scale of the light-intensity graph might be the reason.

As instrument precision plays an important role in scientists’ work, students will again change instrument precision in order to explore how it might affect planet detection.

Finally, students will be challenged to find planets on their own. In this model, students will look at the velocity and light intensity graphs for a random star in the star field. The star is selected by the computer, not by the student. Your students will have to draw conclusions based only on the data in the graphs; the model does not show a planet orbiting a star.

If time permits, the last page of the activity will give your students a chance to set up different scenarios and challenge other teams to detect a planet based on analyzing velocity and light-intensity graph data.

3. Discuss the Activity

Possible discussion questions:

**Using light intensity to find planets**

- Why do stars appear to dim when a planet transits?
- What factors affect the ability of scientists to detect a planet with the transit method?

**Finding planets with indirect evidence**

- How can scientists be sure that they have found a new planet?
- How do technological innovations influence the process of science?

**Discussion after finding planets in the star field**

*Use particular examples of stars and data with the entire class.*

- What data made you feel confident that there was a planet orbiting the star?
• When you were unable to detect a planet, were you able to conclude that the star did not have a planet? Why?
• Now that you’ve had practice in finding planets around stars, what would you do to determine if it is conducive to life?

1. **Answers to Questions**

Section 1: Finding Planets Using The Transit Method

Page 1: Light Intensity

Q. How did you reduce the light intensity of the star?
A. *I made the planet larger and moved it in front of the star.*

Q. Which planet would be most easily detected with the light-intensity method of planet hunting?
A. *Planet C*

Q. Explain your answer in the previous question.
A. *Planet C has the largest diameter, so it should block more of the light from the star than the other planets would.*

Q. Are you certain about your explanation?
A. *Student answers will vary.*

Q. Explain what influenced your certainty rating in the last question.
A. *Student answers will vary. Answers may include a question of whether the planet fully blocks the star when it orbits or if only a portion of the planet blocks the star.*

Page 2: The Importance of Angle

Q. Insert a snapshot of your solution to Challenge A (large planet that has no dimming effect on its star).
A. *Student answers will vary.*
Q. How did you solve Challenge A? How did you make a large planet undetectable by the transit method?
A. I adjusted the tilt of the orbit so that the planet never passes in front of the star, relative to the telescope.

Q. Insert a snapshot of your solution to Challenge B (small planet that has a dimming effect on its star).
A. Student answers will vary.
Q. How did you solve Challenge B? How did you make a small planet detectable by the transit method?
A. I adjusted the tilt to 0 degrees so that the planet passed directly in front of the star. The dimming is very small, but it is detectable.

Q. Which orbital angle prevents you from seeing a drop in light intensity caused by an orbiting planet?
A. 90 degrees

Q. Explain your choice.
A. When the tilt is 90 degrees or close to 90 degrees, the planet does not pass in front of the star enough that dimming of the star's light intensity can be seen.

Q. Are you certain about your answer and explanation?
A. Student answers will vary. Students should be fairly certain because they can test the scenario with the model.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Page 3: Instrument Precision

Q. Most of the planets that have been discovered using the transit method have had large diameters. Why?
A. Planets with large diameters block the most light from their stars. Since the telescopes aren't perfect, only large signals can be readily detected. The largest diameter planets give the largest signals.

Q. A star was picked at random and light intensity was measured over a long period of time, giving the light intensity graph shown below. Could there be a planet orbiting this star?
A. Student answers will vary.

Q. Explain your choice.
A. Answers should include the possibility that any planets are orbiting at a 90 degree tilt or that planets may be too small to be detectable. It is also possible that the "long period of time" was not long enough for the planet to make a full orbit around the star.

Q. Are you certain about your explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Answers should include the unknowns about planet size and orbital angle.

Page 4: Individual Planet Hunt Challenge

Q. Insert a snapshot of your model here.
A. Student answers will vary.

Q. Enter the code for your star. (It is a six-digit code, starting with "HAS.")
A. Student answers will vary.

Q. Do you think that there is a planet orbiting your star?
A. Student answers will vary.

Q. Explain your choice.
A. Answers should include a discussion of the data that was generated from the star, as well as the noise level in the data.

Q. Are you certain about your answer and explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Answers should include the unknowns about planet size, orbital angle, and instrument limitations.

Page 5: Planet Hunting in the Classroom (optional)
Q. Describe an example in which you were very certain from the graphs how the star system was set up, and why you were certain.
A. *Student answers will vary.*

Q. Describe an example in which you were uncertain how the star system was set up, and why you were uncertain.
A. *Student answers will vary.*

Q. How successful were you at detecting others' planet setups? What made it difficult?
A. *Student answers will vary.*
Is there life in space?
Activity 4: Habitable Conditions

Overview

The fourth activity introduces the students to conditions for habitability. It revisits the characteristics of stars and planets that make a planet more favorable for habitability. First, students look at properties of five different star types and the zone of habitability around each star. Then students explore the potential habitability of planets orbiting different star types, getting feedback on the orbit, planet-type, star type, and distance from star. Finally, students contemplate which types of planets on which scientists should focus their efforts in the search for an Earth-like planet.

Learning Objectives

Students will be able to

• compare the zone of liquid water possibility around different star types.
• explore what conditions make a planet suitable for life.
• evaluate planet characteristics to decide whether a planet is worth further investigating for evidence of life.

Lesson Plan

1. Estimated Time

This activity should take approximately 45 minutes.

2. Introduce the Activity

Scientists are finding new planets around distant stars all the time. Which ones are worth pursuing in the search for life in space? Ask students to think about conditions that would make a planet more or less habitable. In the NOVA scienceNow video scientists, mentioned liquid water as one criterion for life. Ask your students why liquid water is a criterion for life and what other factors scientists should consider.

Section Highlights

Section 1: Habitability
Students begin by learning about five different star types; they are asked to think about how the lifespan of a star and the temperature of a star might affect the planets that orbit them and potential for that planet to house life forms. The models in this activity define the habitable zone as the zone in which liquid water is likely to be found. The models represent the liquid water possibility zone with a blue donut encircling the star. Students are encouraged to use the model to explore different scenarios in which they can change planetary characteristics and test different star types. Be sure to have students “create” planets that go in and out of the habitable zone (have elliptical orbits), planets that are just on the edge of the habitable zone, planets that have large mass and planets that have small mass. Have them look at the feedback (from the check solar system button) to see what other clues they might find about planet habitability.

3. Discuss the Activity

Possible discussion questions:

**Search for life in a vast universe**

- What does it mean for a planet to be in the “habitable zone?”
- Which planets in our solar system are in (or near) the habitable zone?
- What are characteristics of stars that make them more or less favorable for finding potentially-habitable planets?
- If a planet orbits mostly in a habitable zone, but then is out of the zone for some time, do you think it should be considered as potentially-habitable?
- Should scientists be looking for another planet that is “just like Earth?” Should scientists consider different types of planets? Why?
- What conditions can life tolerate on Earth? Can you think of life forms that live in extreme conditions on Earth? Does that influence your opinion about where scientists should begin looking for life outside of Earth?

4. Answers to Questions

Section 1: Habitability

Page 1: Types of Stars

Q. Earth is about 4.5 billion years old. The first micro-fossil evidence of life on Earth dates to about 3.4 billion years ago. Scientists think that it takes millions of years for life to evolve. Which star type is least likely to have a planet on which life could have evolved?
A. A-class star

Q. Why do you think that star type is least likely to have a planet on which life could evolve?
A. A-class stars have shorter lifespans than G- and M-class stars. If it takes millions of years for life to evolve and the star only exists for 10-100 million years, that is probably not enough time for life to evolve.

Q. Are you certain about your answer and explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Answers may include a question of whether life needs to evolve on the planet or be imported from a passing asteroid.

Page 2: Zone of Liquid Water Possibility

Q. If a planet orbits its star too closely, what would happen to any water on the surface?
A. The water would evaporate.

Q. Explain your choice.
A. If the planet is too close to the star, the planet's surface will be very hot. If it is very hot, the water will not exist as liquid on the surface; it will evaporate.

Q. Are you certain about your explanation?
A. Student answers will vary. Students should be fairly certain since, on Earth, water evaporates when the surface is hotter.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Q. Why is the M-class star's zone of liquid water possibility so close to the star?
A. M-class stars are not very hot, so the heat needed to have liquid water on the surface (rather than frozen water on the surface) is present only close to the star.

Q. Our Sun is a G-class star. The Earth orbits the Sun within the zone of liquid water possibility. A scientist finds an Earth-sized planet orbiting its K-class star at the same distance as the Earth orbits the Sun. Is it likely that the newly-discovered planet has liquid water on the surface?
A. no

Q. Explain your answer in the last question.
A. The planet orbits well outside of the liquid water zone, so any water on the surface will be frozen.

Q. Are you certain about your answer and explanation?
A. Student answers will vary. Students should be fairly certain because they can test the scenario with the model.
Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Page 3: Goldilocks Planets

Q. How does a planet's size affect its potential to support life?
A. Larger planets are able to hold an atmosphere. Atmospheres are necessary for life on the surface. A larger planet is also more likely to have tectonic activity, which means that there is a source of heat from underground as well as the stabilizing effect on carbon dioxide levels of the rock cycle.

Q. Scientists find an Earth-sized planet orbiting an F-class star, slightly outside of the zone in which liquid water can exist. Is it possible that this planet could support living things?
A. Student answers will vary.

Q. Explain your choice.
A. Answers should include the possibility of tectonic activity that would be a source of warmth that could melt some of the ice into liquid water.

Q. Are you certain about your answer and explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Page 4: Favorable Conditions for Life

Q. Which planet is most likely to have conditions that would be favorable for life?
A. Student answers will vary.

Q. Explain your choice.
A. Answers should include a discussion of the planet type (rocky or gaseous), planet size (detectable from the movement of the star), orbiting position (inside or outside of the zone of liquid water possibility), and star class (with yellow, orange, and white stars having the best potential for harboring habitable planets).

Q. Are you certain about your answer and explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Answers should include the unknowns about planet size (those that don't visibly affect the motion of their stars), planet type (whether a rocky planet is necessary for life), and whether or not life has to evolve on the planet or can be deposited on the planet from another source (blue star).
Is there life in space?
Activity 5: Looking for Signs of Life

Overview

The final activity in the space investigation focuses on how telescopes can be used to look for signs of living things on other planets. Students begin by exploring different types of radiation that a star can emit. Then, students use a simple model to explore how various wavelengths of light interact with matter differently. Students learn how to interpret absorption spectra. Finally, students explore how scientists use the light from a star to look at planetary atmospheres and discover how this information might reveal more clues as to which planets are more likely to be habitable.

Learning Objectives

Students will be able to

- investigate how matter can absorb and emit light of different frequencies.
- interpret visible light emission spectra.
- determine how planetary spectra can be used to search for life on other planets.

Lesson Plan

1. Estimated Time

This activity should take approximately 45 minutes.

2. Introduce the Activity

Spectroscopy is a powerful tool for identifying atoms and molecules in gases. Scientists are using this technique to look for evidence of life outside of Earth. Introduce the activity by revisiting the questions from the beginning of the investigation, with a particular focus on which atmospheric gases might be evidence that a planet harbors life. Ask students to think about Earth as an example and focus on products of respiration and photosynthesis. You might want to also ask them to think about methane, ozone, and other atmospheric gases that might be indicators of life.
Section Highlights

Section 1: Spectroscopy

This activity returns to the questions that opened the investigation. At the start of the space investigation, students thought about what conditions might make a planet suitable for life. This activity returns that question, but now the focus is on what gases would be in the atmosphere of a suitable planet.

The first page is important for setting students up to explore why scientists are using the electromagnetic radiation for detecting signs of life. The models used in this section represent light as photons, where different wavelengths are represented by different numbers of “wiggles” in each photon packet. When students are using the model, talk about the way light interacts with matter (as shown by the dashed halo around an atom).

Knowing that only some wavelengths of light interact with matter is useful because the absorption of the wavelengths, represented as absorption spectra, can be used like fingerprints to identify specific matter from a distance. Scientists use different wavelengths, not just visible light, to identify substances on distant planets. Frequently, infrared spectra are used to identify matter on distant planets.

The end of the activity tries to synthesize how scientists are trying to answer the question “Is there life on other planets?” Spend time discussing with your students the different methods, returning to a discussion regarding the probability of finding habitable planets and what affects the probability.

3. Discuss the Activity

Possible discussion questions:

Spectroscopy

- Does light interact with all matter in the same way?
- What are the different ways light can interact with matter? Give some examples.
- Why do scientists look at a planet’s absorption spectra in the search for habitable planets?
- What gases does life (as we know it) require?
- What gases does life (as we know it) produce?
- What gases are likely to be present in the atmosphere of a planet harboring life?

Search for life in a vast universe

- What makes for a habitable planet?
- What are the requirements for life?
- What is the probability of finding a habitable planet or moon?
- What are the different ways scientists are searching for planets?
- Why do scientists have to use indirect measurements to find planets? Why can’t they detect planets directly?
4. Answers to Questions

Section 1: Spectroscopy

Page 1: Looking for Evidence of Life

Q. What gases would be in the atmosphere of a habitable planet?
A. Student answers will vary. Students may suggest that the atmosphere should be similar to that of Earth or that it should be similar to the atmosphere that existed on Earth early in its history. Others may suggest that the atmosphere could be entirely different because other planets may support entirely different forms of life.

Page 2: Electromagnetic Spectrum

Q. Waves in the electromagnetic spectrum vary in size – from very long radio waves, the size of buildings, to very short gamma rays, smaller in size that the nucleus of an atom. How does this model show the difference between longer-wavelength infrared radiation and shorter-wavelength visible light?
A. The waves are more squished together in the shorter wavelength lights. The waves in the infrared radiation are more spread out.

Q. How does the wavelength change when you move the slider from infrared to ultraviolet?
A. The wavelength gets shorter as you move from infrared to ultraviolet.

Page 3: Light-Matter Interactions

Q. In the model, what type of light was absorbed by and emitted from the atoms?
A. green

Q. What happened to the photons that were not absorbed by the atoms?
A. The photons that were not absorbed went straight through the atoms without being affected.

Page 4: Absorption Spectra

Q. The absorption spectrum for hydrogen is shown below. Which of the mixtures in the model contains hydrogen?
A. Mixture B

Q. Explain your answer.
A. Only Mixture B had the same pattern of lines as those shown in the known hydrogen spectrum. There were additional lines, but neither Mixture A nor Mixture C had lines in the same place to match the hydrogen spectrum.

Q. Are you certain about your answer and explanation?
Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Q. There are many different elements in the gases of stars and planetary atmospheres. A particular star is composed of hydrogen and neon. What would its absorption spectrum look like?
A. It would look like a combination of the hydrogen spectrum and the neon spectrum.

Q. Explain your answer.
A. Because both hydrogen and neon are present, both hydrogen and neon would be seen in the absorption spectrum. It would look like a combination.

Q. Are you certain about your answer and explanation?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.

Page 5: Planetary Atmospheres

Q. The absorption spectrum from a star looks like the one shown below. A planet transits in front of the star and scientists measure the absorption spectrum of the planetary atmosphere. If the planet has an atmosphere, how should its absorption spectrum compare to the star's spectrum?
A. It should have more absorption lines.

Q. Explain your choice.
A. The substances in the planet's atmosphere would absorb certain wavelengths. When those wavelengths are absorbed, more lines are created on the spectrum.

Q. Are you certain about your explanation in the last question?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary. Students may be uncertain about the composition of the planet's atmosphere; if the planet's atmosphere has the same substances as the star, then no additional absorption lines would be recorded.

Page 6: Evidence of Life?

Q. What combination of substances in a planet's atmosphere would suggest that the planet might be suitable for life?
A. Student answers will vary. Students may suggest that ozone is necessary to protect organisms from ultraviolet radiation or carbon dioxide is a sign of an atmosphere that
has organisms or supports a greenhouse effect that would warm the planet enough to support life. Students may suggest that only the presence of water vapor is necessary to indicate support for life/evidence of life.

Q. Explain your answer.
A. Student answers will vary. Explanations should provide rationale for the combination of substances needed in the atmosphere.

Q. Are you certain about your answer to the last question?
A. Student answers will vary.

Q. Explain what influenced your certainty rating in the last question.
A. Student answers will vary.