

Unit 4

Earth in Space:

How are we connected to the patterns we see in the sky and space?

Student Procedure Guide



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Earth in Space:

How are we connected to the patterns we see in the sky and space?

Student Procedure Guide

Core Knowledge Science



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Earth in Space

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Lesson 1: How are we connected to the patterns we see in the sky?

A New Phenomenon

In your notebook



1. Your teacher will show you a video of a new phenomenon. Make a T-chart in your science notebook and record what you notice and wonder as you watch the video. Be prepared to share your thinking with your class.

Share Manhattanhenge notice and wonder.

With your class



2. Discuss the following questions with your class:
 - Why do you think people feel connected to this phenomenon?
 - What else did you notice in the Manhattanhenge phenomenon?
 - What did you wonder about this phenomenon?

What is happening to cause Manhattanhenge?

With your class



3. Orient yourself with the two maps of New York City. Keep in mind that the best views of Manhattanhenge are said to be on 34th Street.

On your own



4. Follow your teacher's instructions and use *Initial Manhattanhenge Model* to develop and use a model to explain how Manhattanhenge happens and why we don't see it every day.

Cause and Effect

Turn and talk



5. Discuss the following questions with your partner and be prepared to share your thinking with your class.
 - What objects are interacting to cause us to see Manhattanhenge?
 - What changes or interactions in the system can help explain why we only see Manhattanhenge on certain days of the year?

Related Phenomena and Patterns

With your group



6. Discuss the following questions with your group.
 - What other phenomena or patterns have we seen with other objects in the sky (either during the day or during the night)?
 - Have you ever noticed something in the sky look totally different than any other time you have seen it?
7. Follow your teacher's instructions for recording and posting your ideas about *Phenomena in the Sky* and *Patterns* on sticky notes.

Expanding Outward from Our Experiences

There might be stories our family or community knows about what they or others have observed in the sky.

Home Learning



8. Go home and poll your friends, family, and trusted community members. First, share with them what we have been talking about and share an example of a pattern or event we discussed in class. Let them know that this is not about weather but about patterns we think are connected to space. Then ask them these questions and record responses on *Community Connections to the Sky*:
 - What patterns or phenomena have they seen in the sky?
 - What stories have they heard from their family and community about patterns others have observed in the sky or about things on Earth that are connected to patterns and objects in the sky?

Adding to Our Patterns

With your group



9. Share the ideas you got from family and community members with the people at your table. Record at least one new idea on a sticky note and follow your teacher's instructions for posting your sticky note.

Expanding Our Horizons

Turn and talk



10. Discuss these questions with your partner:
 - How could we find out more about what phenomena and patterns people across the world have observed in the sky over thousands of years?
 - Might we be able to observe the same phenomena and patterns today or at some point in the future?

Podcast Jigsaw

With your group



11. Follow your teacher’s instructions and use the close listening protocol for your group’s assigned podcast.

Before	- Look at the title of your podcast and discuss with your group. What does the title tell you about what will be in the podcast? - What is a question you have that you hope the podcast will help answer?
During	- Listen carefully, following along with the transcript. - Highlight or underline words, phrases, and ideas that you have never heard before or that you want to know more about. - Each person in your group will be allowed one pause request. When you hear something that you want to discuss or have clarified, raise your hand to use your pause request.
After	- Look at the title of your podcast again. Now that you have heard the podcast, why do you think the podcast producers chose this title? - Respond to the questions on the handout and be ready to share with the class.

Additional Patterns

With your group



12. Respond to the questions on your podcast handout. As you work, follow your teacher’s instructions for recording any new patterns in the sky that you heard about while listening to the podcast.

Additional Patterns

With your class



13. Share the patterns your group recorded on sticky notes, post the notes on the *Patterns in the Sky* poster, and discuss the following questions with your class:

- What did your group wonder about the phenomena in the podcast?
- Why was it important to the people you learned about to study the sky?

Personal Reflection

On your own



14. Record your answers to the following questions on a blank piece of paper:

- Are there any patterns or phenomena in the sky that you feel personally connected to? Explain your connection.
- How are your views about space and science similar to the views you heard about in the podcast? How are they different?
- Did listening to the podcast change any of your views about space and science? If so, how? If not, why not?

Navigation

With your class



15. Discuss the following with your partner:

- Choose a **pattern** for which you want to develop a model and share that pattern with a partner.
- Tell your partner what **parts** you think will need to be in the system you model to explain your pattern.

Initial Models

On your own



16. Choose one pattern to model and write the pattern in the title of *My Initial Model to Explain: _____*, then complete the following:

- Show and describe what the pattern phenomenon looks like from Earth and when it happened/happens.
- Change perspective. Draw and/or describe a model to help explain why that pattern happens. Identify the important parts, motions, and interactions in the system and the perspective you are taking in this model.
- Describe what is happening with the parts and interactions in your system that is causing us to see your pattern or phenomenon.

Feedback on Initial Models

Turn and talk



17. With your partner: Each person gets 2 minutes to present their model.

On your own



18. On your own:

- Go back and make any changes to your model you would like after hearing about other people's models.
- Prepare for the gallery walk by posting your model in the room.

Gallery Walk

On your own



- 19.** Follow your teacher's instructions and visit at least two models and record what you notice on *My Initial Model to Explain*:_____.

Classroom Norms

With your class



- 20.** Follow your teacher's instructions and revisit our classroom norms.

Initial Consensus Model Discussion

With your class



- 21.** Work with your class to develop a record of what we agree on and where we have competing ideas across the initial models. Be ready to share your thinking about the following questions:
- What similarities and differences did you see among parts that were represented in the models you visited?
 - What similarities did you see among the motions and interactions of objects represented in the models you visited?
 - What similarities and differences did you see among perspectives that were represented in the models you visited?

Navigation

On your own



- 22.** To prepare for our next class when we will build our Driving Question Board, answer the following question:
- What questions do you now have about some of the phenomena we have been talking about?

Getting Ready to Build the DQB

Scientists Circle



- 23.** Discuss the following with your class:
- What questions could we ask about these phenomena/patterns and the systems that we think cause them that we could investigate as a class?

Developing Questions for the DQB

Scientists Circle



24. Discuss the following with your class and follow your teacher's instructions for recording questions.

- What questions do we have about:
 - phenomena and patterns in the sky?
 - objects and interactions in the system(s) that might cause them?

Driving Question Board (DQB)

Scientists Circle



25. Follow your teacher's instructions and these procedures for building the DQB:

- The first student reads their question aloud then posts it on the DQB.
- Students who are listening should raise their hand if they have a question that relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads their question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- That student selects the next student, who may have a related question or a new question.
- We will continue until everyone has at least one question on the DQB.

Ideas for Investigation and Data

What kinds of investigations could we do and what additional sources of data might we need to figure out the answers to our questions?

In your notebook



26. Add your ideas to a new notebook page titled *Ideas for Future Investigations and Data We Need* and be prepared to share your thinking with the class.

Where to go next?

Home Learning



27. Look up in the sky, if you can, and keep track of what you notice!

Lesson 2: What patterns are happening in the sky that I have experienced and can observe (through models and tools)?

Preparing to Observe the Sky

Turn and talk



1. What were some of the things in the sky that we were interested in observing to figure out more about some of these patterns?

Native American Sky Story: Navajo Nation

In your notebook



2. Create a Notice and Wonder chart in your notebook and record what you notice and wonder as you watch the video about the Navajo Nation sky story. Be ready to share your ideas with the class.

Native American Sky Story: Paiute

In your notebook



3. Create a Notice and Wonder chart in your notebook and record what you notice and wonder as you watch the video about the Paiute sky story. Be ready to share your ideas with the class.

Turn and Talk

With a partner



4. Discuss the following questions with your partner:
 - What similarities did you notice in each of the two Native American sky stories?
 - What differences did you notice in each of the two Native American sky stories?

Your Observations of the Night Sky

With your class



5. Discuss the following questions with your class:
 - Have you heard of or seen the North Star?
 - Are there other things you have noticed in the sky that don't appear to move over time?

Observe the sky.

In your notebook



6. Create a Notice and Wonder chart in your notebook and record what you notice and wonder as you watch the video about the sky. Be ready to share your ideas with the class.

Identifying Patterns

With your group



7. Discuss the following questions with your group and follow your teacher's instructions for recording your ideas.
 - What patterns did your group notice while observing the video of the sky?
 - Were there any objects that did not follow a pattern?

Adding Questions to the DQB

Scientists Circle



8. Use the wonderings you had while watching the videos in class today to create more questions to add to our DQB. Follow your teacher's instructions for recording and adding new questions.

Building Understanding

With your class



9. Discuss the following questions with your class:
 - What do the patterns we identified from observing the sky help us determine about the interactions of:
 - the Earth and Sun?
 - the Earth and Moon?
 - the Earth and North Star?
 - the Earth and other stars?

Model patterns in the sky.

With your class



In your notebook



10. Discuss the following questions with your class:
 - What objects would we include in our models?
 - What movements should we include in our models?
11. Create a model to help explain why these objects appear to move the way they do.

Where to Go Next

With your class



12. Discuss the following questions with your class:

- What would be some possible advantages in developing a 3D model of the system?
- What are some possible disadvantages or limitations you think we may encounter with such a model?

Lesson 3: How can we explain the Sun's path change over time?

Brainstorm activities.

Turn and talk



1. Discuss this question with your partner: *What are some changes in activities that occur during certain times of the year that are related to changes in the amount of sunlight?*

Observe changes in the Sun.

With your class



2. Discuss this question with your class: *What patterns do we think we are going to see related to the Sun over one day (24 hours) when we speed up time in the software?*

Making Predictions

With your class



3. Discuss the following questions with your class:
 - What about if we speed it up even more and watch the Sun over a year?
 - What patterns will we see?

Making Observations

With your group



4. Divide your team into smaller groups that will make the measurements over 3 to 4 months.
5. After the groups have made their measurements, share them with the rest of the team and be ready to share these with the class.

Share measurements.

Scientists Circle



6. Meet in the Scientists Circle and share your team's measurements with the other teams.

Observing Solar Patterns

With your class



7. Discuss the following questions with your class:
 - What yearly patterns do you observe?
 - What evidence do you have for these patterns?
 - What relationship do you think there is between these solar patterns?

Connections to Other Cultures

With your class



8. Think back to the stories we have heard in the previous lessons and discuss this question with your class: *What connections can you make between those stories and changes in the Sun during a year?*

Initial Ideas

Turn and talk



9. Discuss the following questions with your partner:
 - Do you think these year-long patterns have happened over thousands of years?
 - Why or why not?

Collect data about changes in the Sun over time.

With your group



10. Follow your teacher's instructions for using two websites to record information for March 20, June 20, September 22, and December 21. Your teacher will assign your group a specific year. Be ready to share your findings with the class. Record the following:
 - Sunrise, sunset, and length of daylight
 - Solar elevation

Share data about changes in the Sun over time.

With your class



11. Share your group's findings with the class, and record data from other groups on *Sun Patterns Over Many Hundreds of Years*.

Building Understanding

With your class



12. Discuss the following questions with your class:

- How has the amount of daylight changed over 500 years? Over 1,000 years? Over 1,500 years?
- How has the solar elevation changed over 500 years? Over 1,000 years? Over 1,500 years?
- How does this compare to the data you recorded using the videos of the simulation?
- In what ways does this data help explain why different communities created rituals to mark changes in the patterns of daylight during a year?

Making Connections

With your class



13. Discuss the following questions with your class:

- What connections can we make between the patterns in the data collected in this lesson back to the patterns identified by other civilizations we studied in earlier lessons?
- Look back to the model of the Earth–Sun–Moon system you made in Lesson 2. How could we use that model to see if the data we’ve collected can be explained by the model?

Modeling the System

With your group



14. Discuss the following with your group and be ready to share your thinking with the whole class.

- What parts of the system do we need to include in our 3D model in order to explain the patterns of the Sun from one year to the next that we collected in this lesson?
- What could we use to represent them?
- What changes could we make to the parts of the 3D model to see if the data we’ve collected can be explained by it?

Model Map

With your class



15. Follow your teacher’s instructions for making a model map in your notebook for our 3D Sun–Earth representations.

Modeling Length of Day

With your class



16. Follow your teacher's instructions for placing pushpins at sunrise and sunset.
17. Follow your teacher's instructions for measuring and recording the path between the pushpins. Keep in mind that the shorter the measurement, the less time the observer spends in the light and the more time the observer spends in the dark.

Modeling the Earth-Sun System in 3D

With your class



18. Follow your teacher's instructions and complete the following:
 - Position your observer (round pushpin), and mark the observer's path with a rubber band. Place the sphere on the wire coat hanger stand, and push it down until it is level with the lightbulb.
 - One group member should move the foam Earth slowly around the lamp Sun while keeping the North Pole pointed at Polaris in the classroom. Pause at each of the positions illustrated on the handout and use pushpins to mark sunrise and sunset.
 - For each position, record the length of the observer's path between the two pushpins (to the nearest half-inch). The shorter the measurement, the less time the observer spends in the light and the more time the observer spends in the dark. Then on the image of the horizon in the table, draw what you predict the path of the Sun will look like for this observer at each position.

Evaluating Our Model

With your class



19. Make sure your model map is filled out and discuss the following with your class:
 - Based on the measurements you have made, are our models accurate?
 - How well does what you measured with our 3D model match the data we recorded from the NOAA websites?

Navigation

With your group



20. Consider our modeling assumptions:

- Earth spins on its axis.
- Earth's axis points toward Polaris.
- Polaris is directly above us.
- The hours of daylight and nighttime flip during the year.

21. Discuss this question with your group: *Which of the modeling assumptions would you change that would let us reach 15 hours of daylight?*

Revise our modeling of the system.

With your group



22. Follow your teacher's instructions for collecting materials for your group and making measurements.

23. Adjust your group's 3D models to better match the data we recorded, and record your findings on *Modeling the Earth—Sun System*.

24. When you are finished collecting data, finish filling in your model map.

Building Understanding

With your class



25. Discuss the following questions with your class:

- What adjustment did you make to your model that was the best fit for the data we recorded?
- What did that adjustment do to the orientation of Earth in space?
- Once the Earth was tilted, how did that change the amount of sunlight on the surface?
- Once the Earth was tilted, how did that change the path of the Sun in the sky?
- How does this relate to the angle of the elevation of the Sun?
- How does this change our model?

Update Progress Trackers.

With your class



- 26.** Discuss the following with your class, and follow your teacher's instructions for updating your Progress Tracker: *What new interactions should we include in our models?*

Brainstorm phenomena.

Turn and talk



- 27.** Discuss the following questions with your partner:
- What other phenomena on Earth could we explain with tilt?
 - Which of the "Activities that happen when the amount of sunlight changes" could be explained by Earth's tilt?

Lesson 4: How do these changes in sunlight impact us here on Earth?

Navigation

With your class



1. Discuss the following question with your class: How would you describe the temperatures around the four dates when we measured the amount of daylight and solar elevation: March 20, June 20, September 22, and December 21?

In your notebook



2. Answer the following question in your notebook: If the amount of daylight in March and September is about the same, why do you think there is such a difference in temperatures?

Looking Back

With your class



3. Discuss the following questions with your class:
 - How could we use what is in our Progress Trackers and models to explain seasons?
 - How does tilt help explain seasons?

Examine seasonal temperature data.

With your group



4. Work with your group and examine the seasonal temperature data for the two cities on *Seasonal Temperature Data*. Be ready to share your ideas with the class.

Building Understanding

With your class



5. Discuss the following questions with your class:
 - How does the pattern of average high temperature of both cities compare?
 - What pattern is there between temperature and the average distance of Earth from the Sun?
 - What could explain this pattern? What other data might help us?

Modeling Sunlight Energy

With your group



6. Have one member of your group get the following supplies you will need for the investigation:
 - 3 paper plates
 - 5 pipe cleaners in 3 colors
 - 3 pieces of graph paper
 - 1 piece of cardboard
 - protractor & ruler
 - scissors & tape
 - pencil & marker
7. Use *Modeling Sunlight Angles* to investigate how angled sunlight affects how much light energy we get every second.

Making Sense

With your class



8. Complete the following with your group:
 - Use the making sense portion of *Modeling Sunlight Angles* to calculate the light energy per second for each time of year.
 - Once finished, add your data to the class chart.

Building Understanding

With your class



9. Discuss the following questions with your class:
 - How do the angles of the pipe cleaners relate to the solar elevation measurements we made?
 - What pattern do you see in the energy from light per square of graph paper data?
 - What relationship was there between the angle of the Sun in the sky (represented by the pipe cleaners) and the watts per square? Why?
 - Can someone explain how this model explains why it is warmer in the summer here and colder in the winter?

Defining Seasons

Turn and talk



10. Discuss the following question with your partner: How do we know when one season ends and another begins?



- 11.** Read about how the transition between seasons are determined using *Defining Seasons*.

Update Progress Trackers.

With a partner



- 12.** Work with a partner and follow your teacher's instructions for updating your Progress Tracker.

Southern Hemisphere Puzzle

With your class



- 13.** Think back to differences in seasons mentioned in some of the podcasts from Lesson 1. Following your teacher's instructions for taking notes about Jessie's descriptions of seasons in Australia and discuss the following questions:
- How does this happen?
 - How are there different seasons?
 - How are those seasons different in the Southern Hemisphere?
 - Are we all on the same Earth and in the same position related to the Sun?

Gotta-Have-It Checklist

With a partner



- 14.** Brainstorm what key components and interaction should be in our models.

With your class



- 15.** Discuss the following questions with your class:
- What key components should be in our models?
 - What key interactions should be in our models?

Individual Assessment

Writing in Science



- 16.** Follow your teacher's instructions for completing the assessment on *Lesson 4 Gotta-Have-It Checklist*.
- Make sure you can find your Lesson 1 initial model, Progress Tracker, and Gotta-Have-It Checklist.
 - You will have the next 20 minutes to complete the assessment.

Questions We Had About Sun Patterns and Connections

Home Learning



- 17.** Use *The Equator*, *the Midnight Sun*, and *the Analemma* to read about some additional phenomena related to the patterns of the Sun we see in the sky.

Navigation

With your class



- 18.** Discuss the following questions with your class: Can we use our Gotta-Have-It Checklist to explain something other than the seasons?

Lesson 5: How can we explain phenomena like Manhattanhenge?

Navigation

With your class



1. Discuss the following question with your class: Why do places in the Southern Hemisphere experience their seasons at the opposite time of year compared to places in the Northern Hemisphere?

Explaining Manhattanhenge

With your class



2. Discuss this question with your class: Last time we identified some additional phenomena that we said we could explain with the same model. What were some of those phenomena?

Manhattanhenge Dates

With your class



3. Examine the chart of Manhattanhenge dates. What patterns do we notice?

Make a prediction.

With a partner



4. Discuss the following questions with your class:
 - What parts should we include on our class consensus model?
 - What interactions should we include on our class consensus model?

Investigate Sun patterns that could cause Manhattanhenge.

On your own



5. Use Stellarium videos to investigate the prompts on *Connecting Patterns in the Sun to Manhattanhenge*.

Develop a Gotta-Have-It Checklist.

With a partner



6. Identify the parts and interactions of the model we used for the Manhattanhenge phenomenon from Lesson 1 that are still needed to help explain the phenomenon. Also identify the ones we need to change based on our new understandings. If something needs to be changed, work with your partner to change it.

Create Class Consensus Model.

Scientists Circle



7. What parts should we include on our class consensus model? What interactions should we include on our class consensus model?

Explain the phenomenon.

On your own



8. Use the class consensus model to explain why Manhattanhenge occurs during certain times of the year.
9. Complete the discussion *Self-Assessment for Classroom Discussions*.

Manhattanhenge Dates

With a partner



10. Follow your teacher's instructions and add any new questions you have to the DQB.

Add questions to the DQB.

Scientists Circle



11. Use the pattern you notice in the table on Slide I to make a prediction.
12. Discuss with your partner: When is the next year after these that you would expect the second occurrence of Manhattanhenge to occur on July 11?

Answer question on the DQB.

With a partner



13. Work with a partner to complete the following:
 - Choose one question from the DQB you both feel we have answered and remove that sticky note.
 - Discuss with your partner the answer to the question on the sticky note.
 - Record the answer to the question on a new sticky note.

Observing the Moon

Home Learning



14. Record observations of the Moon in the sky by taking a photo, sketching a picture, or describing the Moon in a paragraph. Talk to one of your trusted people and use the Lesson 5 Community Guide for Looking at the Sky. Be ready to share your observations in our next class.

Lesson 6: Why do we see the shape of the Moon change?

Navigation: Sharing Home Learning

With your class



1. Share your observations of the Moon and discuss the following questions:
 - What did you notice when you looked up at the Moon?
 - What did it look like?
 - When did you make this observation?

Student Images of the Current Moon

With your class



2. Follow your teacher's instructions and discuss the images of the Moon shown.

Making Predictions

Turn and talk



3. Discuss this question with a partner: Does the Moon always look like the Moon you observed?

Connect to humans across cultures and time.

With your class



4. As your teacher explains the origin of some ancient representations of the Moon, think about connections you can make to these representations of the Moon and why so many people have observed and recorded Moon phases.

Turn and talk



5. Discuss the following questions with a partner:
 - What connections can you make with the images?
 - Why do you think so many people across the world observed and recorded the phases of the Moon?

Initial Models

Writing in Science



6. Follow your teacher's instructions for completing *Lesson 6: My Initial Model to Explain*: _____.
- First, fill the blank in with "The current appearance of the Moon." Then complete the following:
 1. Show and describe what the Moon currently looks like from Earth and when it happened.
 2. Change perspective. Draw and/or describe a model to help explain why the Moon looks the way it does. Identify the important parts, motions, and interactions in the system and the perspective you are taking in this model.
 3. Describe what is happening with the parts and interactions in your system that is causing us to see the current phase of the Moon.

What to Include in Our Model

With your class



7. Discuss the following questions with your class:
- What parts or objects should we include in our model?
 - Are there any interactions we want to include?
 - Why do we feel those objects and interactions are important to include?

Navigation

With your class



8. Discuss the following question with your class: What could we do to help us understand why the Moon looked like it did when we made our observations?

Modeling the Earth-Moon-Sun System in 3-D

With your group



9. Follow your teacher's instructions and complete the following:
1. Position your observer (thumbtack) on your Earth. Place the sphere on the stand with the dowel and push it down until it is level with the lightbulb.
 2. Position a small sphere at the end of a paper clip or skewer to represent the Moon. One group member should move the Moon slowly around the foam Earth. Remember to keep your own shadow out of the way of the model so that you do not interrupt the path of the light!
 3. How can you get the thumbtack person to "see" something that looks like the current phase of the Moon?

Make a prediction.

Writing in Science



10. Follow your teacher's instructions for completing *Lesson 6: My Initial Model to Explain*: _____.

- First, fill the blank in with "The next phase of the Moon." Then complete the following:
 1. Show and describe what the next phase of the Moon looks like from Earth and when it happened.
 2. Change perspective. Draw and/or describe a model to help explain why the Moon looks the way it does. Identify the important parts, motions, and interactions in the system and the perspective you are taking in this model.
 3. Describe what is happening with the parts and interactions in your system that is causing us to see the current phase of the Moon.

Moon in Other Languages

Home Learning



11. Share the word for Moon in another language you are familiar with. Ask your friends and family if they know additional words for Moon in other languages.

Sharing Our Predictions

Scientists Circle



12. Discuss the following questions with your class:

- What did you predict the next phase of the Moon would be?
- Why did you make this prediction?

Moon Phases Interactive

With your class



13. Observe the interactive with your class.

- What is the perspective in the interactive?
- How does what we see in the interactive compare with what we see using our 3-D/physical model?

Complete a model to explain.

On your own



14. Complete the *Shape Patterns of Earth-Sun-Moon System* to explain why the Moon looks that way.

- Add the location of the Moon on the circle that represents the orbit of the Moon.
- Show the lit and unlit halves of the Moon.

Create a classroom consensus lunar phase reference.

Scientists Circle



15. Use the ideas from your individual work to create a classroom version of the Moon phases chart:

- How is the Moon positioned in the Earth-Sun-Moon system so we see each phase?

How can we see the Moon at different times?

With your class



16. Use the interactive to explore whether a person could see the Moon during the day.

Lesson 7: Why do we see eclipses and when do we see them?

Navigation

With your group



1. Discuss the following questions with your group:
 - Have you observed an eclipse or heard about what people can see when one occurs?
 - What do you think is going on when there is an eclipse?

Notice and wonder about a solar eclipse.

In your notebook



2. Create a T-chart in your notebook to capture what you notice and wonder as you watch the video of a solar eclipse.

Share eclipse noticings and wonderings.

With your class



3. Discuss this question with your class: What did you notice and wonder about the solar eclipse?

Initial Models

Writing in Science



4. Follow your teacher's instructions for completing *My Initial Model to Explain*: _____. First, fill the blank in with "An Eclipse." Then:
 1. Show and describe what the eclipse looked like from Earth and when it happened.
 2. Change perspective. Draw and/or describe a model to help explain why the eclipse looks the way it does. Identify the important parts, motions, and interactions in the system and the perspective you are taking in this model.
 3. Describe what is happening with the parts and interactions in your system that causes an observer to see an eclipse.

Navigation

With your class



5. Discuss this question with your class: What could we do to help us understand what causes an eclipse?

What to Include in Our Model

With your class



6. Discuss the following questions with your class:
 - What parts or objects should we include in our model? What interactions do we want to include?
 - Why do we feel those objects and interactions are important to include?

Moon's Orbit

With your class



7. Follow your teacher's instructions and add the Moon's orbit to our physical models.

Model the solar eclipse.

With your group



8. Use the physical model to figure out and show what is going on during a solar eclipse like the one we saw in the video.

Develop key model ideas.

With your class



9. Discuss the following question with your class:
 - What happens with the Earth, Sun, and Moon when we see a solar eclipse?
 - Let us describe it using our words and our physical models.

Develop key model ideas.

Turn and talk



10. Discuss this question with a partner: Is there a solar eclipse every time there is a New Moon?

Model a New Moon without an eclipse.

With your group



11. Use the physical model to figure out if there can be a New Moon without an eclipse.

Develop key model ideas.

With your class



12. Discuss the following question with your class:

- Can there be a New Moon without an eclipse?
- Let us describe it using our words and our physical models.

Parts and Movements to Include in Our Model

If solar eclipses do not happen every month, how often could they happen?

With your class



13. Discuss the following questions with your class:

- What parts or objects should we include in our model?
- What parts will move and how? What parts will not move?

Add to Progress Tracker.

Why do we see eclipses, and when do we see them?

In your notebook



14. Follow your teacher's instructions for adding to your Progress Tracker.

Reflecting on Our Models' Boundaries and Limitations

With your class



15. With your class, reflect on the models we have created. The three models we created were:

- Model of "How does a solar eclipse happen?"
- Model of "Why do we not see a solar eclipse with every New Moon?"
- Model of "How often might we see a solar eclipse?"

Think about:

- How did the parts and interactions in each of these models connect with each of the questions we were trying to figure out?
- What are some parts and interactions we did not include in each model? Why did we leave those things out?

Navigation

Turn and talk



16. Discuss this question with a partner: What do you think a person on Earth would see when the Moon is full and aligned with the Earth and Sun?

Lesson 8: What does a lunar eclipse look like and how can we explain it?

Navigation

In your notebook



1. Follow your teacher's instructions and add *Analyzing Lunar Eclipse Images* to your notebook.
 - Complete the predictions in part A of the handout.

Analyze lunar eclipse images.

Writing in Science



2. Examine the lunar eclipse images provided by your teacher. As you observe, consider the following:
 - What do you notice?
 - Are there any patterns you observe?

Similar changes in what the Moon looks like across the duration of a lunar eclipse have been observed with every lunar eclipse.

- What new questions do you have about this phenomenon?

Notice and wonder with a partner.

With a partner



3. Using the lunar eclipse images, share with your partner the following:
 - What did you notice?
 - Do you see any patterns?
 - What new questions do you have about this phenomenon?

Discuss model predictions.

With a partner



4. Discuss the following with your partner:
 - What parts of the lunar eclipse did our model predict?
 - What parts did our model not predict?
 - What might we need to add or revise about our model to explain what we saw?
5. Record your ideas on Parts D and E of *Analyzing Lunar Eclipse Images*.

Consider possible causes.

With a partner



6. Discuss the following with your partner:
 - What are some possible causes for the parts of a lunar eclipse that our model did NOT predict and/or you can't explain yet?
 - What do you think is happening?
7. Record your ideas on Part F of *Analyzing Lunar Eclipse Images*.

Predict possible causes.

With your class



8. Discuss the following with your class:
 - What parts of this phenomenon did our model predict and explain?
 - What parts of this phenomenon did our model not predict or explain?

Gather related phenomena.

Turn and talk



9. Discuss the following with a partner, and be ready to share your ideas with the class.
 - Can you think of other times where you have seen or heard about the Moon or the Sun or something else in the sky becoming dimmer or changing colors?
 - When or where does that happen?

Revisiting Our DQB

With your class



10. Discuss the following with your class:
 - What new questions came up for you as we observed the lunar eclipse photos and brainstormed related phenomena?
 - What questions from our original DQB belong on our new poster about color changes?

Making a Preliminary Model

Turn and talk



11. Discuss the following questions with your partner. Skim back through your science notebook if you need some ideas, and be ready to share your ideas with the class.

- What sort of tools have we used previously to try to explain Earth-Sun-Moon patterns?
- How could reusing those tools help us make progress on understanding these color-related phenomena?
- What are some new tools or sources of data that you think would be useful for investigating this type of phenomena?

Collect our own data.

How could we collect data about the Moon's or Sun's brightness and color?

We will collect and compile data to answer this question to share with the whole class.

Home Learning



12. Over the next few days:

- Use the camera on a phone or tablet to take pictures of the Moon or Sun when it is at different positions in the sky: directly overhead, on the horizon, etc.
- Whenever you take a photo, use a light meter app to measure the light using a measurement called lux. Take a screenshot of the light meter reading to go with each sky image.

Lesson 9: Why do the Moon and Sun appear to change color near the horizon?

Navigation

Last time we realized that our model could not explain the color change we saw in the Moon during a lunar eclipse.

With your class



1. Discuss this question with your class: *What other phenomena did we mention related to when we have seen color changes of the Moon and Sun?*

View images of the sky at different times.

On your own



2. Examine the images your teacher will show you of the sky and answer the following questions in your notebook:
 - What do you notice about the sky?
 - What do you wonder about the sky?

Would it always look like that?

Turn and talk



3. Discuss the following questions with your partner and be ready to share your ideas with the class:
 - Would the brightness and color of the Sun look the same at sunset for that same day everywhere on Earth?
 - Would the brightness and color of the Moon look the same at moonrise that same day everywhere on Earth?
 - Why do you think it would be the same or not?

Consider the Sun without the atmosphere.

Turn and talk



4. Discuss this question with your partner and be ready to share your ideas with the class:
 - What do you think light from the Sun would look like if there was no atmosphere between us and the Sun?

What do we know about the Earth's atmosphere?

With your class



5. Follow your teacher's instructions for discussing what we figured out about the Earth's atmosphere.

In Earth's Atmosphere

With your class



6. Follow your teacher's instructions for discussing objects in the nearer Earth atmosphere.

Above Earth's Atmosphere

With your class



7. Follow your teacher's instructions for discussing the height of other objects people have launched into space.

Two Views of the Sun

Turn and talk



8. Discuss what you notice about the Sun/sunlight in the photos taken from Earth and from space with your partner. Be prepared to share your ideas with the class.

Can light travel through empty space?

With your class



9. Recall our investigations in the Sound unit and examine the image of the phone in the vacuum jar. Discuss with your class how this image provides evidence that light can travel through empty space (unlike sound)?

Sunset from the International Space Station

With your class



10. Follow your teacher's instructions and watch the video of the sunset as seen from the International Space Station (ISS).

Turn and talk



11. Refer to the series of still images from the video and share what you noticed with a partner.

Revising Our Model

With your class



- 12.** Now we will use all of these new findings to inform a revision to our model of how we see things in the sky. Follow your teacher's instructions and work with your class to revise your model and add *Analyzing Lunar Eclipse Images* to your notebook.

Zooming in on Perspectives A and B

With your class



- 13.** Examine the second model on *Analyzing Lunar Eclipse Images* and discuss perspectives A and B with your class.

With a partner



- 14.** Discuss the following with your partner and be ready to share your ideas with the class.
- What similarities and differences are there between what Person A and Person B are experiencing?
 - Why might the sky look different to each of them?
 - How would it look if there was no atmosphere?

Share possible causes for the color changes we see.

With your class



- 15.** Discuss this question with your class: *What variables did you identify that might be causing the differences we see in the sky between noon and sunset?*

Lesson 10: How does light interact with matter in the atmosphere?

Navigation

With your class



1. Discuss the following questions with your class:
 - What ideas did we have last time about why sunsets and sunrises are often reddish?
 - What variables might affect the color or brightness of the light we see when looking in the direction of the Sun?

Investigating Light in the Atmosphere

With your class



2. To understand how light interacts with our atmosphere, discuss with your class how we can represent the following elements in our investigation:
 - atmosphere (made of gasses and larger particles)
 - sunlight

Map our investigation materials to our model.

With a partner



3. Follow your teacher's instructions for adding *Investigation Elements Map, Predictions, and Results* to your notebook and work with your partner to complete the "because" column of the first table.

Making Predictions

On your own



4. Examine the drawings in the second table of *Investigation Elements Map, Predictions, and Results* and complete the following:
 1. What situation in real life is that investigation setup simulating?
 - Annotate the drawings on your handout with the time of day.
 2. Predict what you'll see from each position.

Atmosphere Investigation

With your group



5. Work with your group to carry out the investigation and complete the following:
 1. Gather your supplies.

2. Follow the procedures on *Instructions for the Light and Milky Water Lab*.
3. Record your observations and answer the questions on *Investigation Elements Map, Predictions, and Results*.

Atmosphere Investigation: Cleanup

With your group



6. Work with your group to complete the following:
 - Carefully empty your container into the sink as directed.
 - Rinse the container and pat dry with paper towels or leave to air dry on the counter.
 - Wipe off your teaspoon and return it to the correct place.
 - Return flashlights, milk powder, and other supplies to the correct place.

Atmosphere Investigation: Conclusions

With your group



7. Work with your group to complete the following and be ready to share your ideas with the class.
 - Look back at all your observations starting with the plain water.
 - Record your responses to the questions at the end of *Investigation Elements Map, Predictions, and Results*.

Making Sense of Our Experiences

Scientists Circle



8. Discuss the following questions with your class:
 - What did you notice about the color and brightness of the light you saw in the different conditions in your investigations?
 - What are possible causes of those changes in color and brightness of the light you saw?

Home Learning

Home Learning



9. Today we saw white light change to other colors, like blue or orange, after it interacted with matter. Answer the following questions for home learning.
 - When else have you noticed white light changing into other colors after it interacted with matter? Ask your family and friends this same question.
 - Jot down a few ideas and bring them with you to share with the class next time.

Lesson 11: How does the shape of a water droplet or an ice crystal cause sunlight to form into a rainbow?

Navigation

With your class



1. Revisit our new “milky water” atmosphere model from class yesterday, and discuss the following question: What did we see yesterday when we shined white light on our simulated atmosphere?

Navigation: Adding to Our Phenomena

Turn and talk



2. With an elbow partner, share all of the related color-splitting phenomena you thought of between yesterday and today and discuss the following questions.
 - Where and when else have you seen white light separated into different colors? What did you see?
 - Were there any special conditions that caused the light to separate into colors?

Analyzing Data

With your class



3. Follow your teacher’s instructions for examining the images of light split up into colors.
4. Discuss the following questions with your class.
 - What things do these phenomena appear to have in common?
 - What differences do you notice?
 - If we consider perspective, what has to happen for us to view these phenomena?

Making Predictions

In your notebook



5. Predict. In your science notebook draw and describe.
 - What do you think a raindrop looks like when falling from the sky?
 - What do ice crystals look like in our atmosphere?

Analyzing Structures

With your class



6. Follow your teacher's instructions for observing closely the different shapes, sizes, and patterns ice can take in our atmosphere. Discuss the following questions.
 - What do you notice?

Making Predictions

Turn and talk



7. Discuss with a partner: What do you think will happen when we shine a beam of white light through different geometries? Make some predictions for each situation below.
 - White light through a round glass filled with water
 - White light through a hexagon glass filled with water
 - White light through a round glass bowl of water with a mirror in the water
 - White light through a triangular prism without water

Planning Our Investigation

With your group



8. Follow your teacher's instructions to complete the following investigation procedures:
 - At every station
 - Turn the flashlight on.
 - Mark the center of the beam on the box with a small piece of blue tape.
 - Slide the object (glass, jar, prism, or bowl with mirror) into the beam of light.
 - Record any changes you noticed in this condition for the position of where the beam of light falls, and the color of the light at that position.
 - When you have time
 - Move the object around, testing various distances, angles, and geometries.
 - Write observations of what you see.
 - Take note of the type (color) of light you see as well as the location of each color.
9. Return all items to their original locations before you leave a lab station

Procedure at Each Station

With your group



10. Follow your teacher's instructions and complete the following:

- Mark where the light is going to before you place the object into the beam of light.
- Mark where the light is going to after you slide the object into the beam of light.
- Record any changes you noticed for
 - the position of where the beam of light falls,
 - the color of the light at that position, and
 - the brightness of light at that position.
- Feel free to change
 - the position of the object,
 - the vertical angle of the light, and
 - the height of the light.
- Please do not change
 - the direction of the light, or
 - the amount of water.

Analyzing and Interpreting Our Data

Yesterday we explored light shining through different materials and geometries.

Turn and talk



11. Discuss the following questions with a partner:

1. What happened to the *path* of light as it passed through the different geometries and mediums?
2. What happened to the *color* of the white light as it passed through different mediums and geometries?
3. What happened to the *brightness* of the light as it passed through different mediums and geometries?

Develop a model.

Scientists Circle



12. Follow your teacher's instructions and work with your class to develop a model of one of the conditions you observed in the Rainbow Lab.

Applying the Light Model

Writing in Science



13. Follow your teacher's instructions and complete the following:

- Using our Gotta-Have-It checklist, create a new model showing the effect of either the triangular prism or mirror in the bowl on the beam of light.
- Add the light source.
- Add the surface that light eventually was projected on.
- Then show the complete path of light-starting at the light source and showing all the matter it interacts with before reaching the surface it was projected on.
- Then show how that light then reached your eye.

Navigation

With your class



14. Discuss the following questions with a partner:

- What did we discover/learn from our observations during the Rainbow Lab?

Make predictions.

What might we see when we combine beams of light of different colors together so they overlap on the same spot in space?

Turn and talk



15. Discuss your predictions for what you think the color and the brightness of these combinations of overlapping light will look like:

- When light from A and B overlap
- When light from B and C overlap
- When light from A and C overlap
- When light from A, B, and C overlap
- Be prepared to share these predictions with the whole group.

Plan our investigation.

Scientists Circle



16. Discuss the following questions with your class:

- What do we need to consider if we want this to be a fair test?
- What would be our independent and dependent variables?
- What are our control variables?

Add to the Progress Tracker.

In your notebook



- 17.** Follow your teacher's instructions for updating your Progress Tracker and include words, pictures, and anything else to capture your thinking about the question: What do we see during eclipses, and when do we see them?

Navigate.

Turn and talk



- 18.** Which of these new discoveries that we have made could help us better explain why the Moon turns red and not totally dark during a lunar eclipse?
- Be prepared to share these with the whole group.

Lesson 12: Why does the Moon always change color during a lunar eclipse?

Navigation

With your class



1. Discuss the following questions with your class:
 - What new discoveries have we made that might help us explain why the Moon turns red and not totally dark during a lunar eclipse?
 - What specific evidence or activity helped us build those understandings?

Examining Prior Models

With a partner



2. Use *Evaluating Past Models* to evaluate the models from Lessons 7, 9, 10, and 11. For each model, discuss the following with your partner:
 - What parts of the model should we carry over into a revised model?
 - What science ideas should we carry over into a revised model?
 - What parts or ideas should we discard or change?

Revising Lunar Eclipse Models

With your group



3. Follow your teacher's instructions and work with your group to develop a revised model to explain how a lunar eclipse can change the apparent color of the Moon by adding onto prior models. Be prepared to share your revised model with the class.

Share group lunar eclipse models.

Scientists Circle



4. Follow your teacher's instructions for sharing your group model and discuss the following questions with your class:
 - What similarities do the group models have?
 - What differences do the group models have?
 - What information from the group models should we be sure to include in our class consensus model?

Develop Class Consensus Model.

Scientists Circle



5. Discuss this question with your class: What information would we add to our prior model to reflect our new understanding and honor our group models of how a lunar eclipse can change the apparent color of the Moon?

Update Progress Trackers.

In your notebook



6. Follow your teacher's instructions and update your Progress Tracker for the lesson question: Why does the Moon always change color during a lunar eclipse?

Prepare for an assessment.

With your class



7. Follow your teacher's instructions for completing *Explaining Fishing Related-Phenomena*.

Lesson 13: What new patterns do we see when we look more closely at other objects in the sky?

Navigation

In your notebook



1. Follow your teacher's instructions for taking stock of the Driving Question Board, and complete the following in your notebook:

- Make a T-chart with these headings:
 - 1-2 questions we have partly or fully answered
 - 1-2 questions we have not yet answered
- Record 1-2 questions under each heading.

With your class



2. Discuss these questions with your class:

- How can we classify or group the types of questions that we have already investigated or answered?
- What are the types of questions that we have not already investigated or answered?

Observing Planets in the Night Sky

With your class



3. Follow your teacher's instructions for examining how some planets look at a specific location, on a certain date, and at a specific time.

Experience and document connections with planets.

In your notebook



4. Follow your teacher's instructions for adding *Experiences and Connections with the Planets* to your notebook, and record your experiences by answering one or more of the questions in the table.

With a partner



5. Complete the following with a partner:

- Share and discuss some reflections from *Experiences and Connections with the Planets*.
- Record new questions that come up based on your and your partner's reflections.

Make connections.

With your class



6. Discuss what connections have been made by us and others to
 - a. phenomena related to light and color in the Earth's atmosphere, and
 - b. phenomena related to the Earth-Sun-Moon system.
7. What were some sources of data that we used to figure out what patterns there were and what connections people made to them?

Obtain information and make connections.

On your own



8. Read about astronomers' observations from long ago and different cultural connections people have made to Venus. Annotate your reading by underlining cultural connections that people have made to Venus over time. Highlight observations that astronomers from different cultures have made about Venus.

Patterns in observations of Venus.

With your class



9. Follow your teacher's instructions for observing Venus before sunrise and after sunset.

10. Discuss the following question with your class:

- What components would we need to include in a model that explains the patterns of Venus in the night sky?

In your notebook



11. Develop an initial model to show the relationships of Earth, the Sun, and Venus to explain the patterns of Venus in the sky.

With your class



12. Discuss the following questions with your class:

- a. What differences do these models have?
- b. What types of information would help us determine which model is accurate?

Identify additional sources of data.

With your class



13. What are some technologies or devices that you know of that can help people see objects far away in greater detail than they can with their unaided eyes?

Make predictions.

Turn and talk



- 14.** What sort of things do you think people might see when looking at Venus when using a telescope that they could not see with their unaided eyes?

Notice and wonder.

The image shown here is of the drawings that Galileo made over the course of several months, when Venus was visible in the western sky after sunset.

On your own



- 15.** Record what you notice and wonder about Galileo's drawing in your notebook.

Navigate.

Turn and talk



- 16.** Discuss what you noticed and wondered about the drawings that Galileo made of Venus after viewing it through a telescope over many days.

Notice and wonder.

With your class



- 17.** When telescopes were first invented, there were no cameras to take photographs. But here are some images of Venus in the western sky that an amateur astronomer photographed through a telescope in 2004.
- What do you notice?
 - How do these compare to Galileo's observations?

Make connections.

With your class



- 18.** Discuss the following questions with your class:
- a. Where have we seen something in the night sky changing in a predictable pattern before?
 - b. How is what we noticed about the phases of Venus similar to the phases of the Moon?
 - c. How is what we noticed about the phases of Venus different from the phases of the Moon?

Make predictions.

With your class



Think back to what we figured out about solar and lunar eclipses in Lesson 7.

19. What had to happen in order for us to see a solar and lunar eclipse?

With your group



20. Discuss the following questions with your group:

- a. Do you think something similar could happen with Venus?
 - b. If not, why not?
 - c. If so, where would Venus need to be located in relation to the Sun and Earth for this to happen?
- Be ready to share your group's ideas with the whole class.

Analyze and interpret data.

- The video below was recorded on June 5, 2012, using a digital camera connected to a telescope.
- It is a time lapse where 1 Earth hour = ~1 second in the video.
- The large orange circle is the Sun. The small black dot is Venus.

With your class



21. Follow your teacher's instructions for discussing the scope of our observations.

Compare patterns.

The type of event we saw is called a transit of Venus.

- The last transit of Venus occurred in 2012.
- The next transit of Venus will occur in 2117.

A solar eclipse of the Sun is another type of transit.

- The last solar eclipse occurred June 10, 2021.
- The next solar eclipse will occur December 4, 2021.

With your class



22. How does the frequency of Venus transits compare to the frequency of lunar eclipses?

Use a model to explain multiple phenomena.

With your group



23. Earlier we identified that the parts of a model that could help explain some of the patterns we noticed with Venus would need to include the Sun, Earth, an observer on Earth, light rays, and Venus.
24. Use *Competing Models of the Venus, Earth, and Sun System* and *Explaining Venus-Related Patterns* to show where Venus and Earth would need to be located in the system that would help explain each Venus-related pattern.
25. After doing this, draw and label where Earth and Venus would need to be located in the system to explain that pattern.

Analyze data and use a model.

On your own



26. Add your responses to these questions on the back of your handout:
 - What do you notice in the data below?
 - If we added Mercury, Mars, and Jupiter to the system model of Earth, Venus, and the Sun, what do you expect to be similar to Venus? What do you expect to be different?

Make an argument.

With your class



27. Because we are now trying to account for patterns in what these objects look like, by figuring out where they are located and how they might be moving in relation to the Sun, they are considered part of the same system or solar system.
28. If we added Mercury, Mars, and Jupiter to that previous system model, what do you expect to be similar to Venus? What do you expect to be different?
29. Collect *Explaining Venus-Related Patterns*.

Navigate.

People have built much larger and more powerful telescopes in recent years than existed 400 years ago.

Turn and talk



30. What sort of things do you think people might be able to see when looking at a planet, like Venus, Mercury, Mars, or Jupiter using more and more powerful telescopes?

31. What other technologies do you know of, besides telescopes, that scientists use to collect data about different planets?

Starting in the late 1950s, scientists have been launching rockets with cameras and other data collection equipment on them into space to visit our Moon, other planets, and other objects in space.

- In some cases, they flew by or orbited around those objects.
- In other cases, they landed on them.
- Similarly, many missions have gone to other planets, like Jupiter. Getting closer to this planet has helped us discover that it has many more moons than we can see through telescopes alone.
- Galileo originally was only able to observe 4 moons of Jupiter through his telescopes. Now we think it may have 79 moons, many much smaller than the 4 moons that Galileo originally saw.
- These missions either fly by Jupiter and collect data, including photographs, of the planet and its moons on the way out to farther reaches of the solar system or orbit Jupiter for a number of years, collecting data and sending it back to Earth.
- Some missions have actually sent data collection probes into the atmosphere of Jupiter, which have transmitted data back to Earth.

Some Other Missions to Collect Solar System Data

This infographic shows a subset of NASA missions (supported by a division of NASA called the Jet Propulsion Laboratory) to various planets and other objects in the Solar System over the years. There have also been many other NASA missions and missions by other space agencies from around the world that are not represented here. A lot of data from these missions and others are available.

Navigate.

Turn and talk



32. What types of data would you want to be able to collect if you could send data collection equipment to any of these other objects in our solar system?

- Be ready to share your group's ideas with the whole class.

Navigate.

With your class



33. What sort of data would you want to be able to collect if you could send data collection equipment to other objects in our solar system?

Analyze and interpret data.

In your notebook



34. Title a new page, “Patterns of planets, moons and other objects in our solar system.”

35. Title a 2nd page “Wanderings.”

36. Be ready to work in small groups and record patterns.

With your group



37. An infographic combines the words “information” and “graphic.” They are visual representations of information and data that are designed to tell you a lot about a topic very quickly. *Looking for Patterns in the Solar System Infographics* contains data collected by spacecraft and telescopes about the objects we had questions about. We can use some of the same close reading strategies that we use when we read text to interpret an infographic.

38. Analyze and interpret data from infographics for the objects we had questions about.

Close Reading Protocols-Infographics

39. *Analyzing and Interpreting Data from Infographics Close Reading Protocol* is designed specifically to focus students on obtaining information from infographics.

Tour the solar system.

With your class



40. Note any additional patterns you discovered and questions you wonder about the different objects in our solar system.

41. Add these to your notebook on the “Patterns of planets, moons and other objects in our solar system” and “Wonderings” pages.

Update Progress Trackers.

In your notebook



42. Lesson Question: What new patterns do we see when we look more closely at other objects in the sky?

- Include words, pictures, and anything else to capture your thinking.

Navigate.

Turn and talk



43. What wonderings do you have about the solar system after analyzing the data in the infographic and taking a tour of the solar system?

- Be ready to share your group’s idea with the whole class.

Lesson 14: Why do some solar system objects orbit planets and others orbit the Sun?

Navigation

With your class



1. Use your science notebook to locate the patterns and wonderings about the solar system you recorded last time.
2. Share one pattern or wondering with your partner to prepare for sharing with the class.
3. Discuss the following questions with your class.
 - How does the path that Earth moves through space affect the patterns we experience on Earth?
 - What other objects in our solar system and the paths they follow through space affect the patterns we experience on Earth?
 - How would what we experience be different if Earth and these other objects did not follow the patterns of motion through space that they do now?

Develop an explanation.

In your notebook



4. Pick any 1 pair of objects in our solar system you noticed tend to move around each other. Write that pair of objects down.
5. Write an initial explanation in your notebook for how and why your first object tends to move around your second object the way it does.

Identify the parts and properties of a two-object system.

With your class



6. Discuss the following questions with your class.
 - What do we already know about the motion of the Moon relative to Earth?
 - What is similar and what is different about both of these objects in the Earth-Moon system?

Connecting to Prior Experiences

With your class



7. Remember that in *Collisions Unit* we use sentence frames to write cause-and-effect relationships like this:
 - 8.1 When we [change to the system], we observe [effect on the system].

Turn and talk



8. In your prior work in the *Magnets Unit*, you built a homemade speaker out of wire coils, a plastic cup, and a magnet. This led to a series of additional investigations you pursued across the unit.
9. Share examples of some of the cause-and-effect relationships you investigated in *Magnets Unit*, and be ready to share these with the whole class.

Conduct a thought experiment.

Turn and talk



10. Discuss the following questions with a partner and be ready to share with the whole class.
 - What if the Moon was a lot larger or smaller? Would that cause any change in how it moves (effect)?
 - What if the Moon was a lot closer to Earth or a lot farther from Earth? Would that cause any change in how it moves (effect)?

Develop an initial model.

On your own



11. Follow your teacher's instructions and complete the following on *Simulating a Two-Object System*.
 - **In part A:** Use the model on the handout to develop an initial explanation for what causes the Moon to move around Earth in the pattern of motion that it does.
 - **In part B:** Choose a question to record a prediction for, and explain why you made the prediction you did.
 - **In part C:** Consider whether your prediction applies to other orbiting objects in the solar system.
12. Develop an initial model in your science notebook to explain the effect of changing size or location of one orbiting object in a pair of objects.

Navigate.

With your class



13. Discuss the following questions with your class.
 - What were some other pairs of objects that you picked for part C of your handout?
 - If a similar change was made in the system of these two objects, did you think it would cause the same effect as what you predicted in part B of your handout?

- 14.** Consider what we would need in a computer simulation in order to explore our questions and predictions further, and discuss the following with your class:
- What variables would we want to be able to manipulate or change in the system?
 - What interaction or outcomes would we want to be able to visualize or measure in that simulation?

A Simulation of a Two-Object System-Fixed Perspective

With your group



- 15.** Review the following tips for using the interactive, and follow your teacher's instructions and explore the interactive to test your predictions.
- You must click "Setup" to initialize the simulation and after any changes to the system conditions.
 - Click "Go/Pause" to start or stop the motion of the object.
 - You can change mass, distance, and speed using these sliders.
 - Remember to press "Setup" if you want the changes to go into effect!
 - You can notice the speed and the gravity force on each object.
 - You can visualize Object B's speed (set in initial conditions), the gravity force acting on Object B, and the orbital path of Object B.
 - Inputs you can change
 - Object B mass
 - Object B to A distance
 - Object B speed
 - Effects you can visualize
 - Gravity forces
 - Grid
 - Gravity force on Earth and the Moon
 - You can also visualize a different perspective by zooming some, more, or leaving the default perspective.

Make a prediction.

On your own



- 16.** Complete part 1 and 2 on *What causes one solar system object to move around another?*.

Explore the interactive.

With your group



- 17.** Complete part 3 on *What causes one solar system object to move around another one?*

Building Understandings Discussion

With your class



- 18.** Discuss the following questions with your class.:

- Were you able to use the simulation to get the outer object out of a stable orbit and crash into the inner object (or fly away)? If so, how?
- How are the gravity forces on the outer object and the gravity forces on the inner object in this simulation related?
- How does the strength of the gravity force impact the motion of the outer object?

Navigation

Consider some of the patterns we have seen in the organization of our solar system:

- There are planets and moons that follow predictable orbits.
- These are influenced by gravity forces between all of these objects.
- There is a lot of empty space between these objects.

On your own



- 19.** Answer the following questions in your notebook.

- Do you think all the objects in our solar system will remain in these orbits far into the future?
- What do you think might have happened that could help explain why our solar system is organized the way it is today?
- What new wonderings does this raise for you?

Lesson 15: How did the solar system get to be the way it is today?

Navigation

In your notebook



1. Respond to the following question in your notebook.
 - What do you think might have happened that could help explain why our solar system is organized the way it is today?

Share ideas.

With a partner



2. Discuss this question with a partner: What are some sources of data that scientists might be able to use to figure out what the solar system was like in the past?

Analyze and interpret data.

With your class



3. Examine the images of the Moon and Mimas (a moon of Saturn), and respond to the prompts:
 - What clues to photographs like this provide us about what the solar system might have been like in the past?
 - If meteor impacts tend to add additional matter to planets and moons, how would the size of all the planets and moons long ago compare to their size today?

Observe a computer model of the solar system over time.

In your notebook



4. Follow your teacher's instructions for watching a computer model and record your responses to these prompts:
 - What I see
 - What I think
 - How has my thinking changed?

Create a storyboard of the solar system formation.

On your own



5. Follow your teacher's instructions and create a storyboard to illustrate your claim about how the solar system formed based on evidence from the computer model and prior investigations.

Share storyboards.

Scientists Circle



6. Follow your teacher's instructions and share your storyboard of the formation of the solar system.
7. As your classmates share their ideas, put a ✓ on specific places in your storyboard where there is agreement.

Develop a Class Consensus Model.

Scientists Circle



8. Discuss the following questions with your class.
 - Which ideas did there seem to be consensus about?
 - What evidence was provided to support those ideas?
 - Which ideas did we not have consensus about?
 - What evidence was provided to support those ideas?

Navigation

Scientists Circle



9. Discuss this question with your class: What questions do you have now?

In your notebook



10. Based on what we figured out about our solar system, what questions would we want to ask about another solar system to see if it formed in a similar way to ours?

Lesson 16: What patterns and phenomena are beyond our solar system that we cannot see with just our eyes?

Navigation

With a partner



1. Look back in your notebook and at the DQB. Discuss these questions with a partner:
 - What were we debating and/or wondering about at the end of the previous lesson?

Hubble eXtreme-Deep Field

With your class



2. The photo on *Hubble extreme Deep Field* was taken using one of the most powerful telescopes, the Hubble Space Telescope. What do you notice and wonder about this photo?

The “Great Debate” in Astronomy

With your class



3. Read from *The Great Debate*.
4. How did Shapley’s model for the universe explain the evidence he had at the time? How did Curtis’s model for the universe explain that same evidence?
5. What would you do to resolve this debate? What kind of data would you collect, and how?

Obtain information: galaxies.

With your class



6. Observe the image on the slide. In the 1920s, scientists used telescopes to confirm that there are islands of stars out there. They named the islands of stars galaxies. This allowed them to build a model for the known universe. Looking at this image and using what you have figured out so far about gravity and objects in space, who do you predict had the correct model, Shapley or Curtis?

Obtain information from *A Tour of the Universe*.

With a partner



7. Watch a video. Record your thinking on *Tour of the Universe*. If time permits, play the video twice. First, just watch it without doing any writing. Then pause at each travel time to Turn and Talk and record noticings and wonderings about the objects and scale in view.

Turn and talk



8. Hold a Building Understandings Discussion about the 3 following prompts.
- Why do you think scientists choose to make the icy Kuiper Belt objects the boundary of our solar system? Why not end the solar system at Neptune or extend it out to include other stars?
 - Does the shape of the galaxy remind you of any other systems that we have studied so far? If so, how? What do you think that means about how the parts of the Milky Way system interact?
 - The video said that “each point represents an entire galaxy of stars.” What does this mean, and how can this help us understand the Hubble Deep Field photo?

The “Great Debate” in Astronomy

With your class



9. Who had the correct model, Shapley or Curtis?

Building Understandings: Tour of the Universe

With your class



10. Why do you think scientists choose to make the icy Kuiper Belt objects the boundary of our solar system? Why not end the solar system at Neptune or extend it out to include other stars?
11. Does the shape of the galaxy remind you of any other systems that we have studied so far? If so, how? What do you think that means about how the parts of the Milky Way system interact?
12. The video said that “each point represents an entire galaxy of stars.” What does this mean, and how can this help us understand the Hubble Deep Field photo?

Navigation

On your own



13. Discuss these questions with the class:
- Which of our questions did you feel we answered today?
 - How does what we figured out connect to our lives on Earth?

Lesson 17: How are we connected to all of the systems in space beyond the planet we live on?

Navigation

On your own



1. Look back through your notebook, Community Guides, and our patterns and Phenomena in the Sky Poster.
2. Follow your teacher's instructions and make a chart in your notebook and record your patterns/phenomena and connections under each heading.

Turn and talk



3. Share the following with your partner.
 - A pattern in the sky that matters to you or your community.
 - What we figured out about those patterns and connections we have to them.

Modeling to Explain a Clumpy Universe

We now know that other stars have systems as well, with planets and probably moons and other objects, but that there is a lot of empty space in between all these parts and systems.

With your class



4. Think about the following:
 - Why is it that we find things in space clumped together, with so much emptiness in between, instead of spread out evenly?
 - Can we make a model of the universe that shows and explains this structure?

Develop a model.

With your group



5. Develop a complete model of how all these space systems fit together and help us organize our ideas about where there might be life.
 - Remember to use "zooming" to represent multiple scales.
 - Include the important parts of each system for considering where we might find life.
 - Show how these systems are held together through interactions among the parts.

Gallery Walk

With your group



6. Move around the classroom to look at your peers' posters. Try to visit 3–4 posters. Notice similarities and differences across models related to
 - how each model uses “zooming” to represent multiple scales,
 - which important parts of the systems each model includes, and
 - how each model shows how these systems are held together through interactions among the parts.

Revise models.

With your group



7. Return to your model to revise any aspects that need further clarification. Remember to focus on
 - how each model uses “zooming” to represent multiple scales,
 - which important parts of the systems each model includes, and
 - how each model shows how these systems are held together through interactions among the parts.

Develop a Class Consensus Model.

Scientists Circle



8. Develop a record of what we agree on and where we have competing ideas across the final models.
 - Be ready to share your ideas about these questions:
 - Which scales were represented in the models you visited that should be included in our consensus model?
 - What interactions among parts did you see in common across the models that could explain why these systems are so well organized?

Evaluate our DQB questions.

With a partner



9. Compare your notes about which questions you think we have answered on our DQB using *Reviewing Our Driving Question Board*. Use these symbols to mark the questions on the handout:
 - We did not answer this question or any parts of it yet: O
 - Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
 - Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓ +

Evaluate our DQB questions.

Scientists Circle



10. Follow your teacher's instructions and mark the questions you think we have made progress on with a sticky dot.

Revisit our Driving Question Board.

Scientists Circle



11. Discuss the following questions with your class.
 - Which questions have we made the most progress on?
 - What have we figured out?

Reflection: The Pale Blue Dot

On your own



12. Follow your teacher's instructions for using *The Pale Blue Dot* to reflect on the unit and Earth's unique place in the universe.

References

Listening Group Roles Reference

- **Progress monitor.** This person periodically asks others to take the measure of the group's progress. This includes watching the time to keep the group on track. Some questions the progress monitor might ask are the following:
 - "What can we say we've accomplished so far?"
 - "What do we still need to know or do to accomplish this task?"
 - "We have _____ minutes left. What can we do in that time to accomplish our task?"
- **Big ideas person.** The role of this student is to relate the podcast to the question we are trying to answer.
 - "How does what you said relate to _____?"
 - "How does this change the way we're thinking about _____?"
- **Clarifier.** This person monitors everyone's comprehension about 1 or 2 key science terms. The clarifier might ask questions such as these:
 - "Do we know what the word _____ refers to?"
 - "Can we put what we just heard/read into our own words?"
- **Questioner.** This person asks probing questions during the activity. The questioner listens for questions posed by other group members and then revoices the questions to make sure that the whole group takes a moment to hear and entertain questions from everyone.:
 - "What does it mean that _____?"
 - "How do we know that _____?"
 - "So, what I think you are saying is _____. Is that right?"
- **Conductor.** This person monitors the airtime of people in the group. The conductor is allowed to control who has "the floor" with the goal of ensuring that everyone gets a chance to talk and that everyone takes time to listen. The conductor should invite comments or questions from group members who haven't been heard from yet. The conductor will also be in charge of playing/pausing the podcast when requested.
 - "_____, we haven't heard from you yet. What do you think?"
 - "Wait _____, we need to hear from someone else before you share again."

Podcast Transcript: Gerardo Aldana - The Descent of the Feathered Serpent

Narrator

Hi, my name is Sergio Salgado, and I'm part of a team called OpenSciEd that provides freely available, high-quality science instructional materials. We spoke with astronomers from around the world to get their perspectives on the relationship between the Earth and the sky. What we learned was fascinating, and we are excited to share their stories with you. We hope these stories get you thinking about how patterns in the sky set the rhythm for your life, your community, and all life on Earth.

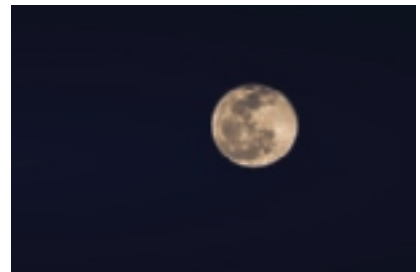
Professor Aldana

If you were to go into a rural Mayan community, say you were to go into rural Yucatán or rural Quintana Roo, and you were to talk to farmers there, what they do is they practice very atraditional agricultural approaches.



Professor Aldana

Now, what's fascinating is if you go and you talk to farmers in these communities today, they'll tell you that they don't just plant as soon as the rains start, and they don't just plant as soon as the Sun gets to a certain position. They wait for the Moon. They wait for the first full Moon after the rains start.



Narrator

That was Gerardo Aldana, a professor of Anthropology and Chicana and Chicano Studies at the University of California in Santa Barbara. We sat down with him to find out more about what he studies and how the ancient Mayan people used patterns in the sky to set the rhythms of their lives.



Gerardo Aldana

Professor Aldana

Being a Latino within the field of science technology had me asking these questions that eventually led me to wonder more about the more abstract level of what is the relationship between science and culture. Is it possible that science and math are part of cultural systems? They're part of worldviews, how groups of people come together and look at the universe.

Those are the questions that really drove me in the end. And I didn't feel like I could understand them by going back and just learning more about European astronomy or European math or European physics. So, the only place that I could really find something independent, something that did not engage what we know about Western science, was Mesoamerica. The focus of my research is on Mayan astronomy, astronomy that was developed within that region that we think of as the Yucatán Peninsula, mostly Guatemala, the Pacific coast of Guatemala and Mexico, and places like Belize and Honduras.



This map shows the approximate extent of the Mayan and Aztec empires in Mesoamerica before colonization by the Spanish.

Narrator

The Mayans are famous for developing a complex writing and number system that they used to record the phases of Venus and the Moon and the movements of planets and stars with great precision. But despite this, most of what we know about Mayan astronomy came from the Europeans who colonized Mexico.



Professor Aldana

In the 16th century, when Spaniards arrived, there were a lot of books still around. The Christians came with the Conquistadores, and they basically said, this type of religion that you practice and everything that goes along with it needs to be removed.

They decided in Yucatán that they were going to collect as many of these books as they could find and have a big, gigantic bonfire and destroy them. The Mayan people were greatly troubled by this burning of their knowledge and their culture. But it was part



of that Evangelical movement at the time. A couple of the books escaped the flames. One of them was taken out of Yucatán, out of this specific region, and it looks like it was transported on one of the first ships to go back to Spain from the Americas.

Narrator

These rare Mayan texts that escaped the violence of the 16th-century colonization are what Professor Aldana studies.

Professor Aldana

It preserves Indigenous perspectives recorded for Indigenous audiences. There's no interaction there with translators, there's no need for somebody to come in and say, we're going to try and interpret what you are trying to tell these people.

Narrator

The Mayans had a calendar with 365 days, just like we do. We asked Professor Aldana how the Mayans chose a 365-day calendar. He told us that the Mayans tracked the location of sunrise over time using a series of distant volcanoes.



Professor Aldana

As time progressed through the year, the Sun would rise further and further south. And it would rise behind different prominent geographic features, other volcanoes, other mountains, as it worked its way down towards the coast, so that by the time you get to the winter solstice, it's actually rising over the ocean. And what you do then is you have this really nice division of the solar year into periods that you mark by sunrises.

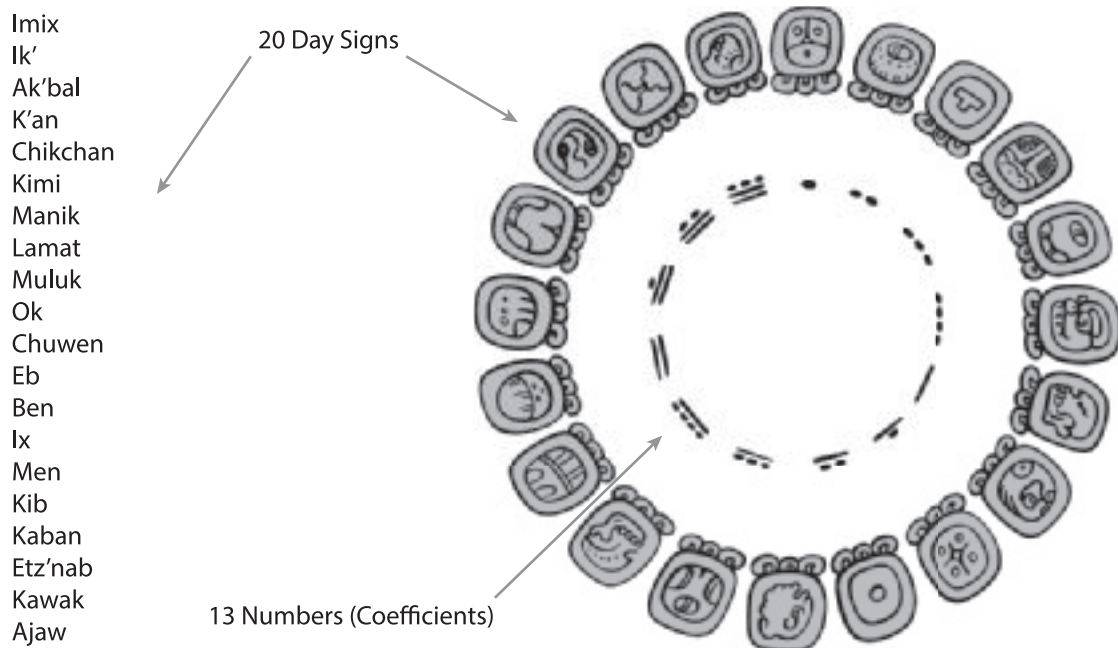


Narrator

But this 365-day calendar was not the only system that the Mayans used to keep time.

Professor Aldana

We have this thing called the Tzolkin by K'iche Maya, it's a 260-day count. Sometimes it's also referred to as the ritual calendar, the sacred count. The count itself is incredibly straightforward. It's just 13 numbers and 20 days, and so when you put 13 together with 20. You get 260 combinations.



Narrator

We asked Professor Aldana if he could recite the name of the day signed in the 260-day count.

Professor Aldana

It's [Mayan] Imix, Ik', Ak'bal, K'an, Chicchan, Cimi, Manik, Lamat, Muluc, Oc, Chuen, Eb, Ben, Ix, Men, Cib, Caban, Eiz'nab, Cauac, and Ahau [Mayan]. So that 20-day sequence gets combined with 13 numbers, and you end up with a 260-day cycle that repeats over and over and over again.

Professor Aldana

There are communities in Guatemala today, Mayan communities, that still use the 260-day count that we see all the way back into the formative period. This ethnographer went in and asked people, where does it come from? Why 260 days? And they found out that it took them back to the midwives, *parteras*. So midwives are in charge of making sure that women have births that are healthy. So they know a lot about women's cycles and about women's health. And it turns out that there's this really interesting phenomenon, cultural and biological, that we find throughout Indigenous communities in the Americas.

Narrator

The midwives told researchers that 260 days corresponds to a human gestation cycle, the length of time between when a woman first misses her period and the birth of the child.

The Mayans used a combination of the 260-day calendar and the 365-day calendar to keep track of time. Every day will be a unique combination



of a day from the first calendar and a day from the second calendar, until 52 years have passed, at which point the system restarts.

So the Mayans used these two calendars simultaneously to create a complex calendric system that tied together a fundamental rhythm of the sky with a fundamental rhythm of the Earth.

Professor Aldana

The very first uses of the lunar cycle were to bring people together for festivals and for doing things like playing the ball game.

Narrator

Professor Aldana explained that for some Mayan rulers, astronomy was not just a way to keep track of time. The patterns in the sky were a political tool that was used to unite people in cities across Mesoamerica.

Professor Aldana

There's 10, 20, 30,000 people in one location. That's not going to be good enough to just say, let's look at the next Moon cycle, right? You need a much more precise system to start timing your events, agriculturally and socially. That's when things really start to get interesting in terms of the relationships between astronomy, what they observe in the sky, calendric systems that they create, and then the agricultural systems that are all tied together with those.

What happens in the late formative period is that these cities already have social stratification, and they realize that there's a utility for astronomy to have political influence, not just practical influence. It's not just agriculture. It's also that you can now read signs in the sky. And you can have those have meaning within either political debates or ideological debates.

Now, astronomy takes on political meaning. And people will say something like, "If there's going to be this kind of eclipse, then it means that there's a tough time ahead. And if there's a tough time ahead, we need to plan accordingly."



NASA/Gopalswamy

Narrator

The intimate relationship between sky and Earth is embodied by the Mayan story of Kukulcán, known to the Aztecs as Quetzalcoatl, the feathered serpent.

Professor Aldana

Quetzal is the name of a bird, and it's combined with the word *coatl*, which just means "serpent" in Nahuatl, a bird serpent or the feathered serpent. In Mayan, there's different words for it. It's either Kukulcán in Yucatán. Kukulcán is the same thing. *Kuk* means Quetzal and *cán* means serpent. So it's feathered serpent, and in K'iche Maya it's Q'uj'umatz.

Quetzal has access to the celestial realm and to the middle realm because it can fly between the sky and the middle world and the trees. And the serpent has access to the underworld because it can go down underground but can also come into our realm in the middle world. Quetzalcoatl, the Kukulcán, can actually move between all three realms of the code of the cosmos, of the universe.

Narrator

The Temple of Kukulcán at Chichén Itzá, a popular tourist site, ties the legend of Quetzalcoatl to the 365-day astronomical calendar in an unforgettable way.

Professor Aldana

It's a radially symmetric pyramid. It's got four sides to it, each with its own staircase. Each staircase has 91 steps on it. So 4 times 91 means there's 364 steps on this building. And then there's a platform at the very top, which looks like it's the final step. So 365 steps, the solar year.

If you go on the equinoxes, the setting Sun casts shadows along the balustrade of the northern staircase. And it creates a diamond pattern. It looks like there's a long diamond pattern going down the entire length of the northern staircase, and at the end of the staircase, there's the



head of a feathered serpent. When you're standing there, it looks like you're seeing the feathered serpent as a rattlesnake descending from the sky onto the ground, heading towards the underworld.



The temple of Kukulcán at Chichen Itza photographed showing the serpent.

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Word Bank

Nahuatl words and locations used in the podcast

Yucatán - Peninsula in eastern Mexico

Quetzalcoatl - Feathered serpent

Mayan words and locations used in the podcast

Kukulcán - Feathered serpent

Tzolk'in - The 260-day Tzolk'in, or sacred calendar, is the oldest calendar cycle known in Mesoamerica, dating back to at least 600 BCE.

Spanish words used in the podcast

Quintana Roo - Mexican state on the Yucatán peninsula

Partera - Midwife

Conquistadores - Spanish colonizers who took the land from the Indigenous people

Other Words

Mesoamerica - means middle America, including Central Mexico to Belize, Guatemala, El Salvador, Honduras, Nicaragua, and northern Costa Rica

Podcast Transcript: Annette Lee - As It Is Above, It Is Below

Narrator

Hi, my name is Sergio Salgado, and I'm part of a team called OpenSciEd that provides freely available, high-quality science instructional materials. We spoke with astronomers from around the world to get their perspectives on the relationship between the Earth and the sky. What we learned was fascinating, and we are excited to share their stories with you. We hope these stories get you thinking about how patterns in the sky set the rhythm for your life, your community, and all life on Earth.



Professor Lee

The relationship with the sky is really important because it gives us our direction, where we come from, what we're doing now, and where we're going.

Narrator

That was Professor Annette Lee, an Indigenous scholar, astronomer, visual artist, and a full-time tenured faculty in the Physics and Astronomy Department at St. Cloud State University. We sat down with her to find out more about her relationship with the sky and how the people in her community have connected to the sky over generations.

Narrator

Professor Lee is mixed-race Lakota, and her communities are Ojibwe and Dakota/Lakota.

Professor Lee

I'm living here currently in the place called Mni Sota Makoce or Minnesota. And I like to also acknowledge this is the land of the Dakota people. And later the Ojibwe people have been living here for hundreds and thousands of years. My family is Lakota, which is from the Wanbli Luta, which is the Red Eagle family. And my husband is Ojibwe.



This map shows the approximate extent of the Lakota and Ojibwe lands in North America before colonization.

Narrator

We asked Professor Lee about why she chose to be an astronomer.

Professor Lee

I've always had a really strong connection to the stars. Science allowed me to pursue astronomy and a connection to the stars. I wanted to go down this path of developing this relationship with the sky.

Science is a laser-focused precision tool. And it has gotten us far and wide. I mean, we got to the Moon, we're sending orbiters and landers on Mars. There is culture in what we think of as objective science, and it's Western European. Its time to acknowledge that other cultures have science and have been doing science and are participating in science.



Several Ojibwe constellations simulated using Stellarium planetarium software. Stellarium & Ojibwe and D/Lakota Astronomy/A.S. Lee

Narrator

When we say "science," we have an image in our head of what that means, and that image comes from Western European history. But knowledge about the natural world was not invented by Europeans like Galileo and Newton. For thousands of years, people around the world have been observing the sky, collecting knowledge about the sky, testing their ideas, and using stories to transmit those ideas to the next generation. And according to Professor Lee, narrowing our definition of what counts as scientific knowledge has come at a price.



Professor Lee

Science has given us all these advancements and technology, but what are the ethics? What are the social considerations that go into this? And we're not dealing with that. When we talk about what's the difference between the Indigenous way of knowing, Indigenous knowledge systems, or Indigenous scientific knowledge systems, one of the very first things is the acknowledgement that all living things are related and that we're all connected. So when we get back to the sky, then the relationship with the sky is really important because it gives us our direction, where we come from, what we're doing now, and where we're going.

Narrator

We asked Professor Lee for an example where we have taken too narrow a focus and forgotten how everything is connected.

Professor Lee

Where I grew up in St Louis, there's a nuclear waste site where they dumped a whole bunch of radioactive waste along the river. Just think about that.

For the majority of human existence, go back 10,000 years, they knew that the land around the river was the best land, the most fertile land, right? Because the river is constantly changing. It's flipping and flopping around. And when it floods it has these rich sediments, these nutrients in the water, but those rich nutrients drop when the floods recede, and that makes the land right next to the river the most fertile, and that's how you grow your food to survive. So the Egyptians knew this, and they had the Nile River, and their entire calendar system was oriented around the flooding of the Nile. Because to grow that food meant the difference between life and death. And that was also connected to the heliacal rising of the star Sirius, the brightest star in the night sky.

Narrator

According to Professor Lee, when people dump nuclear waste next to a river, they have lost focus on how this river is connected to our lives and the rhythms of the Earth. The Egyptians used a pattern in the sky, the appearance of the star Sirius above the Sun each year, to understand and predict a very important rhythm on Earth: the rhythm of the flooding of the Nile each year. And they knew that it wasn't enough to understand just the pattern of the star or just the flooding of the Nile or just the nutrients needed in the soil. Rather, all this knowledge had to be connected for the Egyptians to grow food and survive. Like the Egyptians, for the Lakota/Dakota community, the sky was more than just a set of isolated patterns to be studied.



View in the Delta during the inundation of the Nile.

Professor Lee

It's so fundamentally part of who we are. We come from the stars. *Wichanpi Oyate* in Lakota, *Wichanpi Oyate*. We are star people. It's important to have this relationship with sky because it gives us the information that we need. But it also gives us more than that: the direction, the hope, the guidance.



Narrator

In other words, the sky and the Earth are not separate systems. The sky is where we come from, and it is what sets the rhythm of our lives. Professor Lee told us about the Lakota phrase that describes this relationship between the Earth and the sky.

Professor Lee

I personally remember going to different ceremonies and hearing different elders say, "As it is above, it is below." In Lakota this is *kapemni, kapemni*. What it is, is the idea that there's really two parts to the whole. The top part is the sky or the spirit world. The below is the earth or the material world. So there's these two parts that are equally real and are part of the whole, and their relationship is that they mirror each other. It's a reflection. So the above and the below.

The word *kapemni* has *mni*, and the *mni* is water. So that's a flow. So it's moving. We want there to be this flow because that's what keeps us healthy and strong, and the healing is coming through that flow.

Narrator

We asked Professor Lee about some of the stories that her people used to organize and understand this relationship with the sky. The list of 88 constellations recognized by the International Astronomical Union goes back at least 6,000 years to Babylonia, now modern-day Iraq, but they are no more or less scientific than those of the Lakota/Dakota or the Ojibwe. Indigenous communities also used constellations to organize the patterns they saw in the sky and to make connections between Earth and the larger system of the universe.

[Loon calls in background]

The Ojibwe loon, which is *[Ojibwe] Maang [Ojibwe]*, is right there at the center of their night sky, or where Polaris would be or the Little Dipper. The Loon is part of helping place the stars in the sky and the planets. So the Loon is really special.



The Ojibwe constellation Maang – Loon – simulated using Stellarium planetarium software. Stellarium & Ojibwe and D/Lakota Astronomy/A.S. Lee

Narrator

The Loon is an Ojibwe constellation that is visible all night and all year round. This is not true of most constellations, which rise and set and are only visible at certain times of the year. For example, the familiar Greek constellation of Leo the Lion forms the curved tail of the Ojibwe constellation the Great Panther and includes the stars of Cancer. The Great Panther is only visible for part of the year.



The Ojibwe constellation Mishi Bizhiw – Curly Tail or Great Panther – simulated using Stellarium planetarium software. Stellarium & Ojibwe and D/Lakota Astronomy/A.S. Lee

There are many important cultural teachings about the relationship between the Great Panther and water. According to Ojibwe elder Carl Gawboy, when the Great Panther was overhead in spring, the Ojibwe rejoiced winter's end and the renewal of life. The arrival of spring and the Great Panther also meant snow melt, thin ice, flooding, and violent storms on the Great Lakes.

Professor Lee

We all know we have different things that we experience or we enjoy in different seasons, and you go to the store and you see, you know, St. Patrick's Day or Easter decorations. Or you see in your backyard right now, it's springtime, right? The buds are first starting on the trees, but there's no leaves. You see the birds. They're singing. The snow is melting. So every person has that. That's just what we do.



Professor Lee

But the seasons unfolding in the stars has another meaning. If we can look to the seasons and, getting to know the motion and the seasons go by, each time we can look at the stars, we can acknowledge them, then that gives us the opportunity to participate in this rhythm. And the rhythm is unfolding in the seasons all the time. But also in the stars and in the Sun and the Moon. And the more that we can be a part of that relationship, the more it helps us to get back on track. It helps calibrate our own rhythm.

Everything you need is in the stars. If we can slow down and we can do something simple, like listen, and we're just sitting on the ground on a blanket, under the stars. Then we're listening. We're taking in those rhythms. We're taking in the teachings, the patterns that come from the stars. Everything you need is in the stars.

[Twinkle, Twinkle Little Star by the Black Lodge Singers song fades in.]

This podcast was produced by OpenSciEd in collaboration with Furnace FPS. Production of this podcast was made possible by funding from the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Charles and Lynn Schusterman Family Foundation, and the William and Flora Hewlett Foundation.

Word Bank

Lakota words used in the podcast

Wanbli Luta – Red Eagle

Wichanpi Oyate – Star Nation or Star People

Kapemni – As it is above, it is below

Ojibwe words used in the podcast

Maang – Loon

Mishi Bizhiw – Curly Tail or Great Panther

Podcast Transcript: Thebe Medupe - Rebirth of Selemela

Narrator

Hi, my name is Sergio Salgado, and I'm part of a team called OpenSciEd that provides freely available, high-quality science instructional materials. We spoke with astronomers from around the world to get their perspectives on the relationship between the Earth and the sky. What we learned was fascinating, and we are excited to share their stories with you. We hope these stories get you thinking about how patterns in the sky set the rhythm for your life, your community, and all life on Earth.

Professor Medupe

There was a giant crocodile, which, at the end of the day, swallows the Sun. And at the beginning of the day, it takes out the Sun again. Every morning, the Sun rises in the east. Every evening, it sets in the west. And so the idea there or the story was a model to try to understand what was happening in the sky.



Narrator

That was Thebe Medupe, a professor of astronomy and the Deputy Dean of Faculty in Natural and Agricultural Sciences at North-West University in South Africa. In addition to being an expert on cultural astronomy throughout Africa, Professor Medupe is one of the Tswana people in Southern Africa and was raised in the traditions of his people. We sat down with him to find out more about his relationship with the sky and how the people in his community have connected to the sky over generations.



Professor Thebe Medupe

Professor Medupe

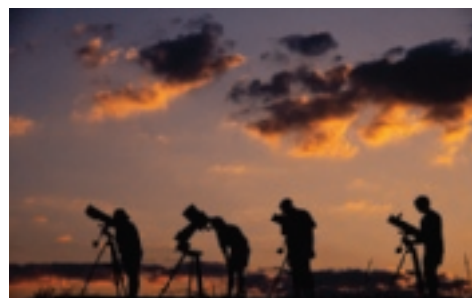
I'm one of the Tswana people of Southern Africa. There are 4 million Batswana people in South Africa, four and a half million of them. My town, Mafikeng, is just on the border between South Africa and Botswana. In 1986, Halley's Comet came to our sky. And all the media, the radio, the newspapers, were talking and writing about astronomy, about stars, about planets and the comets. I wanted to read and learn more about these mysterious stars, you know, and planets. So, I went to a library in my town, and one of the little books I found was explaining or describing how to build a little telescope from simple things you can find at school or at home. And I built a telescope. I was age 13 then, I took my telescope, pointed it at Jupiter, and I saw the moons of Jupiter. That moment was just out of this world for me. I pointed it to the Moon. I saw craters. I saw mountains on the Moon. It was just unbelievable, and that really just developed a very keen interest of science, of mathematics, of astronomy, and from there, that's what I wanted to become: an astronomer.



Halley's Comet as it passed near Earth in 1986

Narrator

Professor Medupe grew up in South Africa at a time when Black South Africans were legally not allowed to do the same things as white South Africans, simply because of the color of their skin.



Professor Medupe

One of the things about our education system during those days was that everything was Eurocentric, so the books of science that we were reading only showed the white scientists, the white heroes. It was a pain for me growing up because I couldn't see my image in the science books that I was reading. The reason why I developed an interest in African traditional astronomy was so that I can find material that could help me show to young Black scientists that African people, also, are interested in science and that science belongs to everyone in the world.



Narrator

When we say "science," we have an image in our head of what that means, and that image comes from Western European history. But knowledge about the natural world was not invented by Europeans like Galileo and Newton. For thousands of years, people around the world have been



observing the sky, collecting knowledge about the sky, testing their ideas, and using stories to transmit those ideas to the next generation.

Professor Medupe

I've done a lot of research on the history of astronomy in Africa. Black people were studying models of the solar system centuries ago—three, four, five centuries ago. There were schools in the Sahara where people were studying these books. Timbuktu is an old city founded about 900 years ago on the banks of Niger River in West Africa. They were teaching astronomy and mathematics in their schools.



Narrator

Although the Tswana were thousands of miles from the metropolis of Timbuktu, Professor Medupe told us that his people were also knowledgeable about the sky and used the patterns that they saw to set the rhythms for their everyday lives.

Professor Medupe

Within the Tswana society, there are people whose responsibility it is to be the keepers of knowledge. These are the people who would be observant, very observant of nature, and, importantly, this information will be passed on by word of mouth to the next generation. Batswana people were agriculture or are agricultural people who live off the land. They were growing crops, they had farming, they kept cattle, and so, that routine was very much determined by the night sky, you know, the different patterns and different types of stars that were appearing and disappearing throughout the year in the night sky.

If you have a well-organized society, time is very important, right? You need to know your stars in order for you to plant in time so that you can feed your community. They needed a reasonably accurate calendar so that they can organize their societies. Throughout Africa from Cape to Cairo, almost, people when they saw the Pleiades rising in the evening, they knew that it was time for planting.



Narrator

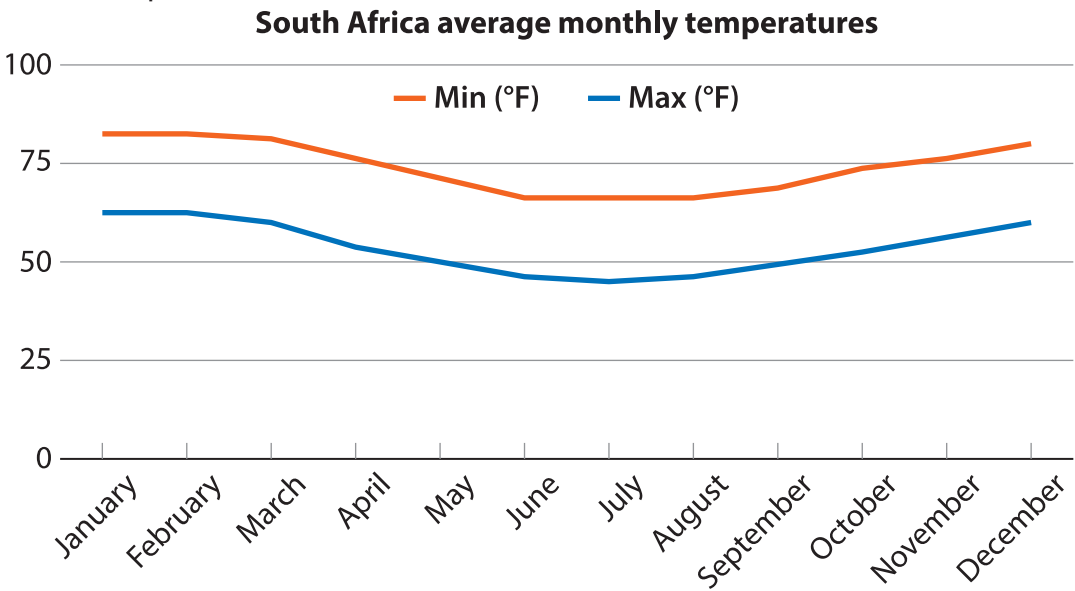
South Africa is located in the southern half of the Earth, so the people there experience different seasons and different constellations in the sky than we’re used to in the northern half of the Earth.



South Africa is in red.

Professor Medupe

In South Africa, because we’re in the Southern Hemisphere, our winter months begin in May, and they end in around August. That’s our cold period. And then after that, we have spring. So, spring is from September until November, then we have our summer from December until around March or April.



Data source: <https://www.climatestotravel.com/climate/south-africa>

Narrator

But even though the seasons and the constellations are different there, the Tswana people still saw many of the same patterns in the sky that we do, and they used these patterns to keep time.

Professor Medupe

They had to have a calendar system of some sort. The basis of that calendar, for example, of the Tswana calendar, is the Moon. So, what Batswana would do is they would look at the different phases of the Moon, and they would count the number of days it takes for one phase to reappear. And that meant that a month in Tswana calendar was 29 and

a half days long. If you multiply 29 and a half days by 12 to get a whole year, that means Tswana calendar was 354 days long, which is 11 days short compared to the solar calendar that we use today. And therefore, the Tswana calendar had to make up for those 11 days that are missing in that calendar every year. And that means that after every three years, 11 days accumulate to almost a month, and therefore Tswana calendar after every three years had 13 months, and the other years they had 12 months.



Narrator

Professor Medupe told us that, like many astronomers across cultures, the Tswana people projected scenes from their everyday lives onto the stars to organize the patterns they saw in the sky.

Professor Medupe

The Southern Cross, which you can't see in the north but which you can see here in the south, those group of stars, the Southern Cross, were called giraffes by Batswana. If you looked at them because they were so low on the horizon, you can see them through the trees, and they imagined giraffes eating the trees, basically. That's why they called them giraffe stars.





The Southern Cross (Crux) as seen from Botswana Stellarium

Narrator

Although we cannot see the Southern Cross in the Northern Hemisphere, there are some constellations that we can see from both hemispheres. Professor Medupe also told us another story about the familiar constellation that we know as Orion.



Professor Medupe

In this story, the belt of Orion is three stars, and those are the three zebras. And then there's a star called Aldebaran, which is part of the Hyades. In this story, it is called the hunter, and the Pleiades are the six or seven stars, seven wives of the hunter. He left his wives to go and hunt the three zebras, hoping to bring meat home. So he tried to shoot at one of the zebras, and he missed. And he couldn't go and get his arrow because there's a lion nearby and that lion is Beetlejuice, and he couldn't go back to his wives because he was too embarrassed to go home without meat. So he stayed there as Aldebaran. That's the story. The point being that different people across the world see different patterns, and they imagine different stories, you know, to go along with those patterns of stars.



Selemela - known in the United States as the Pleiades and in Japan as Subaru. Davide De Martin & the ESA/ESO/NASA Photoshop FITS Liberator

Narrator

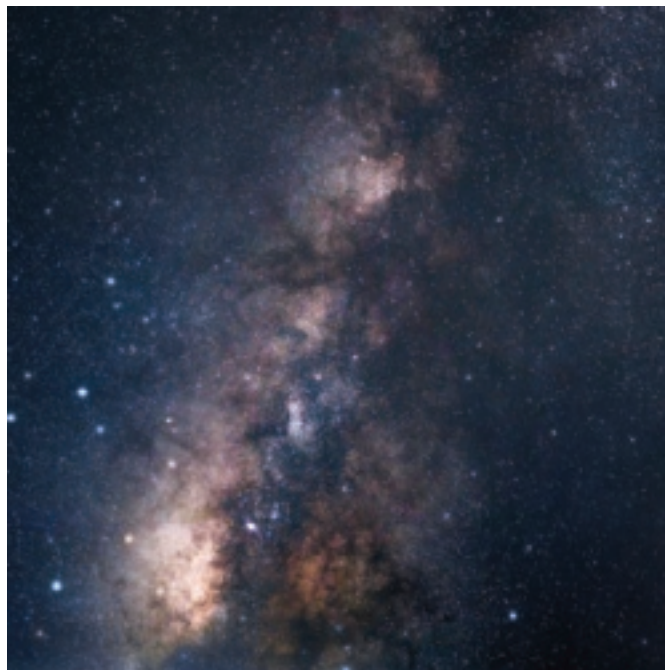
We asked Professor Medupe why he thought the Tswana people were interested in making connections to the sky, beyond using it to set their calendars.



Professor Medupe

Some of the questions that scientists are asking themselves today are the same kind of questions that most people in the world were asking themselves: Are we alone? Where do we come from? What will happen to us in the future? What are stars? What are these things that are shining up there? What's the nature of them?

But the origin of the questions really are the same as people want to be curious about the environment and using different approaches. We want to know our place in the universe, so they needed to know where they're located in the bigger scheme of things.



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Word Bank

Botswana - a country in Southern Africa

Eurocentric - focus on European culture without a wider view of the world

Hyades - star cluster that contains the star Aldebaran

Orion - a well-known constellation of stars

Mafikeng - Professor Medupe's hometown on the border of Botswana and South Africa

Batswana/Tswana people - native people of southwestern Botswana and Northern South Africa

Selemela - group of 7 stars, often called the Pleiades in the United States

Southern Cross - constellation only visible in the Southern Hemisphere

Podcast Transcript: Jessie Ferrari - Wombat Season

Narrator

Hi, my name is Sergio Salgado, and I'm part of a team called OpenSciEd that provides freely available, high-quality science instructional materials. We spoke with astronomers from around the world to get their perspectives on the relationship between the Earth and the sky. What we learned was fascinating, and we are excited to share their stories with you. We hope these stories get you thinking about how patterns in the sky set the rhythm for your life, your community, and all life on Earth.



Jessie

Totem. It's ... it's your connection to generally an ancestor being. You have a Totem for your nation. You have a Totem for your family. And you also have your own personal Totem. You get them from elders, and, generally, you have to go through initiation rites to get your own Totem. We see animals as being our kin, so being our family, and so we have an obligation to take care of them, to make sure that they're safe and they're cared for.

Narrator

That was Jessie Ferrari-Thomas, an Indigenous scholar in Australia who is currently an undergraduate student pursuing studies in ecology, genetics, and the Indigenous practice of fire-sticking. Jessie works with cultural astronomers in Australia to draw connections between Indigenous star knowledge and ecology. We sat down with Jessie to find out more about Jessie's relationship with the sky, and how the people in Jessie's community have connected to the sky over generations.

Jessie

I'm a trans and gender-fluid First Nations person. My tribe's nations are the Yorta Yorta and Bangerang people who are a Koorie people of northeastern Victoria, so on the border of New South Wales. I study ecology and I'm hoping to, in particular, work around conservation. I'm really looking to come at it from angle of Indigenous person and our knowledge systems and how intimately we know animals, especially our Totem animals, and how we can start to engage with Western science.



Narrator

When we say “science,” we have an image in our head of what that means, and that image comes from Western European history. But knowledge about the natural world was not invented by Europeans like Galileo and Newton. For thousands of years, people around the world have been observing the sky, collecting knowledge about the sky, testing their ideas, and using stories to transmit those ideas to the next generation.



Jessie

With Indigenous science, it's... it's very much all knowledge systems are heavily linked, and we don't tend to distinguish them compared to Western science. And it's still based on observation and inferences, and you would do experiments.

Narrator

One example Jessie gave of the way Indigenous systems of knowledge are interwoven was the connection between Totems and the sky.

Jessie

A lot of the stars are also linked in to Totems. And we see quite a few of them as spiritual ancestors... for example, we have a star, Canopus, which represents one of our turtles, Badja Bayaderra, which is the short neck Murray River turtle. They represent and their placement in the sky can mean when they're starting to breed and when they're starting to kind of emerge from burrows, and they start to be more active and that sort of thing. A lot of our knowledge is heavily linked in with the stars. And our Totems as well. And so we see the behavior of animals reflected in the heavens and vice versa.





Narrator

Jessie told us that the Aboriginal flag is a symbol that reflects their close relationship between Earth and sky.

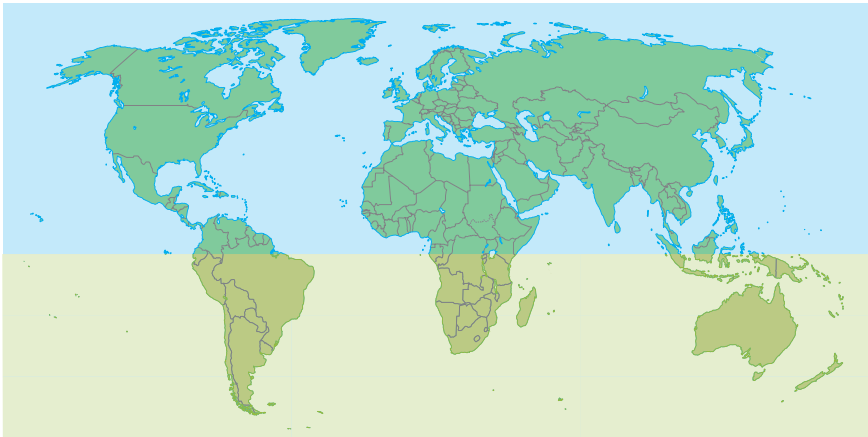
Jessie

The black represents the Aboriginal people of Australia, so it represents our race and us as people. Red represents the red earth, so it represents the red ochre that's very sacred to our people that's used in many, many ceremonies and Aboriginal peoples' continual spiritual relation to the land. The yellow represents the Sun. It's the giver of life, and it's our protector. We all see it as being a giver of life and a light in the sky and a beacon offering us warmth and protection.



Narrator

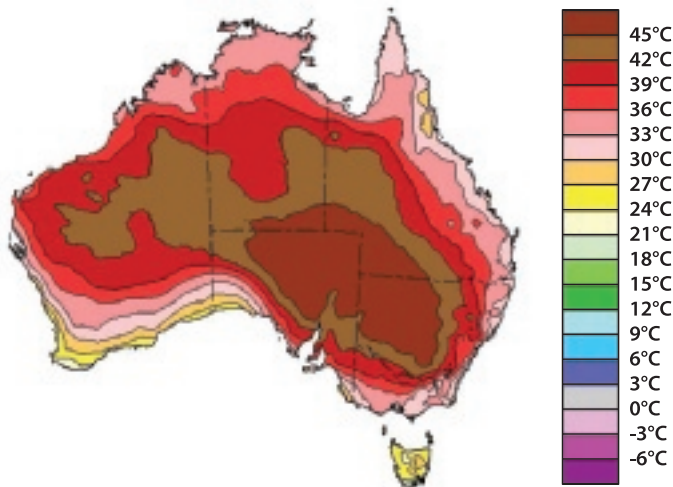
Jessie lives in Australia, which is in the Southern Hemisphere. That means the weather in Australia is warm when we experience cold weather and cooler when we feel the hottest temperatures of the year in the Northern Hemisphere.



Jessie

Generally, from the onset of September all the way to late Feb is when you'll get hot, warm, hot climate.

Highest Maximum Temperature (°C)



Narrator

We might call the time of year when the climate is hot, summer. But Jessie told us that the 4 seasons we are familiar with are not universal. For Jessie’s communities, there are many more seasons than the 4 we are familiar with in our culture. Jessie shared how the stars in the sky help to mark the arrival of those seasons.



Jessie

We observe and keep track of the movement of stars in our sky. By looking at the placement at certain points, it helps us tell what seasons are coming, what weather to expect. So, you have around about 8 seasons, and they're all to do not necessarily with just the temperature and the climate but also with behavior of different animals and the coming of different plants and the behavior of stars in the sky. So, different constellations coming in and out, moving at different points in the sky, or depends on their brightness as well. We do have



this one season among the Wurundjeri called the Waring, or Wombat season... this is around April—July. Wombats, you'll start to see emerge from their burrows to busk, which is like go around grazing and that sort of thing, and graze in the sunshine. And you'll also start to hear the mating courtship displays and calls of the Bullen Bullen, which is the Wurundjeri word for superb lyrebird. During the season, interestingly, the constellation of Sagittarius rises in the southeast after sunset, indicating the midpoint of cold weather. So, when it rises in the southeast, you can tell the cold weather is coming about. So, that's that connection to the sky but also to the behavior of the animals and the coming of food sources.

Narrator

Jessie tells us that a lot of Indigenous knowledge was lost due to colonization and government forcing Indigenous communities to integrate into their culture to purposefully stop certain knowledge.

Jessie

The early policies that really contributed to the loss of language, and even culture, were the moving of people on to missions and also the theft of children. It's what we call the Stolen Generation. Children were taken from their parents, and people were punished for practicing their cultures. I myself am coming to learn more about my culture and engaging more of it. My family are from the Stolen Generation, so I'm reclaiming a lot of that knowledge myself.



Narrator

Along with lost Indigenous knowledge, Jessie tells us how the rhythms of the Earth and the sky have been broken over time due to various changes in the environment.

Jessie

We have what you call the common brown butterfly... they start to really emerge during the Biderap season, or the dry season, so January, February. You start to see the females flying around looking for male butterflies. We're noticing that their population is declining. We're seeing a lot less of that mating going on, and so that means that a lot of bats and birds that rely upon them at first food source end up having to either migrate further out or starve, or they have to find some other food source to adapt to. So, it has really tangible and disastrous effects in the food web, and we can tell that they should be breeding at this point in time by the constellations in the sky, so at midpoint... I think its Canopus, when it's due east at sunset, that's when it should be around about the time that the common brown butterfly females start looking for mates, but we're seeing less of them around and less of them engaging in that. So, it's very, very, extremely worrying.



Narrator

We asked how Jessie's community has been able to reclaim some of the lost knowledge and connections between the rhythms of Earth and sky.

Jessie

We're very much stargazing people, so we definitely look to the stars in general to tell us the time and give us signs. Southern Cross is one that's used to tell whether the days are going to be longer or not. What we can expect in terms of length of the day, because we don't have hours. So, hours is not a concept that we have. We go by the behavior of all the environment around us. So, like if animals start to retire, that's how we know. Okay, so it's this point of the day. So, we should really be focusing on this or we should be gathering this supply or we should be heading back to the camp. The rhythms of the Earth. That's a really great phrase, by the way. I love that. It's paying attention to all those vital and beautiful connections between nature and the heavens and the knowledge that my people have of it and love of it.



This podcast was produced by OpenSciEd in collaboration with Furnace FPS. Production of this podcast was made possible by funding from the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Charles and Lynn Schusterman Family Foundation, and the William and Flora Hewlett Foundation.

Word Bank

Aboriginal people - the various first, Indigenous (native) peoples of Australia

Canopus - the second-brightest star in the night sky, part of a constellation that represents a turtle

First Nations - the first or Indigenous (native) people of an area of land

Victoria - a state in southeastern Australia

trans and gender-fluid - change over time in a person's gender expression or gender identity, or both

Southern Cross - constellation only visible in the Southern Hemisphere

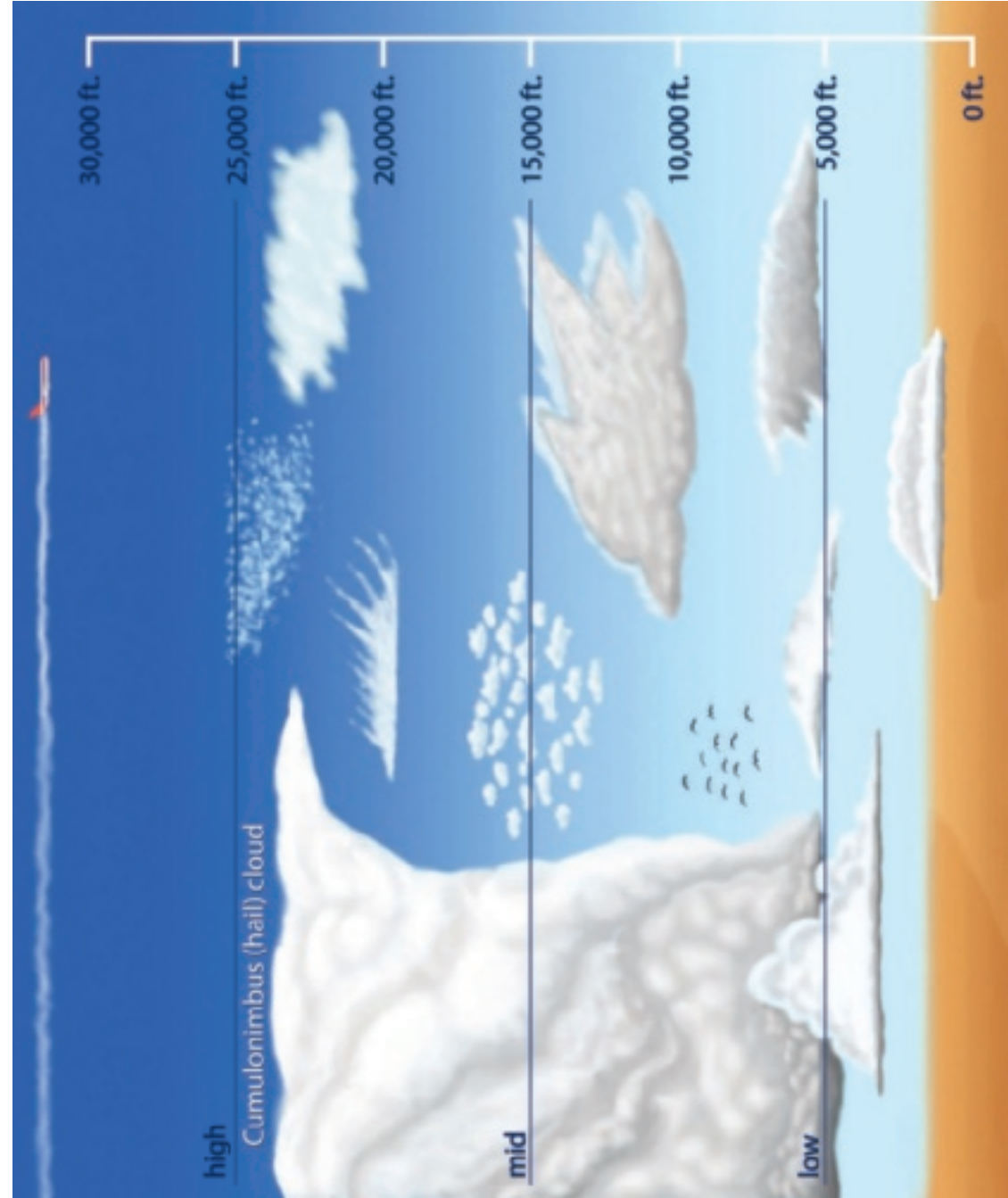
Yorta Yorta, Bangerang, and Koorie people - Aboriginal people of the land that is now considered Southeast Australia

New South Wales - a state in southeastern Australia, just north of Victoria

Lunar Eclipse Images

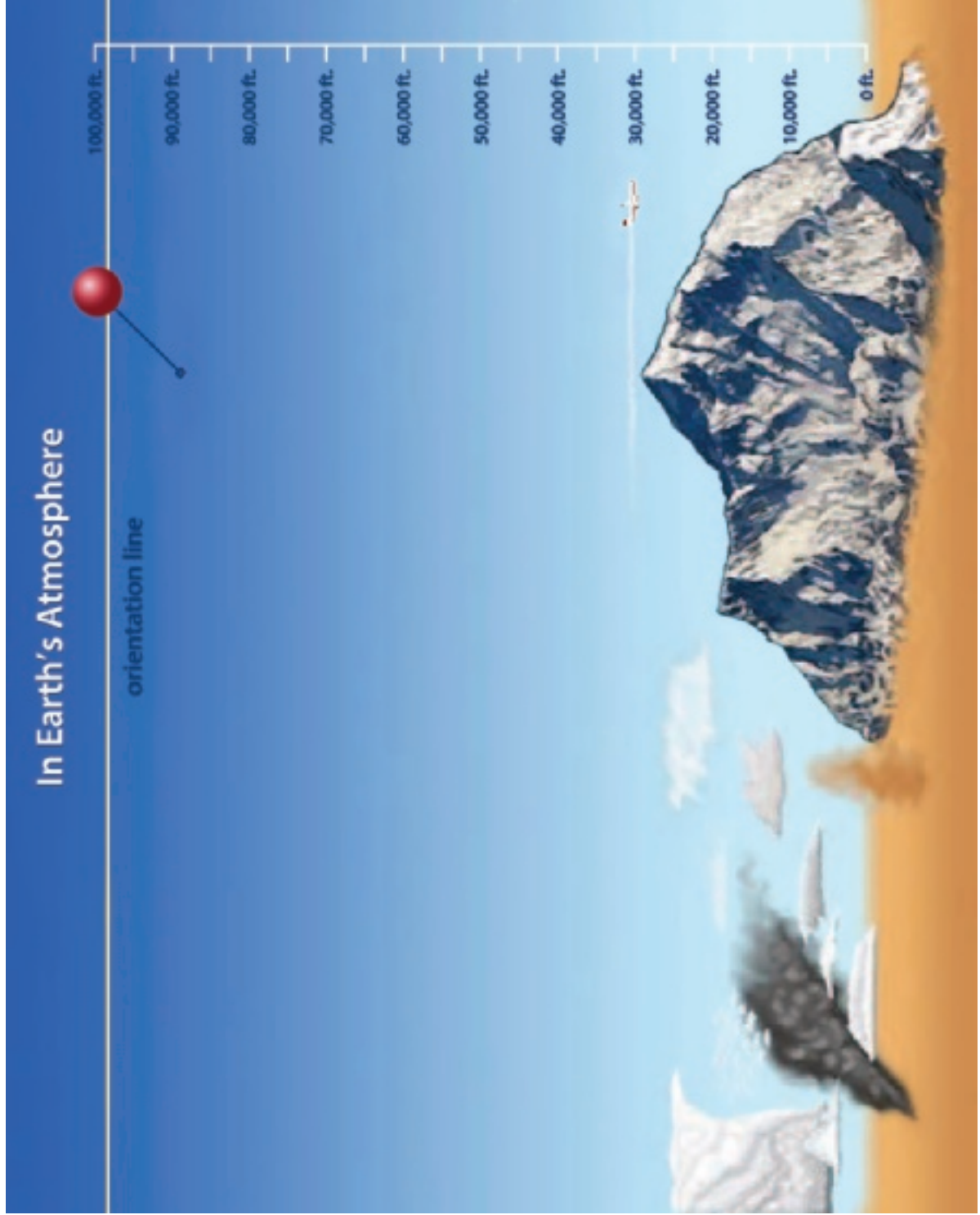
Shortly before the lunar eclipse began	About 6:30 p.m. UTC	About 6:45 p.m. UTC
About 7:15 p.m. UTC	About 7:28 p.m. UTC	About 7:30 p.m. UTC
About 7:50 p.m. UTC	About 8:20 p.m. UTC	About 8:45 p.m. UTC
About 9:14 p.m. UTC	About 9:20 p.m. UTC	About 9:35 p.m. UTC
About 9:55 p.m. UTC	About 10:15 p.m. UTC	Shortly after the lunar eclipse ended

Earth's Atmosphere Diagrams

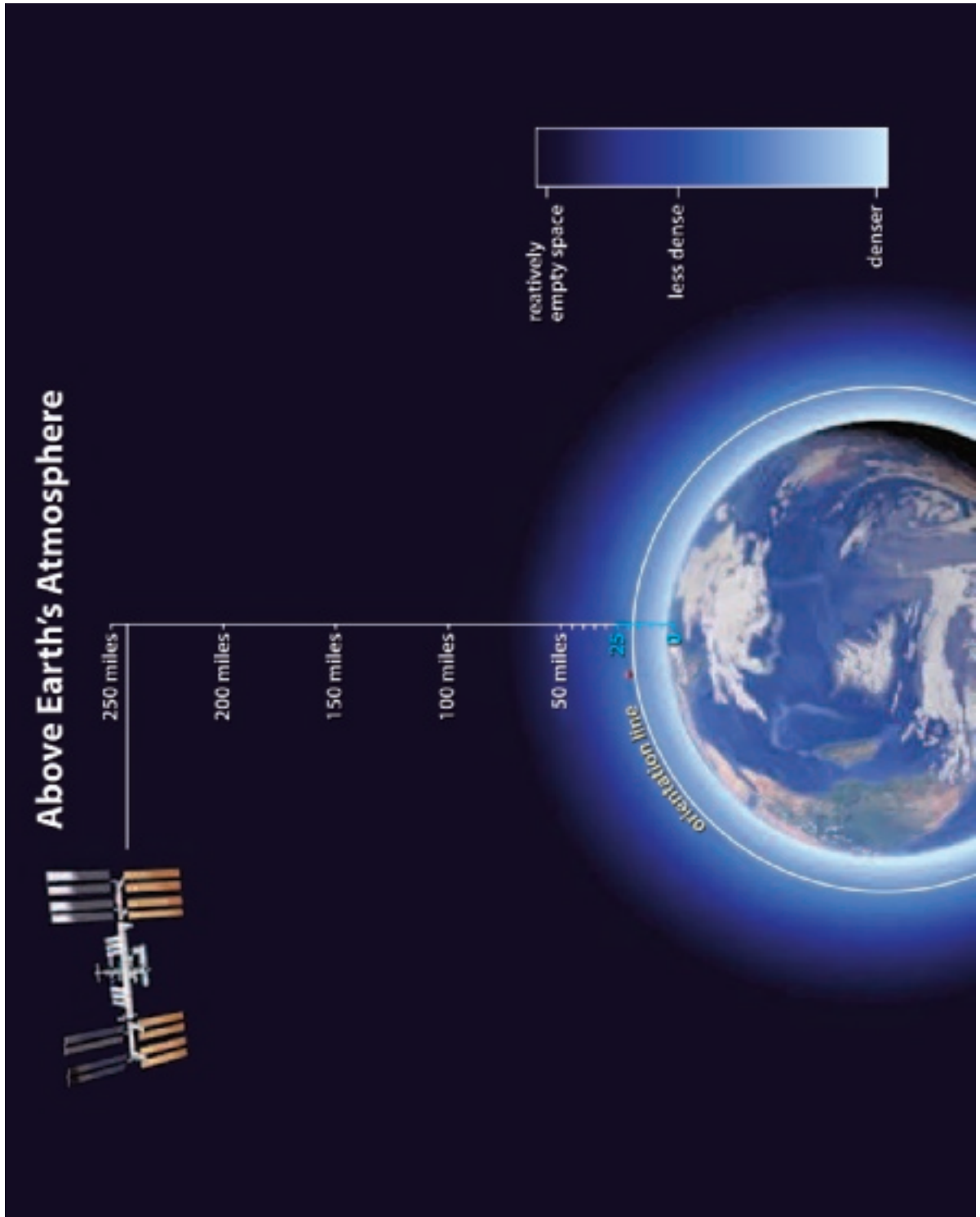


Substance	Gas by volume
Nitrogen	Around 78%
Oxygen	Around 21%
Argon	About 1%
Carbon dioxide	Less than 1%
Water	From 0% to around 6%
Other substances	Less than 1%

In Earth's Atmosphere



Above Earth's Atmosphere



Sunset from the ISS



NASA



NASA



NASA



NASA



NASA



NASA

Instructions for the Light and Milky Water Lab

Follow the steps below to investigate how light shines through a simulated atmosphere. Your group will need the following materials:

- clear rectangular container
- water to fill the container $\frac{3}{4}$ full
- small cup of milk powder
- flashlight
- $\frac{1}{4}$ teaspoon measuring spoon
- small block or thin book to center flashlight on the water
- white paper to place under the container (if needed)
- science notebook with *Investigation Elements Map, Predictions, and Results*
- safety goggles

1. Fill your bin to about 50% full of water and set it on a flat surface with space around all sides.

- If the flat surface you are using is a dark color, slide a sheet or two of white paper under the bin to help you see any color changes more clearly.



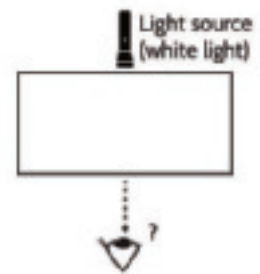
2. Shine a flashlight lengthwise (the long way) through the container and water. Set the flashlight on a small block or thin book to raise it so it shines into the center of the container.

- Observe the light from eye level from the opposite side of the container.
- Observe the container from above.
- Record your observations on your handout in the rows for scenario 1A.



3. Shine a flashlight across (the short way) through the container and water.

- Observe the light from eye level from the opposite side of the container.
- Observe the container from above.
- Record your observations on your handout in the rows for scenario 1B.



4. Add $\frac{1}{4}$ teaspoon of milk powder to the water and stir to dissolve.



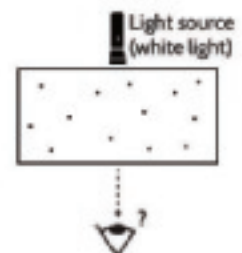
5. Shine a flashlight lengthwise (the long way) through the container and milky water.

- a. Observe the light from eye level from the opposite side of the container.
- b. Observe the container from above.
- c. Record your observations on your handout in the rows for scenario 2A.



6. Shine a flashlight across (the short way) through the container and milky water.

- a. Observe the light from eye level from the opposite side of the container.
- b. Observe the container from above.
- c. Record your observations on your handout in the rows for scenario 2B.



7. Complete the predictions column for the third scenario on your handout (adding an additional 4 tsp milk powder).
8. Add another $\frac{1}{4}$ teaspoon of milk powder to the water and stir to dissolve.
 - Repeat steps 5 and 6 now that you have added more milk powder.
 - Record your observations on your handout in the rows for scenarios 3A and 3B.

4. Add $\frac{1}{4}$ teaspoon of milk powder to the water and stir to dissolve.



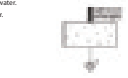
5. Shine a flashlight lengthwise (the long way) through the container and milky water.

- a. Observe the light from eye level from the opposite side of the container.
- b. Observe the container from above.
- c. Record your observations on your handout in the rows for scenario 2A.



6. Shine a flashlight across (the short way) through the container and milky water.

- a. Observe the light from eye level from the opposite side of the container.
- b. Observe the container from above.
- c. Record your observations on your handout in the rows for scenario 2B.



7. Complete the predictions column for the third scenario on your handout (adding an additional $\frac{1}{4}$ tsp milk powder).

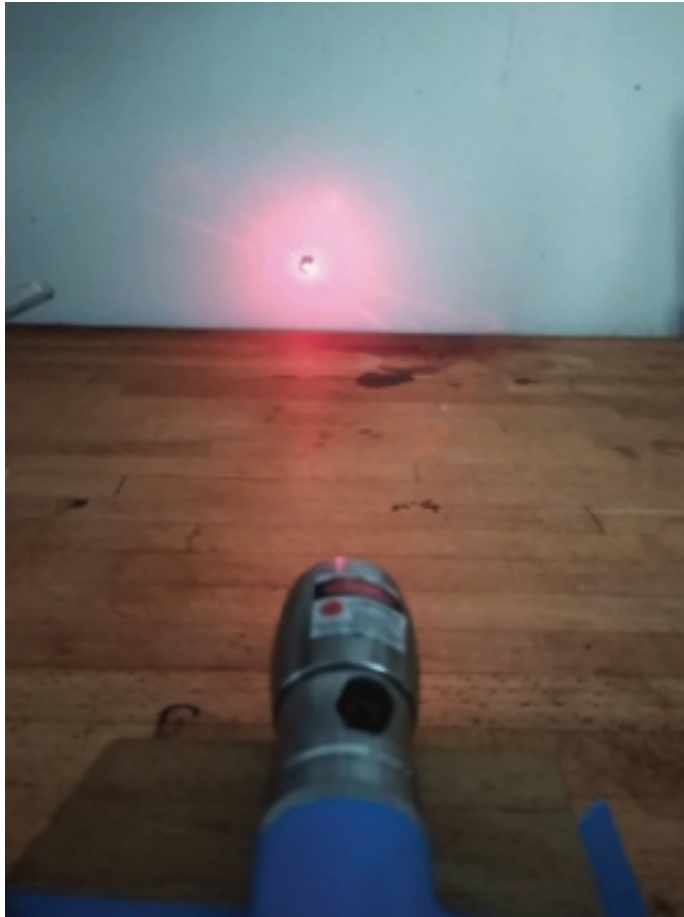


8. Add another $\frac{1}{4}$ teaspoon of milk powder to the water and stir to dissolve.

- Repeat steps 5 and 6 now that you have added more milk powder.
- Record your observations on your handout in the rows for scenarios 3A and 3B.

Example Images Path of Light

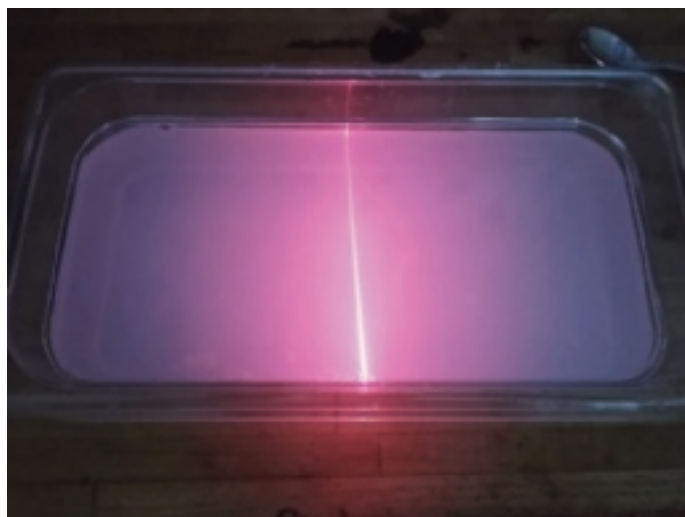
Direct path of laser light with no obstacle.



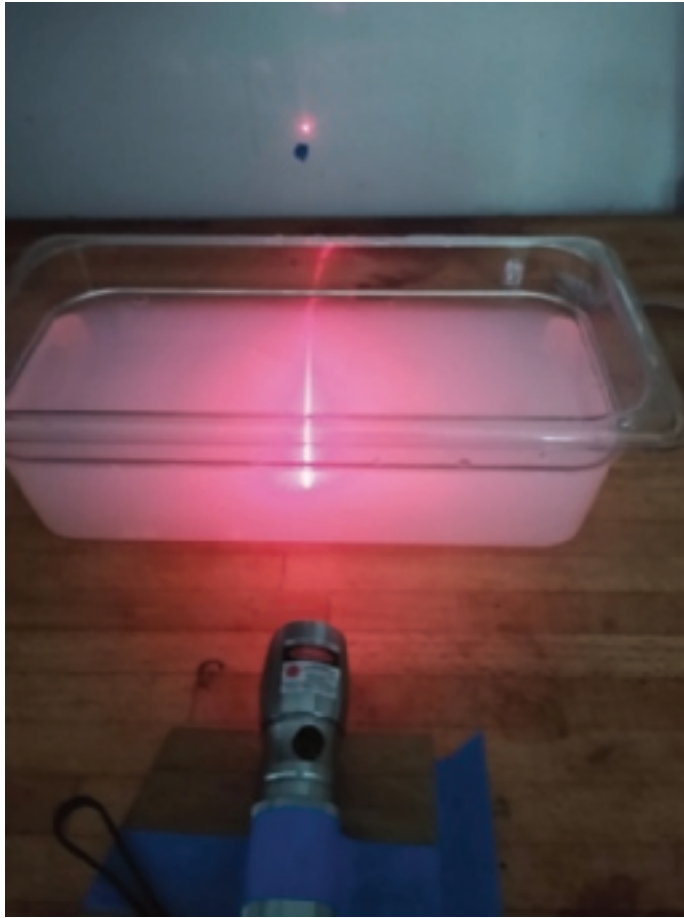
Path of laser light through clear water; laser dot moved off of original spot.



Path of laser light through milky water; shows straight line path.



Path of light through milky water including new position from original spot Short.



Path of light through milky water including new position from original spot Long.



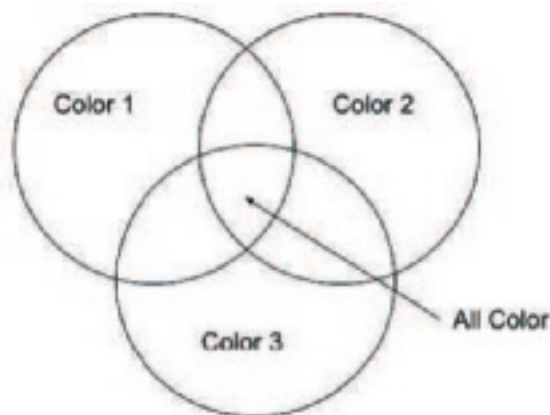
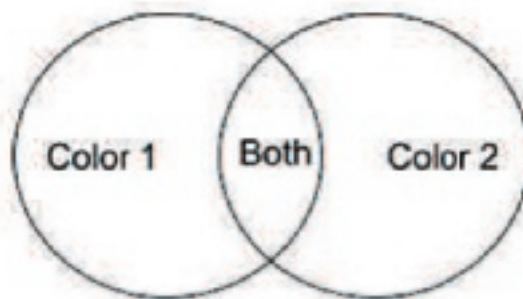
Combining Light Investigation

Part 1: Control Data (with your class)

1. Measure 1 meter from a wall and mark the spot with a piece of tape.
2. Tape one or more pieces of white paper to the wall (unless the wall is already white) to use as a target for the light.
3. Mark the center of the paper with an X. Label the X "Light Sensor".
4. Hold the light sensor on the X and turn it on.
5. Standing on the 1m tape mark, point the flashlight at the light sensor and turn it on. Set the beam to the widest setting. Allow a few minutes to get a steady reading. Record this value (lux) in your lab handout *Rainbow Lab Instructions and Data Collection*.
6. Repeat step 5 for the remaining colors until you have a value for each individual color.

Part 2: Combining Colors (with your partner)

1. Gather 2 flashlights or team up with another lab group for this part.
2. Using the 1m mark you created in part 1, turn on both flashlights with a wide beam and overlap the colors about halfway on the white piece of paper as shown below.
 - Red and Green
 - Red and Blue
 - Green and Blue
3. After observing and recording the colors, place the light meter into the circles where both colors are. Record lux data for the combined colors.
4. Repeat steps 2 and 3 for all color combinations.
5. Gather one more flashlight or combine with a third lab group.
6. Shine all three colors (red, green, and blue) onto the white paper from the 1m mark. Observe and record the colors.
7. Place the light meter into the center of all three. Record the lux data for the combination of the three colors.



Peer Feedback Guidelines

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at: <https://ambitiousscienceteaching.org/sticky-note-student-feedback/>.

Feedback needs to be specific and actionable.

That means it needs to be related to science ideas and provide your own suggestions for improvement. Nonproductive examples of feedback that do not help other students improve are as follows:

- "I like your drawing."
- "Your poster is really pretty."
- "I agree with everything you said."

How to Give Feedback

Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- The poster said _____. We disagree because _____. We think you should change _____.
- I like how you _____. It would be more complete if you added _____.
- We agree that _____. We think you should add more evidence from the _____ investigation.
- We agree/disagree with your claim that _____. However, we do not think the _____ (evidence) you used matches your claim.

Receiving Feedback from Peers

The purpose of feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence you have collected. It can also help you communicate your ideas more effectively to others.

When you receive feedback, you should take these steps:

- Read it carefully. Ask someone else to help you understand it if necessary.
- Decide if you agree or disagree with the feedback and say why you agree or disagree.
- Revise your work to address the feedback.

Looking for Patterns in the Solar System Infographics

Inner Planets

Mercury, Venus, Earth, and Mars are known as the “rocky planets.”



The four rocky planets are smaller than the other planets in the Solar System, and all have hard surfaces that you can walk on. They are the four closest planets to the Sun.

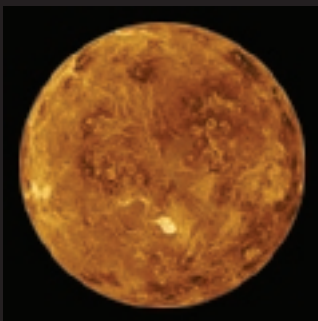
EARTH-LIKE NEIGHBORS

The rocky planets are also known as the terrestrial planets. Terrestrial is a word that means “like Earth.” Mercury, Venus, and Mars are very different from Earth in many ways, but at least they are small enough to have rocky surfaces, unlike the gas giants of the outer Solar System.

Mercury is 5%
of Earth’s mass



Venus is 82% of
Earth’s mass



Earth



Mars is 10% of
Earth’s mass





MERCURY

Mercury is the closest planet to the Sun. It has a strange, egg-shaped orbit that takes the planet as close as 29 million miles (47 million kilometers) and as far as 43 million miles (70 million kilometers) from the Sun.

Being so close to the Sun means that during the day temperatures can reach a searing 800 degrees Fahrenheit (430 degrees Celsius). But because Mercury has no atmosphere, it cools very quickly on the nighttime side of the planet. As a result, temperatures on Mercury at night can drop as low as -290 degrees Fahrenheit (-180 degrees Celsius).

Mercury is the smallest classical planet in the Solar System. It is only slightly larger than Earth's Moon!

Mercury spins slowly on its axis and completes one rotation every 59 Earth days. In fact, Mercury spins so slowly, a day on Mercury is longer than a year on Mercury. It speeds around the Sun every 88 days, traveling through space at nearly 29 miles (47 kilometers) per second, faster than any other planet. This is why Mercury is named for the fastest of the Roman gods.

Mercury's axis of rotation is only tilted 2 degrees from the plane of its orbit around the Sun. That means it spins nearly perfectly upright and does not have seasons.

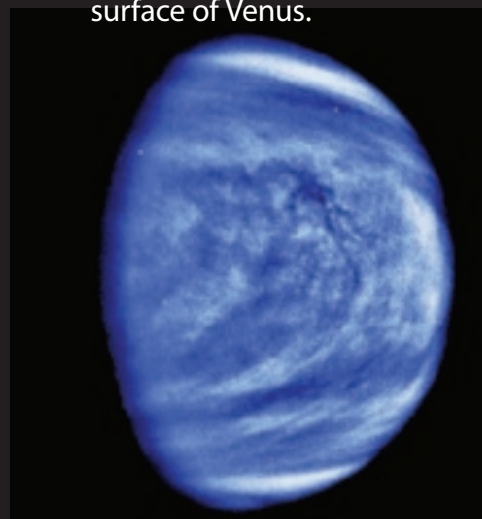
The fact that Mercury's day is longer than its year, combined with its egg-shaped orbit, means that sunrise and sunset appear very different on the surface than they do on most other planets. When Mercury is closest to the Sun, the morning Sun appears to rise briefly, set, and rise again from some parts of the planet's surface. The same thing happens in reverse at sunset for other parts of the surface. This means that one Mercury solar day (one full day-night cycle) equals 176 Earth days—just over two years on Mercury.

VENUS

Venus is the second planet from the Sun. It is sometimes called Earth's twin, because it is so similar in size to our planet. But the similarities end there. Earth and Venus are radically different worlds.

While Earth is just the right temperature for liquid water and life, Venus is the hottest planet in our Solar System. Even though Mercury is closer to the Sun, Venus has a thick, toxic atmosphere filled with carbon dioxide that traps heat, causing heat from the Sun to get confined against the surface of the planet. This is the same "greenhouse effect" mechanism at work right now on Earth. Surface temperatures on Venus are about 900 degrees Fahrenheit (475 degrees Celsius). That is hot enough to melt lead.

Thick clouds veil the surface of Venus.



Due to its thick atmosphere and high temperature, the air pressure at the surface of Venus is crushing – more than 90 times that of Earth. The clouds smell like rotten eggs because they are made of sulfuric acid. The surface of Venus is so inhospitable that landers sent from Earth have never survived there for more than a couple of hours.

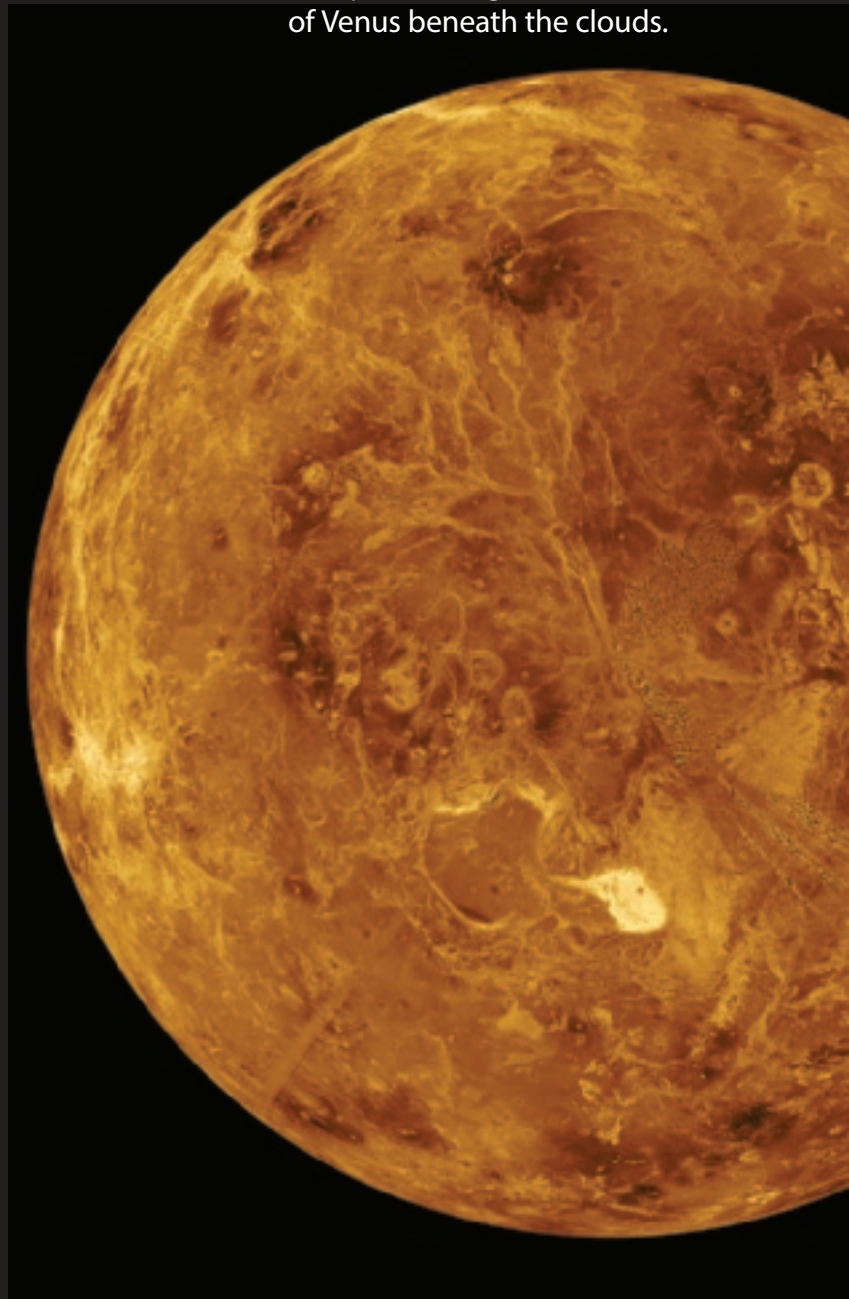
One day on Venus lasts 243 Earth days. One year on Venus takes only about 225 Earth days. So, like Mercury, a day on Venus is longer than a year on Venus. Venus' axis of rotation is only tilted 3 degrees from the plane of its orbit around the Sun. That means it spins nearly perfectly upright and does not have seasons.

Venus is the only planet in our solar system that spins backward on its axis. If you were looking down on the solar system from space, all the planets would be revolving and spinning counterclockwise except for Venus, which revolves counterclockwise but spins clockwise. This means that, on Venus, the Sun rises in the west and sets in the east, which is the opposite of what we experience on Earth.

COULD THERE BE LIFE?

The rocky planets are the only place where life is known to exist in our Solar System, on our planet: Earth. Mars is a focused target for looking for life because we suspect there may be water present. Mercury's extreme temperatures and battered surface make it unlikely that we would find life there. Venus is also an unlikely place for life as we know it, but some scientists theorize microbes might exist high in the clouds where it is cooler and the pressure is similar to Earth's surface.

Composite image of the surface of Venus beneath the clouds.



Our Moon

Most of the planets in our solar system have moons. Earth has one moon. It is the only object human beings have ever visited beyond Earth.



We call it “the Moon” because for a long time it was the only one we knew about. Many languages have beautiful words for Moon. It is “Luna” in Italian, Latin and Spanish, “Lune” in French, “Mond” in German, and “Selene” in Greek.

VISITING THE MOON

The Moon has a very thin atmosphere. Humans need spacesuits to breathe on the Moon.

Astronauts brought back 842 pounds (382 kilograms) of rocks and dirt from the Moon. We are still studying them!

The first humans landed on the Moon on July 20, 1969.

During the next three years, 12 American astronauts walked on the Moon.

We have not been back since.



WHAT IS THE MOON LIKE?

Our Moon is like a desert. It has plains, mountains, and valleys. It also has many craters, which are holes created when space rocks hit the surface. There is no air to breathe on the Moon.

The Moon travels around the Earth. Scientists think the Moon was formed long, long ago when Earth crashed into an object the size of Mars.

We always see the same side of the Moon from Earth. You have to go into space to see the other side.



The Moon is less than a third the width of Earth. If Earth were the size of a nickel, the Moon would be about as big as a coffee bean.

The Moon is farther away from Earth than most people realize. The Moon is an average of 238,855 miles (384,400 kilometers) away. This image shows the Earth and the Moon to scale.



WHY HAVE WE NOT BEEN BACK?

Sending humans to the Moon is expensive. In order to get there, astronauts must be safely launched at a speed fast enough that they will not fall back down to Earth. They must wear special protective gear and bring their own air, water, and food. And then, unlike a robotic mission, the astronauts must be safely brought back to Earth.

COULD THERE BE LIFE?

Unlike some of the other places we might look for life in the Solar System, humans have been to the Moon. But they found no evidence of life.

Maybe in the future, humans could live on the Moon. The Moon has a solid surface to walk on, and it has water ice that humans could melt. But some people question the morality of sending people to live on the Moon, especially when we should be putting our efforts into protecting the only planet we know that can actually sustain life: Earth. What do you think?

EARTHRISE

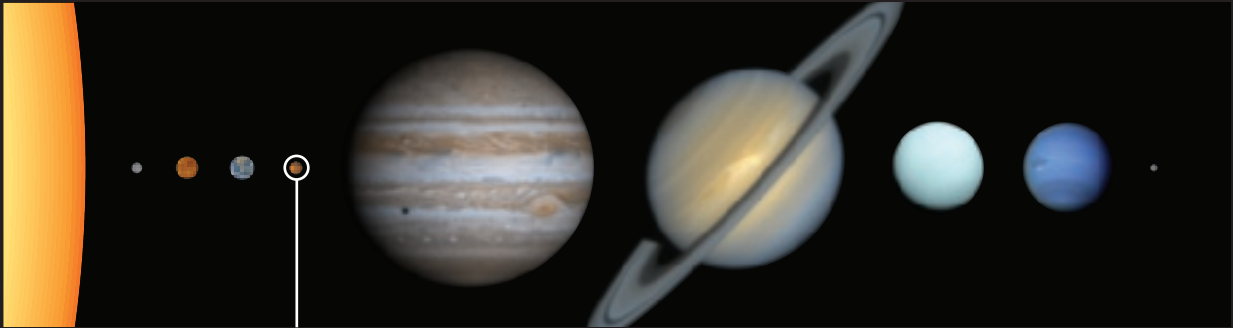
This famous photo was taken on December 24, 1968, from the Apollo 8 spacecraft. "Oh, my God! Look at that picture over there! Here's the Earth coming up. Wow, is that pretty!" said astronaut William Anders when he saw the Earth through the window.

This photo was the first full-color view of our planet from off of it. This photo has been credited with launching the environmental movement, because it helped human beings recognize how special and fragile our living world really is, floating alone in what appears to be a cold and lifeless Universe.

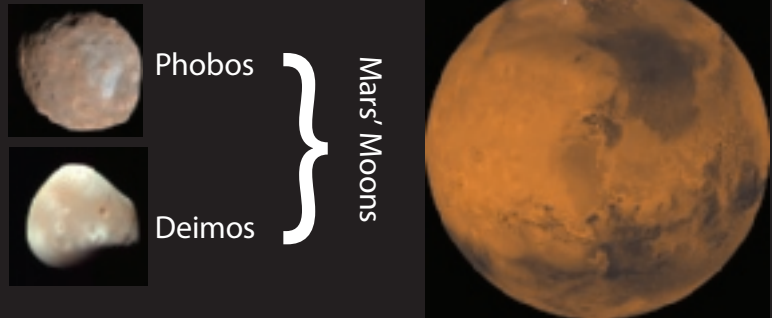


Mars

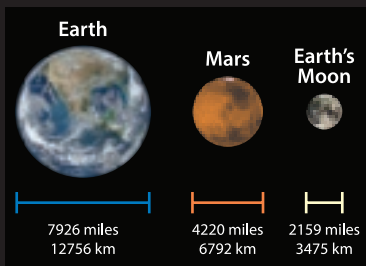
Mars goes around the Sun in 687 Earth days.



Mars is the fourth planet from the Sun. Mars orbits the Sun at an average distance of about 228 million km (142 million miles).



Like its fellow rocky planets, Mercury, Venus, and Earth, Mars has a central core, a rocky mantle and a solid crust.



With a radius of 2,106 miles (3,390 kilometers), Mars is about half the size of Earth. If Earth were the size of a nickel, Mars would be about as big as a raspberry.

Several missions have visited this planet, from flybys and orbiters to rovers on the surface. The first true Mars mission success was the Mariner 4 flyby in 1965.





A large canyon system called Valles Marineris is long enough to stretch from California to New York—more than 3,000 miles (4,800 kilometers). This Martian canyon is 200 miles (320 kilometers) at its widest and 4.3 miles (7 kilometers) at its deepest. That is about 10 times the size of Earth's Grand Canyon.

WHAT IS THE WEATHER LIKE?

Mars has a thin atmosphere made up mostly of carbon dioxide, nitrogen, and argon gases. To our eyes, the sky would be hazy and red because of suspended dust instead of the familiar blue tint we see on Earth. Mars' sparse atmosphere does not offer much protection from impacts by such objects as meteorites, asteroids, and comets.

The temperature on Mars can be as high as 70 degrees Fahrenheit (20 degrees Celsius) or as low as about -225 degrees Fahrenheit (-153 degrees Celsius).

Occasionally, winds on Mars are strong enough to create dust storms that cover much of the planet. After such storms, it can be months before all of the dust settles.



THE RED PLANET

The reason Mars looks reddish is due to oxidization—or rusting—of iron in the rocks, soil, and dust of Mars. This dust gets kicked up into the atmosphere and from a distance makes the planet appear mostly red.

Recorded observations of Mars date as far back as the era of ancient Egypt over 4,000 years ago, when they charted the planet's movements in the sky. Mars was named by the ancient Romans for their god of war because its reddish color was reminiscent of blood. Other civilizations also named the planet for this attribute; for example, the Egyptians called it "Her Desher," meaning "the red one."

SEASONS

SPIN

Just like Earth, Mars spins on its axis, creating patterns of dark and light called days. One day on Mars takes a little over 24 hours.



WATER ON MARS

Mars appears to have had a watery past, with ancient river valley networks, deltas, and lake beds, as well as rocks and minerals on the surface that could only have formed in liquid water. Some features suggest that Mars experienced huge floods about 3.5 billion years ago.

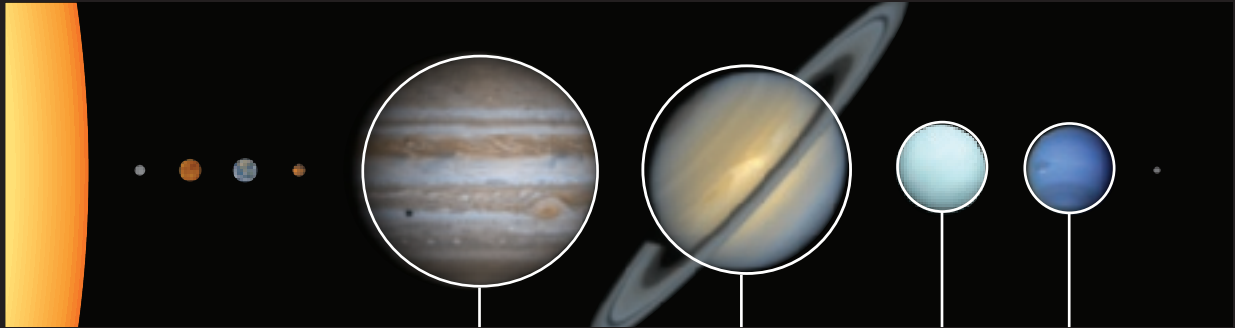
There is water on Mars today, but the Martian atmosphere is too thin for liquid water to exist for long on the surface. Today, water on Mars is found in the form of water-ice just under the surface in the polar regions as well as in briny (salty) water, which seasonally flows down some hillsides and crater walls.

COULD THERE BE LIFE?

Scientists do not expect to find living things currently thriving on Mars. Instead, they are looking for signs of life that existed long ago, when Mars was warmer and covered with water.

Outer Planets

Jupiter, Saturn, Uranus, and Neptune are known as the “gas giants.”

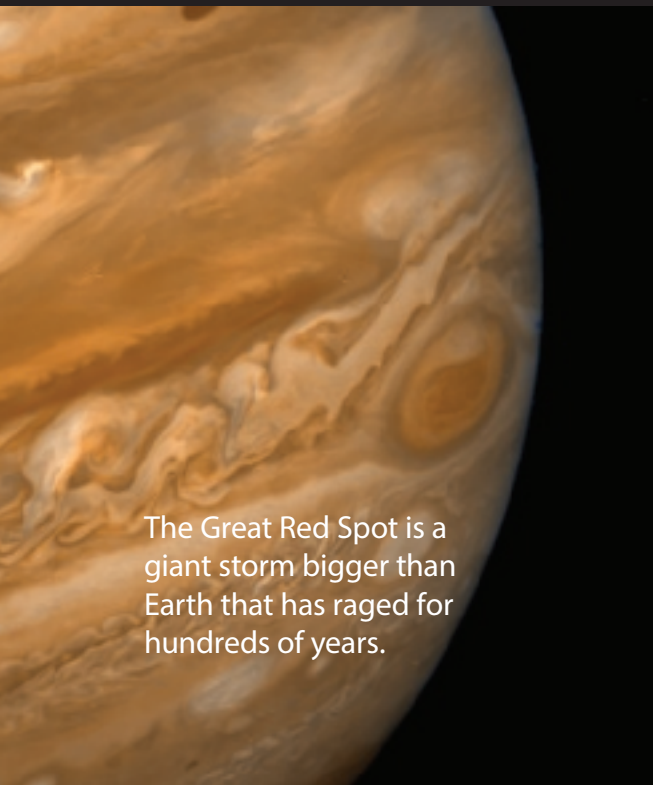


The four gas giants do not have hard surfaces that you can walk on. They are mostly swirling gases and liquids. The extreme pressures and temperatures deep inside the gas giants would crush and melt anything trying to fly into these planets.

HOW BIG ARE THE GIANTS?

Jupiter is the biggest planet in the Solar System. You could fit 1,321 Earths inside of Jupiter. Neptune is the smallest gas giant in our Solar System, but you could still fit 58 Earths inside.

Jupiter has more than twice as much mass as all the other planets combined! Its stripes and swirls are actually cold, windy clouds floating in hydrogen and helium gas.



The Great Red Spot is a giant storm bigger than Earth that has raged for hundreds of years.

JUPITER

Jupiter is surrounded by dozens of moons. Jupiter also has several rings, but unlike the famous rings of Saturn, Jupiter's rings are very faint and made of dust, not ice.

Jupiter has the shortest day in the Solar System. One day on Jupiter (the time it takes for Jupiter to rotate or spin around once) takes only about 10 hours. But Jupiter's year is not short. It takes 12 Earth years for Jupiter to revolve around the Sun one time.

Jupiter's equator is tilted by just 3 degrees. This means Jupiter does not have seasons as extreme as other planets, like Earth.

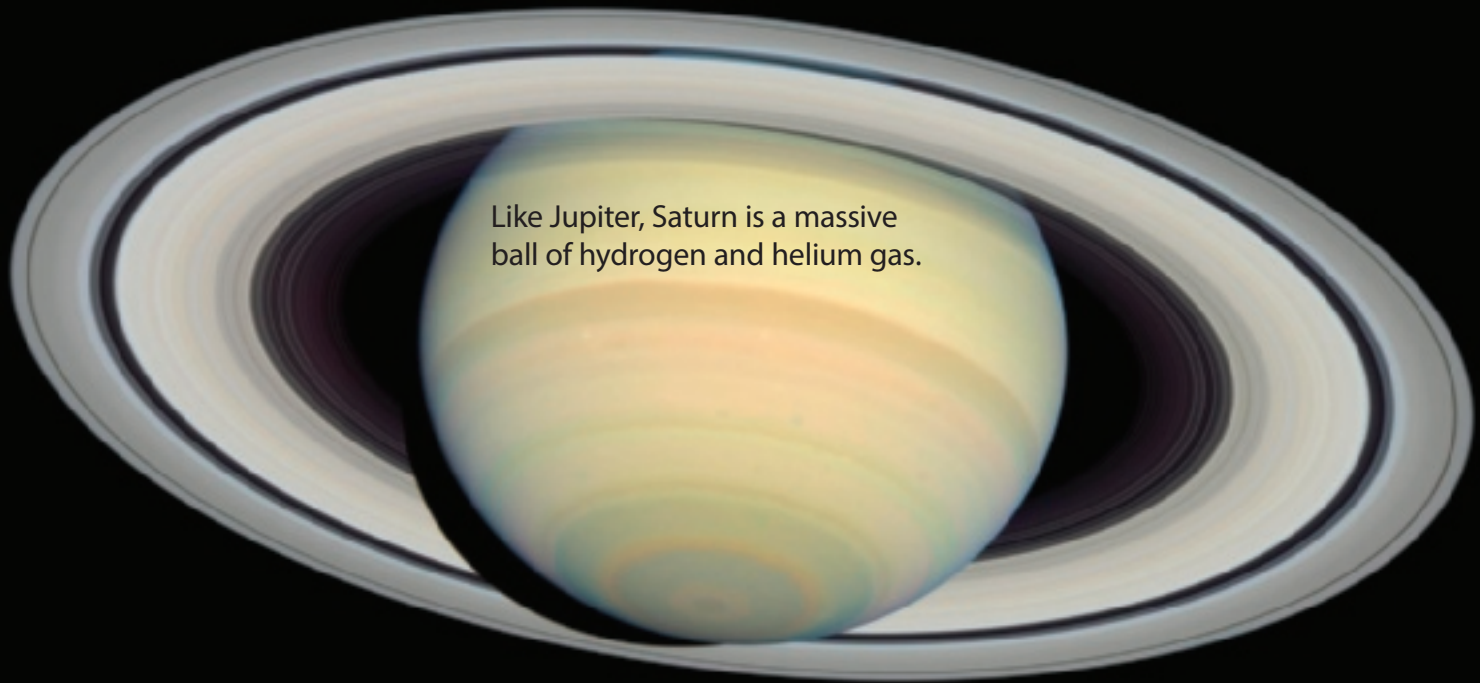
SATURN

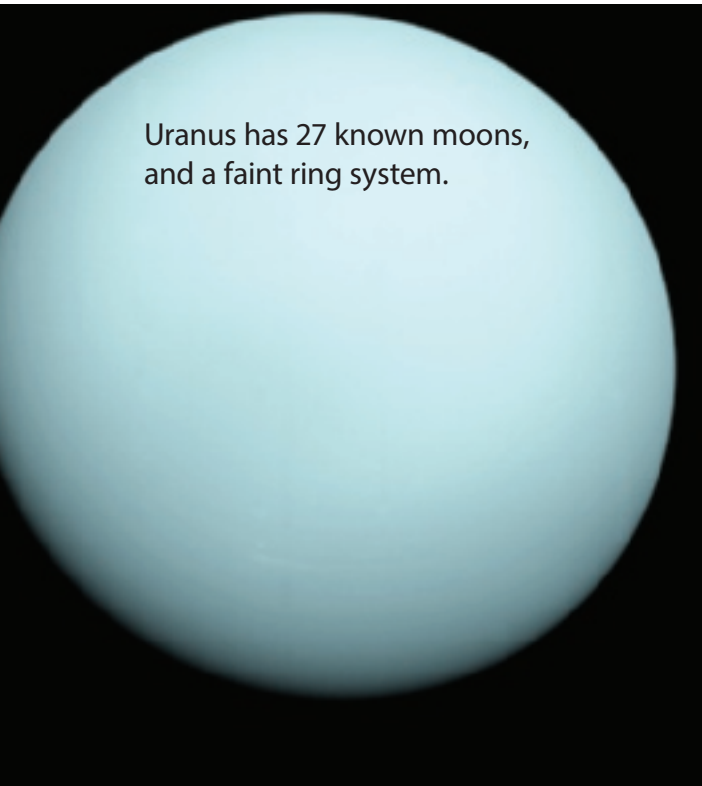
Saturn is the second-largest planet in our Solar System. It has a beautiful system of icy rings. It is not the only planet to have rings, but no other planet has rings that are as spectacular or as complex.

Saturn's rings are thought to be pieces of comets, asteroids, or shattered moons that broke up before they reached the planet. They were probably torn apart by Saturn's gravity. They are made of ice and rock. The smallest ring particles are about the size of a speck of dust, and the largest are as big as mountains.

Saturn's axis is tilted by 26.73 degrees, which is similar to Earth's 23.5-degree tilt. It takes 29 Earth years for Saturn to revolve around the Sun one time.

This means that, like Earth, Saturn experiences seasons.





Uranus has 27 known moons, and a faint ring system.

URANUS

While Mercury, Venus, Mars, Jupiter, and Saturn are easily visible in the sky with just your eyes, Uranus was the first planet found with the help of a telescope, in 1781.

Uranus is called the sideways planet, because it rotates on its side. This is probably due to a collision in the early history of the solar system that knocked it sideways.

Uranus' unique sideways rotation makes for weird seasons. The planet's north pole experiences 21 years of nighttime in winter, 21 years of daytime in summer, and 42 years of day and night in the spring and fall.

It takes 84 Earth years for Uranus to revolve around the Sun one time.



NEPTUNE

Dark, cold, and windy, ice giant Neptune is the eighth and most distant planet in our Solar System. Neptune takes about 165 Earth years to orbit the sun.

COULD THERE BE LIFE?

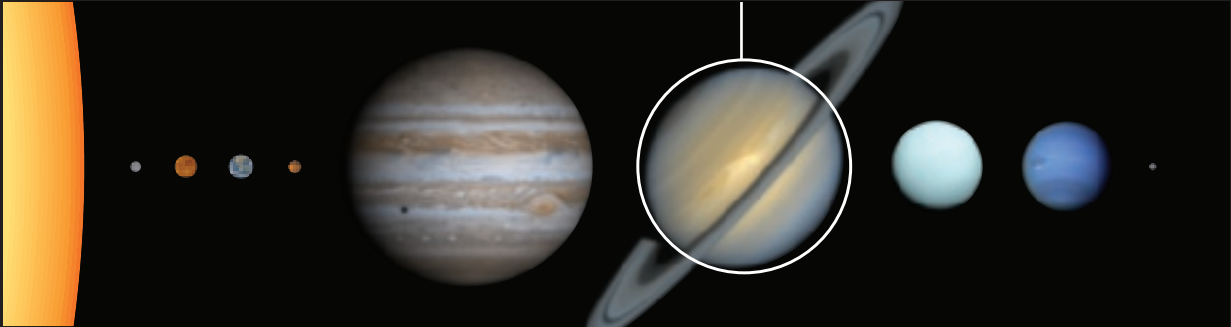
The environment on the gas giants is probably not conducive to life as we know it. The temperatures, pressures, and materials that characterize these planets are most likely too extreme and volatile for organisms to adapt to.



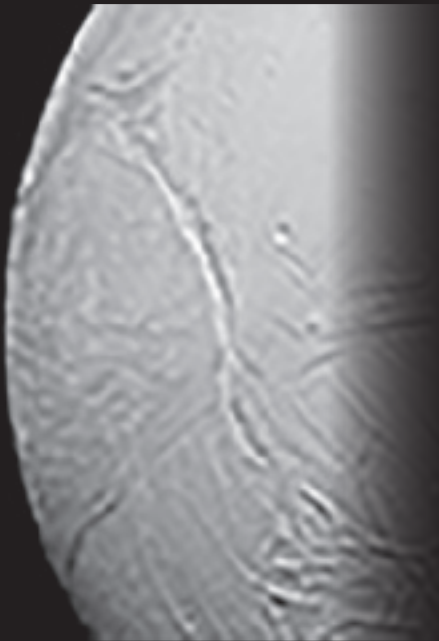
Neptune has 14 known moons and a faint ring system.

Saturn's Moons

Saturn has dozens of known moons. Some estimate that it has 150 moons. Many of these moons are very small. The largest moons are worlds in their own right, and good places to look for life.



Saturn's largest moons are called moons because they go around a planet. If these moons broke free and began to orbit the Sun instead of Saturn, we would call them planets.



ENCELADUS

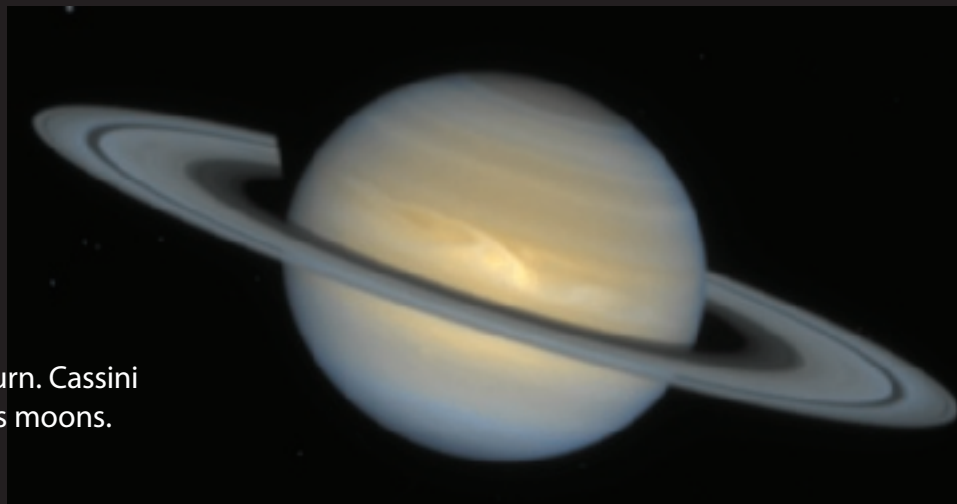
Enceladus is covered in water ice. Underneath the ice there is a giant ocean of liquid water.

Jets of water spray out from the underground ocean. Chemicals that form the building blocks of life on Earth have been detected in this water.

Because of this, Enceladus is one of the places in our solar system where scientists think life could exist.

CASSINI

The Cassini spacecraft visited Saturn. Cassini sent back photos of Saturn and its moons.



TITAN

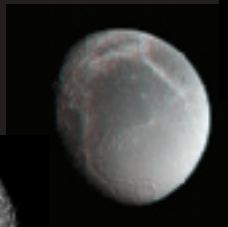
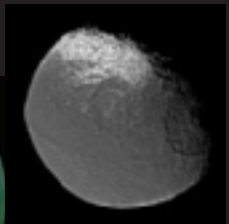
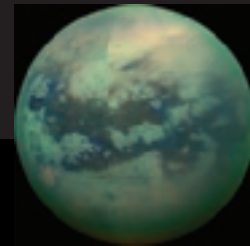
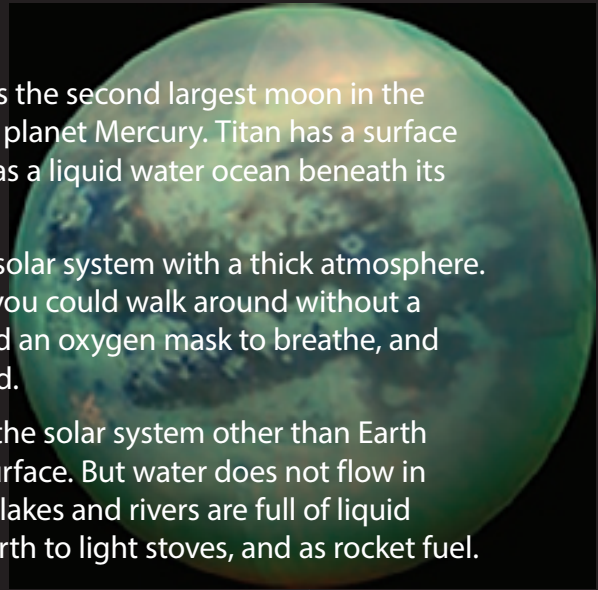
Saturn's largest moon, Titan, is the second largest moon in the Solar System. It is bigger than planet Mercury. Titan has a surface of water ice. Titan probably has a liquid water ocean beneath its surface.

Titan is the only moon in the solar system with a thick atmosphere. The air is dense enough that you could walk around without a spacesuit. But you would need an oxygen mask to breathe, and protection from the bitter cold.

Titan is also the only place in the solar system other than Earth known to have liquid on its surface. But water does not flow in Titan's lakes and rivers. These lakes and rivers are full of liquid methane, which is used on Earth to light stoves, and as rocket fuel.

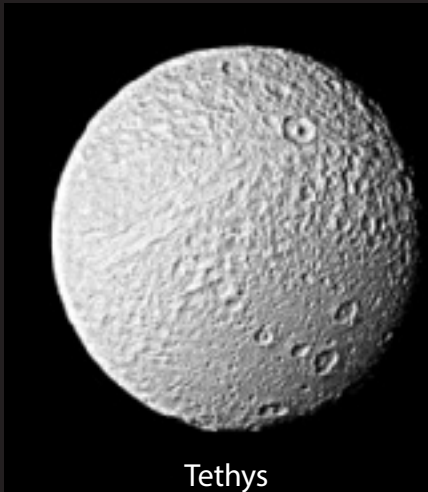
Titan's underground ocean might be a place where life could exist. Titan's surface lakes and seas of rocket fuel might also be places to look for life, but it probably wouldn't be anything like life on Earth!

Titan has no known moon, but it is possible for a moon to have moons.

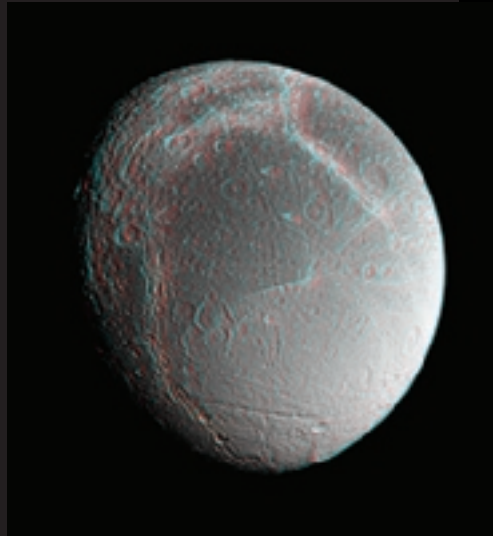


RHEA, DIONE and TETHYS

Rhea is the second-largest moon of Saturn. Rhea is a small, airless, cold moon that is very similar to its sister moons: Dione and Tethys. On the hottest days, these moons only get as warm as -281 degrees Fahrenheit (-174 degrees Celsius)! Because these moons are so bright, scientists think that they are made of water ice, which behaves like rock when it is that cold.



Tethys



Dione



Rhea



In this image (taken by Cassini) Rhea is just partly hidden behind Saturn's rings.

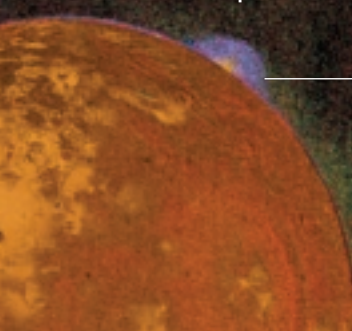
Jupiter's Moons

Jupiter has dozens of moons. The most famous are the four "Galilean Moons": Io, Europa, Ganymede, and Callisto.

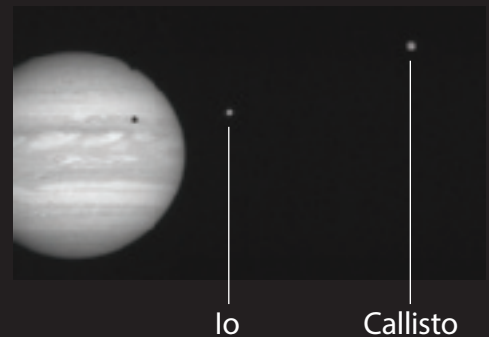


The Galilean Moons are called moons because they go around a planet. If these moons broke free and began to orbit the Sun, we would call them planets.

Galileo Galilei discovered these four moons in 1610. You can see them easily with a small telescope. This photo (at right) was taken with a simple backyard telescope attached to a digital camera!



Volcanic eruption



Io

Callisto

IO

Io is covered in volcanoes. Sulfur from the volcanoes makes the surface colourful. Io is very close to Jupiter, and Jupiter is the largest planet in the Solar System.

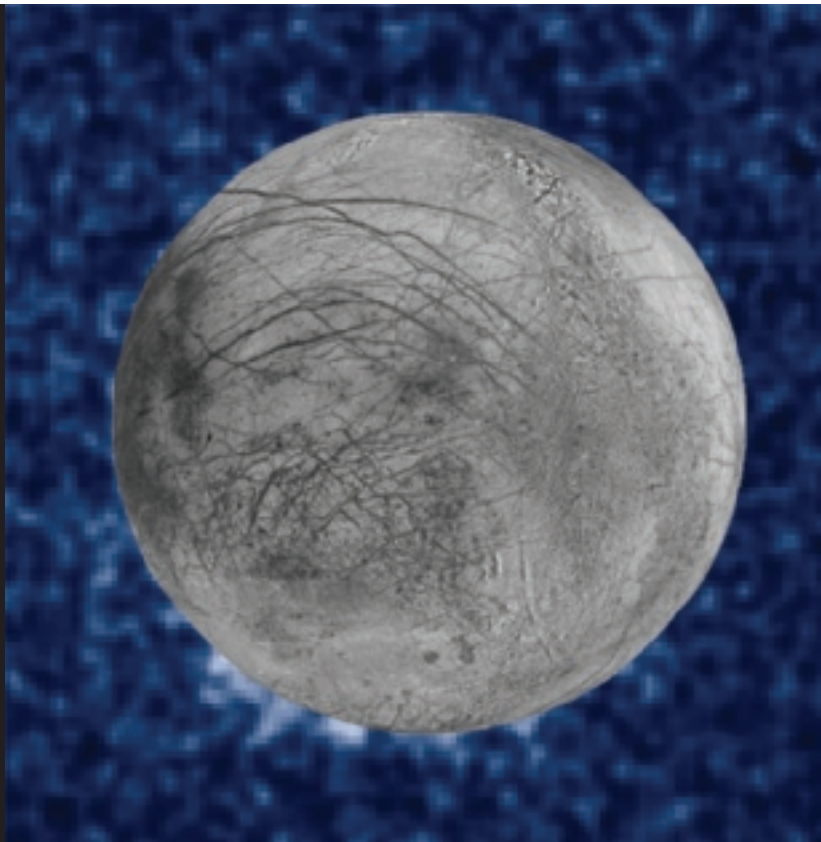
This photo of the moon Io was taken by the Cassini spacecraft, on its way to Saturn. Io appears to hover above the clouds of Jupiter.

The distance between Jupiter and Io is about the same as the distance between the Earth and the Moon.

EUROPA

Europa's surface is mostly water ice. But underneath there may be an ocean of liquid water! The evidence suggests that Europa has twice as much water as Earth.

Europa has an oxygen atmosphere that is too thin for humans to breathe. But even so, Europa is one of the best places in the solar system to seek life. This is because it has liquid water, energy, and the right chemical elements.



On Earth, we find life wherever we find water. We have found animals in freezing water under ice, and in boiling hot water near deep sea vents. We have even found life like this tardigrade in boiling, acidic lakes on the peaks of the highest mountain ranges on Earth!

If something can live in these extreme conditions on Earth, could there be life swimming in the oceans of Europa?



GANYMEDE

Ganymede is the largest moon in the Solar System. It is more than twice as big as our Moon. It is even larger than the planet Mercury! It is also the only moon known to have its own magnetic field. A magnetic field is good for life as we know it, because it protects life forms from dangerous radiation from the Sun.

CALLISTO

Callisto's surface has a lot of craters. This shows us that in the early Solar System, Callisto was hit with a lot of rocks flying through space. The Earth probably also had a lot of collisions in the early Solar System. But wind, flowing water, and the dramatic impact of life over time has washed away the evidence of these impacts on our planet.



Dwarf Planets

Dwarf planets, so-called because they are smaller than the planets shown below, are mostly found beyond the orbit of Neptune, in a place called the Kuiper Belt.



A dwarf planet orbits the Sun, unlike a Moon. A dwarf planet must also be round, unlike the oddly shaped rocky asteroids. But in order to be considered a “classical planet,” like Earth or Jupiter, an object must be large enough to have cleared the area that it orbits in. These objects either fall into the planet or are flung into space. Dwarf planets like Pluto have not done this.

There may be hundreds of dwarf planets in our Solar System. Right now, we only know about a handful of these because they are small and far away, which makes them difficult to spot.

PLUTO

Pluto is perhaps the most well-known dwarf planet, and one of the largest. It is 1,473 miles in diameter and was discovered in 1930. Pluto is very far from the Sun, 3.6 billion miles (5.8 billion km) away on average (about 40 times as far as Earth), in a region called the Kuiper Belt. Because it is so far, Pluto takes 248 Earth years to go around the Sun once, and is very, very cold. Pluto has several moons, including one called Charon that is almost half the size of Pluto. The little moon is so big that Pluto and Charon are sometimes referred to as a double dwarf planet.



CHARON



PLUTO



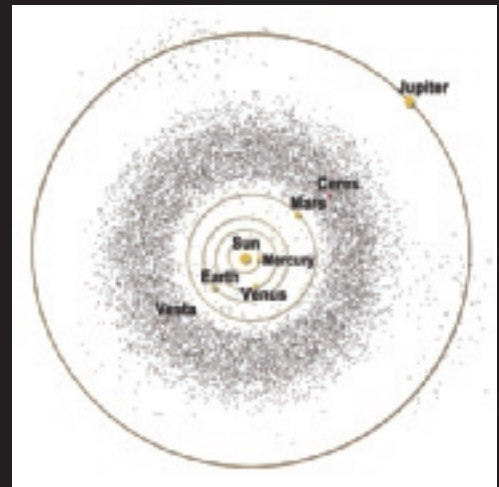
Some people were very upset when astronomers decided that Pluto was a dwarf planet in 2006. Some people marched with signs to show how they felt. But just like every classical planet is unique, each dwarf planet is also unique. Astronomers decided to call these planets dwarf planets because it is convenient for organizing the great diversity of objects in our Solar System, not because they are fundamentally different, or less important.

CERES

Ceres' radius is just 296 miles (476 km). If Earth were the size of a nickel, Ceres would be about as big as a poppy seed. Scientists would like to search for possible signs of life on Ceres. It has something many other planets do not: water.

The asteroid belt is a region in between Mars and Jupiter where we find millions of small, rocky objects that we call asteroids.

Ceres is special because it is the only object in the Asteroid Belt that is classified as a dwarf planet, instead of an asteroid. This is because it is round.



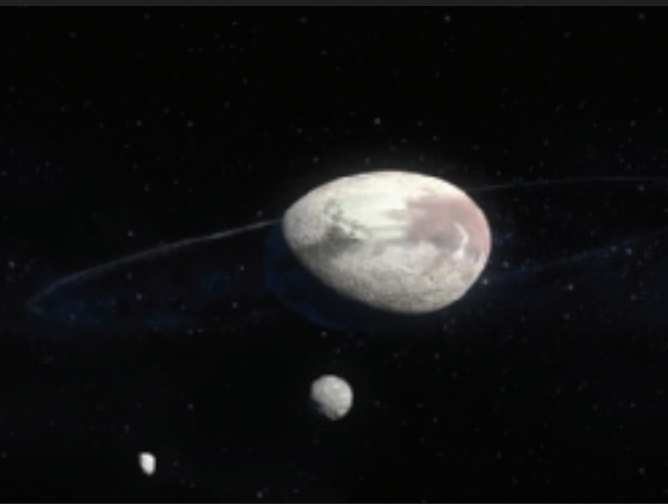
MAKEMAKE

Along with fellow dwarf planets Pluto, Eris, and Haumea, Makemake is in the Kuiper Belt, a region outside the orbit of Neptune. Slightly smaller than Pluto, Makemake is the second-brightest object in the Kuiper Belt as seen from Earth (Pluto is the brightest). It takes about 305 Earth years for this dwarf planet to make one trip around the sun.

Makemake holds an important place in the history of solar system studies because it—along with Eris—was one of the objects whose discovery prompted the International Astronomical Union to reconsider the definition of a planet and to create the new group of dwarf planets.

Makemake is named after the Polynesian Rapanui god of fertility.





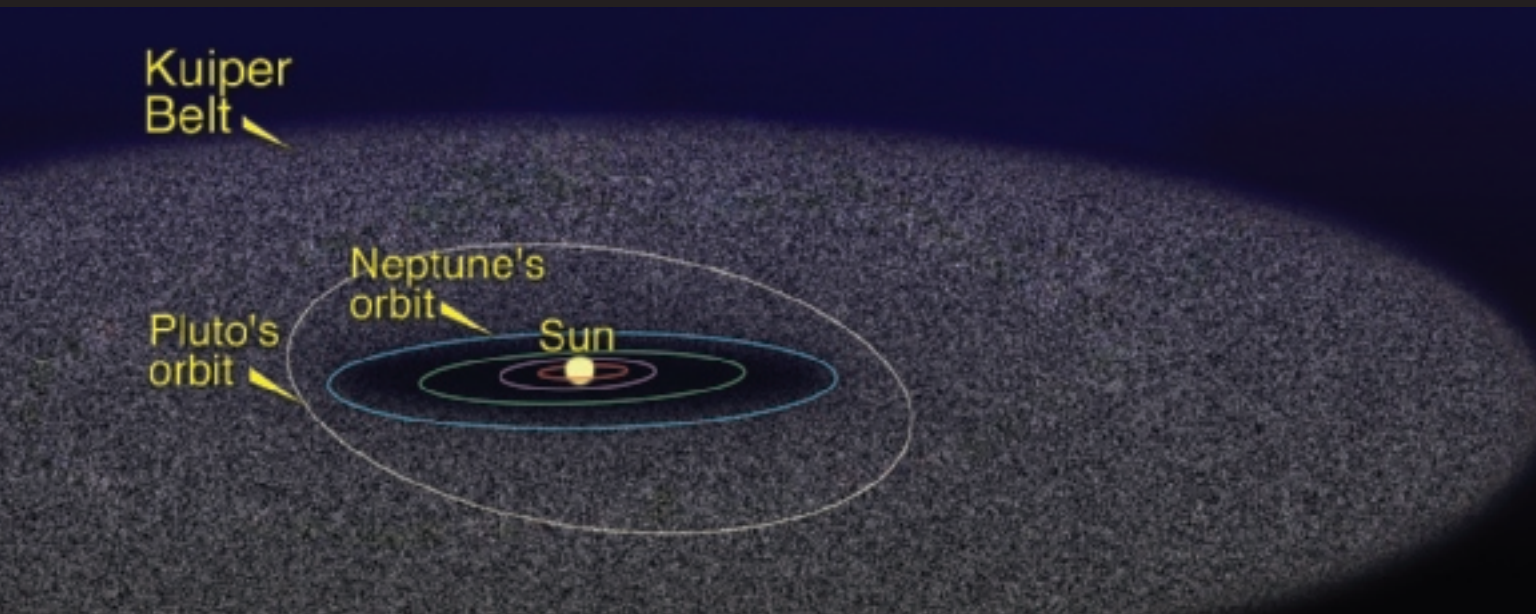
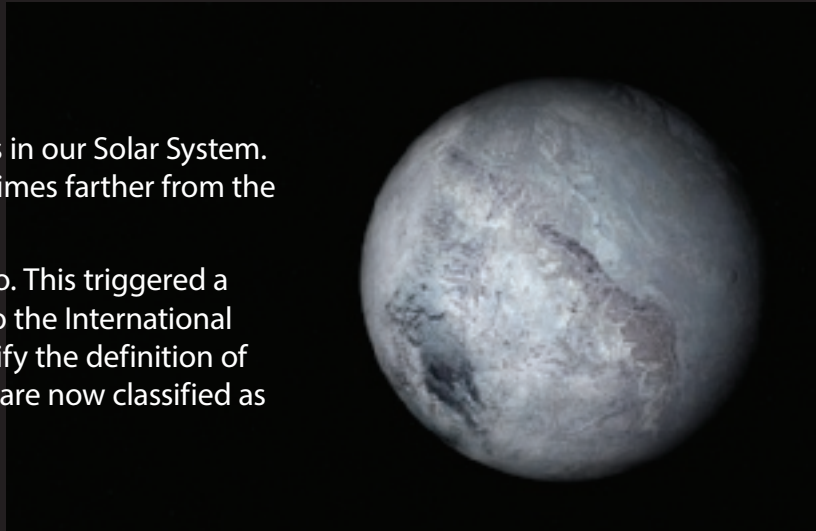
HAUMEA

Haumea is in the Kuiper belt and is about the same size as Pluto. Haumea is one of the fastest rotating large objects in our Solar System. Its fast spin distorts Haumea's shape, making this dwarf planet look like a football. Haumea was named after the Hawaiian goddess of fertility. Haumea has two known moons: Namaka and Hi'iaka. Hi'iaka is the patron goddess of the island of Hawai'i and of hula dancers. Namaka is a water spirit in Hawaiian mythology.

ERIS

Eris is one of the largest known dwarf planets in our Solar System. It's about the same size as Pluto but is three times farther from the Sun.

At first, Eris looked like it was larger than Pluto. This triggered a debate in the scientific community that led to the International Astronomical Union's decision in 2006 to clarify the definition of a planet. Pluto, Eris, and other similar objects are now classified as dwarf planets.



Hubble eXtreme Deep Field



NASA, ESA, G. Illingworth, D. Magee, and P. Oesch (University of California, Santa Cruz), R. Bouwens (Leiden University), and the HUDF09 Team

Reading: Defining Seasons

Meteorological versus astronomical seasons

You may have noticed that meteorologists and climatologists define seasons differently from “regular” or astronomical spring, summer, fall, and winter. So, why do meteorological and astronomical seasons begin and end on different dates? In short, it is because the astronomical seasons are based on the position of Earth in relation to the Sun, whereas the meteorological seasons are based on the annual temperature cycle.

The astronomical seasons

People have used observable periodic natural phenomena to mark time for thousands of years. The natural rotation of Earth around the Sun forms the basis for the astronomical calendar, in which we define seasons with two solstices and two equinoxes. Earth’s tilt and the Sun’s alignment over the equator determine both the solstices and equinoxes.

The equinoxes mark the times when the Sun passes directly above the equator. In the Northern Hemisphere, the summer solstice falls on or around June 21, the winter solstice on or around December 22, the vernal or spring equinox on or around March 21, and the autumnal equinox on or around September 22. These seasons are reversed but begin on the same dates in the Southern Hemisphere.

Because Earth actually travels around the Sun in 365.24 days, an extra day is needed every fourth year, creating what we know as a leap year. This also causes the exact date of the solstices and equinoxes to vary. Additionally, the elliptical shape of Earth’s orbit around the Sun causes the lengths of the astronomical seasons to vary between 89 and 93 days. These variations in season length and season start would make it very difficult to consistently compare climatological statistics for a particular season from one year to the next. Thus, the meteorological seasons were born.

The meteorological seasons

Meteorologists and climatologists break the seasons down into groupings of three months based on the annual temperature cycle and our calendar. We generally think of winter as the coldest time of the year and summer as the warmest time of the year, with spring and fall being the transition seasons, and that is what the meteorological seasons are based on. Meteorological spring in the Northern Hemisphere includes March, April, and May; meteorological summer includes June, July, and August; meteorological fall includes September, October, and November; and meteorological winter includes December, January, and February.

Meteorological observing and forecasting led to the creation of these seasons, and they are more closely tied to our monthly civil calendar than the astronomical seasons are. The length of the meteorological seasons is also more consistent, ranging from 90 days for winter of a non-leap year to 92 days for spring and summer. By following the civil calendar and having

less variation in season length and season start, it becomes much easier to calculate seasonal statistics from the monthly statistics, both of which are very useful for agriculture, commerce, and a variety of other purposes.

Reprinted from:

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Reading: The Equator, the Midnight Sun, and the Analemma

Day and Night at the Equator

In the Southern Hemisphere, the days are longest in December, and summer begins. In the Northern Hemisphere, the days are longest in June, and this is when summer begins. But what about in between? When is summer at the equator, exactly in the middle?

In most places near the equator, summer and winter do not really mean anything. No matter the time of year, you can expect temperatures to hover in the high 70s to low 90s degrees Fahrenheit. And whether it is June or December or any month in between, these areas receive about 12 hours of sunlight and 12 hours of darkness in a day.

The North Pole of Earth tilts toward the Sun in summer and away from the Sun in winter. This means that there will be a big difference in how much energy a place near the North Pole gets from the Sun as Earth moves in its orbit around the Sun. But the angle of sunlight at the equator never changes much. Sunlight is always direct, and the Sun is always high in the sky at midday for someone near the equator.



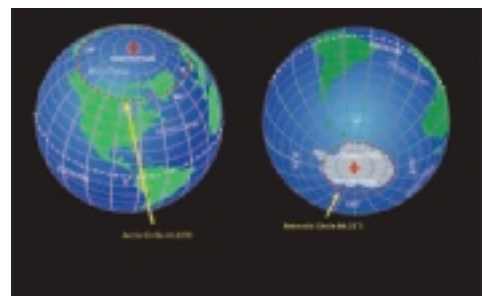
The Midnight Sun

If the days and nights are equal all year round near the equator, what do you think happens at the North and South Poles?

As you move further north from the equator, the nights become shorter and days become longer and longer until they stretch for over 24-hours, weeks, or even months! When the day is so long that we can see the Sun at midnight, we call it the midnight Sun.

From March 21 to September 23, the Sun is visible 24 hours a day at the North Pole. That is six months of daylight! As a person moves southward from the North Pole, the number of days of continuous sunshine decreases until they leave the Arctic Circle. Parts of Scandinavia, Russia, Alaska, Canada, and Greenland are within the Arctic Circle, so they experience the midnight Sun for part of the year.

The midnight Sun occurs in the Northern Hemisphere when the North Pole of Earth tilts toward the Sun in summer. The opposite is true of the South Pole. When



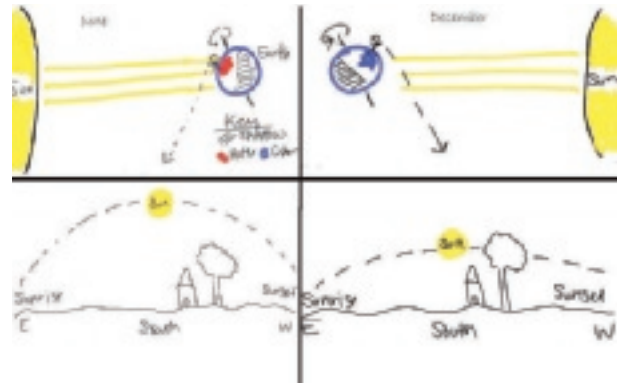
people close to the North Pole are experiencing the midnight Sun, people in Antarctica are experiencing up to six months of darkness, without seeing the Sun at all. Then the pattern switches, and the people close to the North Pole will see six months of darkness, while at the South Pole the midnight Sun is seen from September 23 to March 21. The tilting of Earth's axis, together with the curvature of Earth's surface and the orbit of Earth about the Sun, also causes the seasons.

The Analemma

The Sun's path through the sky changes over a year. What do you think would happen if you took a photo of the Sun every day at the exact same time of day? What would you see?

When photographers take a photo of the Sun at regular intervals—for example, every two weeks at the same time of day, for a year and combine the images—they get a shape called an *analemma*, which looks like a figure 8. You might expect that at certain times throughout the year the Sun's position would move higher and lower. This is because the North Pole of Earth tilts toward the Sun in our summer, and away from the Sun in our winter, affecting the apparent height of the Sun in the sky. But the analemma shows us that the apparent position of the Sun not only varies higher and lower as you would expect with the change of the seasons but also slightly east and west.

This motion is due to the fact that Earth travels around the Sun in an ellipse. If Earth were to orbit the Sun in a circle, Earth's speed around the Sun would be constant. However, because Earth's orbit is elliptical the speed of Earth varies throughout the year. The speed of Earth is fastest when it is closest to the Sun, in January, and slowest when it is farthest away from the Sun, in July. This change in speed means that the Sun will be slightly ahead of schedule in the sky sometimes (further to the west), and slightly behind schedule in the sky other times (further to the east). This pattern, combined with the changes in the apparent height of the Sun in the sky, explain the analemma shape we see when we photograph the Sun every day.



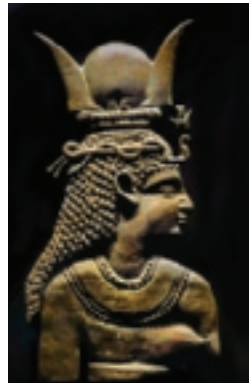
Reading: Venus in Cultures from Around the World

Many cultures have had strong connections to the planet Venus as well as sophisticated abilities to predict the appearance of Venus in the night sky. Some of the observations that these cultures have made of Venus were recorded thousands of years ago.

The ancient Maya in Mesoamerica, for example, recorded specific dates related to the movements of Venus over 800 years ago. Venus was associated with an important god, Quetzalcoatl, and they timed important events, such as military campaigns, around the appearance of Venus in the night sky.

In ancient India, Venus was associated with Shukra, meaning “brightness” or “clearness” and was an important figure in Vedic mythology. Shukra is one of the nine Navagrahas, heavenly bodies that influence life on Earth. As in Western cultures, Venus (Shukra) is associated with Friday in India.

While Venus, as we call it today, is named after the Roman goddess of love, many other cultures also associated the planet with a goddess of love, such as Aphrodite in the ancient Greek world, Isis in the ancient Egyptian world, and Friia in ancient Norse mythology. Friia is the origin of “Friday” in the English language, and “viernes” in Spanish is also connected to Venus.



Not only Venus but also the planets Mercury, Mars, Jupiter, and Saturn were known to all of these cultures. These five planets were well known because they did not follow the regular patterns that the stars take in moving across the night sky. Instead, the planets appeared to “wander” across the background of the rest of the stars, standing out because from one night to the next the position of the planets in comparison to the stars changed, whereas stars kept their same position in relation to one another, even as they appeared to spin about a fixed point in the sky (e.g., the North Star or the Southern Cross).

Almost all people from ancient times would have identified Venus as the third brightest object in the night sky, with only the Sun and the Moon shining brighter. However, they would have also noticed the way in which the brightness of Venus changed over time, sometimes becoming less bright from one day to the next, other times becoming more bright from one day to the next.

Stargazers from long ago, along with stargazers today, would see that Venus does not travel very high over the horizon, never exceeding more than 45 degrees of altitude (90 degrees being directly overhead) and more frequently seen much lower in the sky.



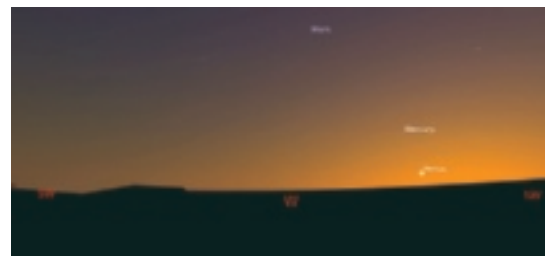
Image of night sky taken using Stellarium on March 10 2018 at 6:51 p.m. near Boston, MA. This is how the sky would have appeared to the unaided eye. Stellarium



NASA/Bill Dunford



Stellarium

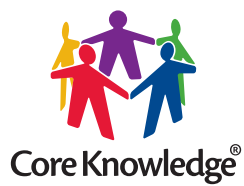


Stellarium

Because tracking Venus in the sky was important for religious or cultural reasons, the astronomers of several ancient cultures became very proficient at recording and then predicting the precise appearance of Venus in the night sky over time. Venus often appeared either in the eastern sky just before sunrise or in the western sky just after sunset. In fact, in many places there was debate about whether these two appearances of Venus were in fact the same object or two different objects.

When astronomers decided that these were two appearances of the same object, they discovered a pattern about where Venus appears and how long it appears for that we can still observe today:

1. Venus can be seen in the morning sky for about 263 days. It is visible in the eastern sky just before and as the Sun rises.
2. Next, Venus is not visible in the night sky for about 50 days.
3. Next, Venus can be seen in the evening sky for about 263 days. It is visible in the western sky just after and as the Sun is setting.
4. Next, Venus is not visible in the night sky for about 8 days.
5. Next, the previous four steps repeat, over and over again.



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