Journey to the Sun

Lessons & Activities

With the

National Solar Observatory

A Middle School curriculum guide to the Sun and the Stars.

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Contents

Journey To The Sun Teacher Guide Lesson 1

Grades: 6 - 8
Duration: 1-2 days
Standards: MS-ESS1-1

Exploring Astronomy

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Objectives

At the end of this lesson, students will be able to:

- Describe some ways in which early Polynesians used astronomy for voyaging.
- Explain why Hawai'i's geography has made it key for astronomy.
- Describe ways in which astronomy was practiced in early civilizations
- Explore the Sun's impact on society, both in history and present day.

Standards

MS-ESS1-1
Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

Key Vocabulary

Astronomy

Observations

Predictions

Materials

- ☐ Lesson packet: www.nso.edu/educators/jtts-curriculum
- ☐ Slideshow: "***Exploring Astronomy***"
- ☐ Video ***How Maui Slowed the Sun*** by Peter Gossage mp4
- ☐ Video ***Mauna Kea Observatories.***mp4
- ☐ Prizes for Quick Share (optional)

Background

This is the first of a series of lessons, developed by NSO for the Maui County School District, focusing on astronomy and the Sun. As such, it is meant primarily as an engagement piece to increase student excitement surrounding astronomy and solar observations.

Examples of astronomy in early Polynesia are included to highlight historical astronomy applications. Early Polynesians accomplished astonishing feats through their study of astronomy.

At the end of the short slideshow, students are presented with a research activity where they will explore the many ways in which astronomy was studied and used in early cultures. With this knowledge, they can then compare with modern astronomy to draw conclusions on how the discipline has changed over time, both in the tools used and the observations made.

Directions

Using the slideshow provided, review with students the information provided on each slide.

Slide #

2. This slide is an introduction to astronomy and early Polynesians as keen astronomers. In Queen Liliʻuokalani's 1897 translation of the Kumulipo, she wrote "The ancient Hawaiians were astronomers".

4. Polynesians used their knowledge of astronomy and other natural indicators to complete astonishing voyages without any modern scientific instruments or charts.

5. One important tool for navigation was the memorization of the night's constellations. Early Polynesians identified, named, and memorized the star formations that they observed.

6. An example of early voyagers observing the sun specifically, is provided on this slide. Navigators look at the shape of the ocean and the character of the sea at sunrise and sunset to note any significant changes in characteristics such as wind or swell patterns. Additionally, sunrise and sunset are used as directional indicators.

7. An example of using night stars for navigation, is the use of the Hānaiakamalama (Southern Cross) star formation. Hānaiakamalama gets lower the farther north you go. Navigators memorize the positions of star formations to determine how far they are along their journey.

8. "Quick Share" can be used as a quick check for understanding. It is also meant as a way to get students excited about the knowledge that they've just gained.

9. Explain that because Hawaiʻi is located in the middle of the Pacific Ocean, far away from cities and sandy deserts, it has some of the clearest skies for observing celestial objects.

10. Play the embedded time lapse video of Mauna Kea observatories by Jason Chu.

11. Because the world's most powerful solar telescope is located on Maui, solar scientists will look to Maui as the center of solar research. This places Maui students at the center of opportunity for leading solar astronomy.

12. Play the Solar time-lapse videos.

13. Introduce the activities included with this lesson. Students may choose which activity to complete, or opt to do both.

Review

- "How does astronomy compare between past and present?"
- "Do you think people relied more on solar information in the past or present?"

Activity - Exploring Historical Astronomy

Objectives

1. Explore astronomy in early civilizations.
2. Present your findings to the class.

Answer the following questions:

1. What are some examples of early civilizations studying astronomy?
2. What types of observations did they make?
3. Did they make predictions based on their observations? If so, what are some examples?
4. How has astronomy influenced society in the past?
5. How does astronomy compare between past and present? How have tools and technology used to study astronomy changed?
6. In your opinion, did people rely on solar information more in the past or present? Explain.

Suggestions for presentation

- Poster
- Slideshow
- Skit
- Speech

Activity - Recording Observations Through Storytelling

Objectives

Write a story, poem, or proverb to describe a natural phenomenon that you've observed.

Materials

- ☐ "***Recording Observations Through Storytelling***" slide show
- ☐ "***How Maui Slowed the Sun"*** Video

Teacher Guide

Use the slideshow presentation titled ***"Recording Observations Through Storytelling"*** included in the online Lesson 1 packet.

In the presentation, students are shown a series of slides, which give examples of passing on information in the form of: Oli (chant), ʻōlelo noʻeau (proverbs), and moʻolelo (stories). The examples all describe early observations of the Sun and its cycle.

In the activity instructions on the last slide, students are tasked with writing a story, poem, or proverb to describe a natural phenomenon that they've observed.

Ideas for Stories

1. How the Sun / Stars / Planets got into the sky.
2. Why the Sun behaves as it does (Why is it hot? Why is it bright?)
3. How the Sun guides navigators on their journeys.

Example of a cultural, historical story of the Sun

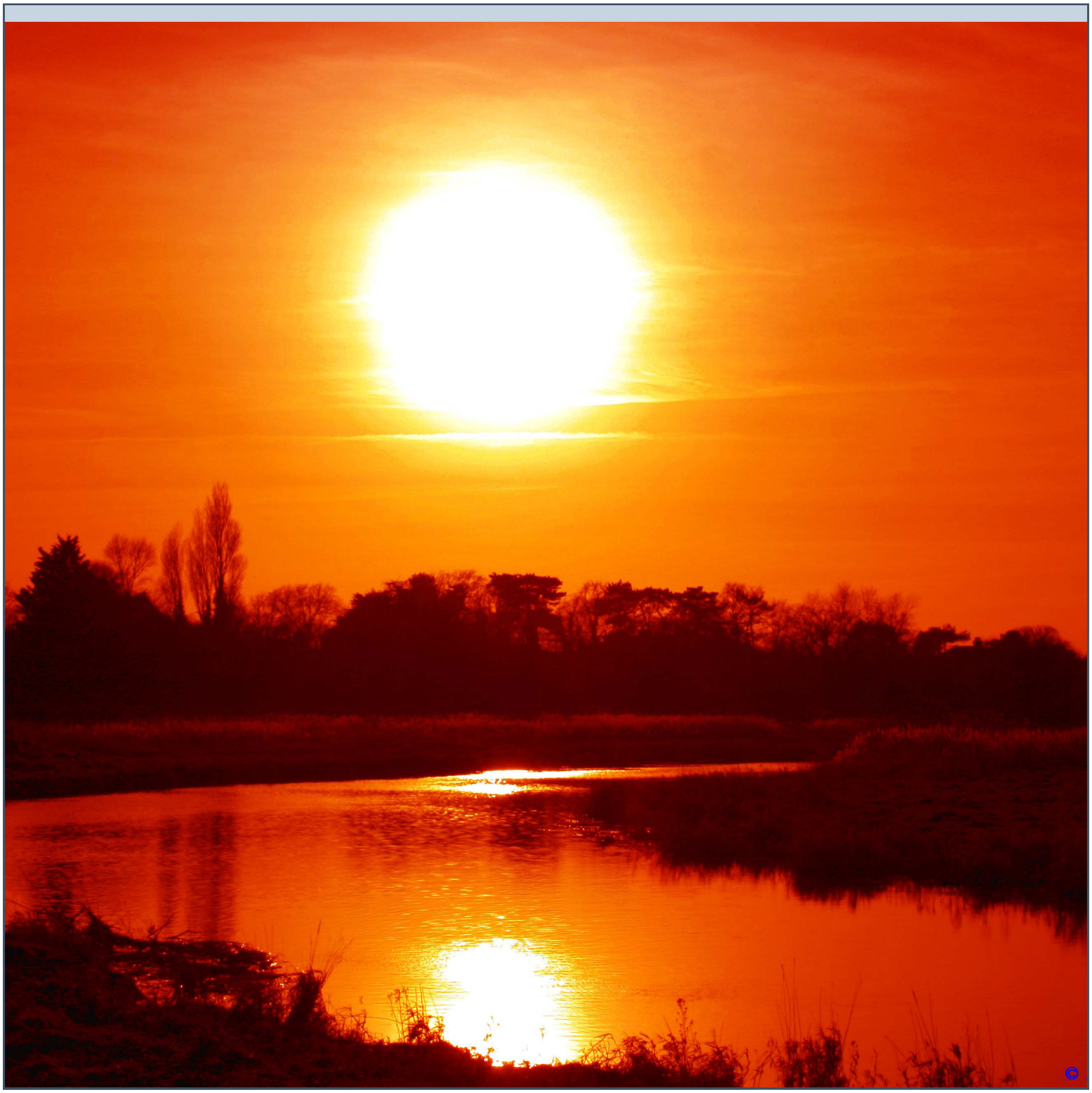
Video: "***How Maui Slowed the Sun"*** based on books written by New Zealand author Peter Gossage.

Journey To The Sun
Teacher Guide
Lesson 2

Grades: 6 - 8

Duration: 1 class period

Standards: MS-ESS1-1
MS-ESS2-1.2.1



Our Relationship with Sunlight

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Objectives

At the end of this lesson, students will be able to:

- Explain the relationship between Sun and Earth.
- Describe the Earth's revolution, rotation, and tilt.
- Relate the Earth's revolution, rotation, and tilt to the period of daily sunlight, summer temperatures, and differences between polar and equatorial regions.

Standards

MS-ESS1-1
Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

MS-ESS2-1.2.1
Develop and use a model to describe phenomena.

Key Vocabulary

Equator

Hemisphere

Revolution

Rotation

Tilt

Materials

- ☐ Lesson Packet: www.nso.edu/educators/jtts-curriculum
- ☐ Slideshow: "***Our Relationship with the Sun***"
- ☐ Video: ***Maui Hawaiian Sup'pa Man*** mp4
- ☐ Activity Materials (see activity sheet)

Background

The Sun has been, and still is, an essential resource. Early civilizations were keen observers of natural phenomena. They detailed, made predictions about, and told stories of their environment, including the differences in periods of sunlight between winter and summer. There is a Polynesian legend in which the demi-god Māui captures the Sun in order to give the people longer periods of sunlight. Modern astronomy explains this phenomenon as being due to the Earth's tilt, its rotation on its axis, and revolution around the Sun.

In this lesson, students explore the relationship between the Sun and Earth, and how we depend on that relationship in our daily lives.

Directions

As students enter the classroom, have Slide 1 on display. This will give them a chance to ponder the ʻŌlelo Noʻeau or "Hawaiian Proverb".

Slide #

2. Ask students to "turn and talk" to a partner about the questions.
   Questions:
   - "How is sunlight connected with life?"
   - "What are some things that we can do during the day, but not at night?"

3-8. Have students interact with the presentation by guessing the mystery words. In this step, students are to guess the word or phrase that describes a way in which people depend on sunlight and daylight hours.

9. Lead a discussion with students about how life is tied to the Sun in many ways.

   Example: Without sunlight there would be no photosynthesis, and therefore no oxygen for living things to breathe.

10. Explain that early civilizations were keen observers of the natural world. The ancient legend of Māui is a cultural example, which describes people depending on longer sunlight periods to perform daily tasks. Optional: refer back to or replay the "***How Maui Slowed the Sun***" mp4 included in lesson one.

11. Pose these questions to the class to gauge pre-activity understanding.

12. Introduce the Learning Target: "I can relate the Earth's *revolution*, *rotation*, and *tilt* to how they affect periods of sunlight between seasons and locations"

13. Introduce and begin the activity: "When will the Sun Rise?". The activity sheet is provided in this lesson package.

14-18. These slides provide visual aids to students as they complete the steps outlined on the activity sheet.

Review

Slide 19: Review Learning Target

Slide 20: Exit Ticket

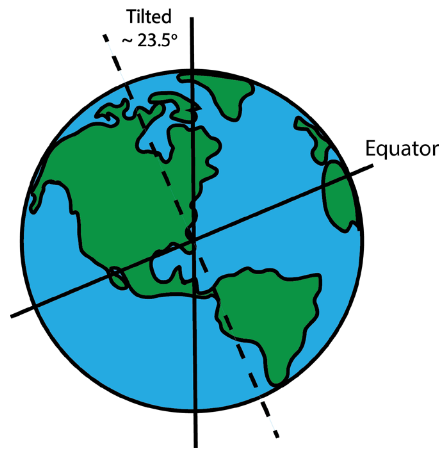
Activity - When Will the Sun Rise?

Adapted by NSO from "The Reasons for the Seasons" © 1996-2016 National Geographic Society

Objectives

1. Describe the Earth's rotation, revolution, and tilt
2. Understand how they effect Sun rise and Sun set time throughout the year

Materials



- □ Foam Balls
- □ Permanent Markers
- □ Flashlights
- □ Pushpins
- □ Stop Watches or other timer
- □ Data Sheets (included)

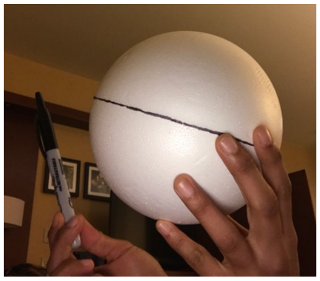
Background

Build background knowledge and curiosity about what causes there to be longer periods of sunlight during summer days and shorter periods during winter. Ask students how they would explain this phenomenon. Our planet does not stand upright, but instead tilts to the side. ***The direction of the Earth's tilt never changes***. Depending on where the Earth is during its revolution around the Sun, the tilt will cause either the northern hemisphere or the southern hemisphere to lean towards the Sun. If you live in the hemisphere leaning towards the Sun, it is summer and you will experience a longer period and more direct sunlight. If you live in the opposite hemisphere, you receive less direct sunlight, have shorter days and it is winter.

Directions

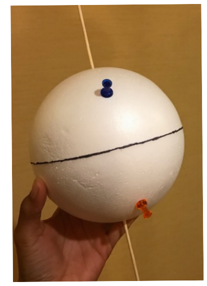
1. Use a pre-made "globe" or foam ball to review the Earth's tilt and axis. Before beginning, introduce the vocabulary terms: ***Tilt, Axis, Hemisphere, Equator, Rotation, Revolution***
2. Students team up in groups of 2 or 3. Each group will mark the "equator" of their foam ball by drawing a line around the middle.
3. Mark the north pole and south pole by drawing dots on the top and bottom of the foam ball.

4. Place one push pin in the northern hemisphere and one in the southern hemisphere. Make sure the pins are on the same side of your Earth and in line with each other longitudinally. You may also place skewers or chopsticks at the north and south poles to better demonstrate the orientation of Earth's tilt (as shown in "Step 4" picture).



Step 2

Step 3



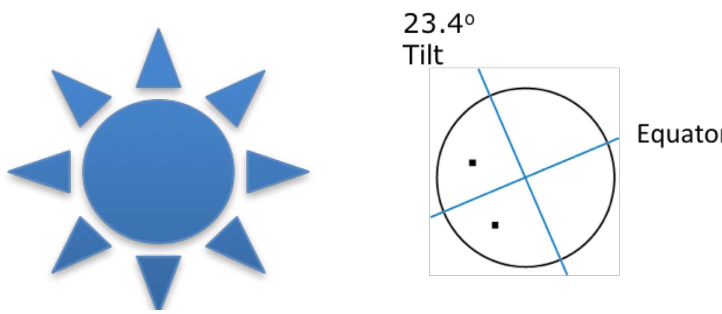
Step 4

5. Choose a point in the room (e.g. over the door) to represent the North Star, at about 23° from directly overhead. This will help students maintain the direction of Earth's tilt.

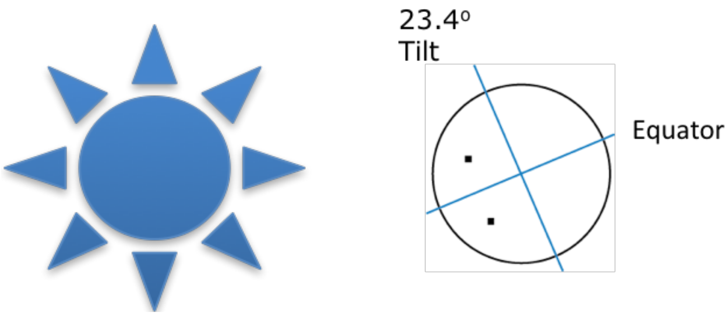
6. Choose one person in the group to represent the Earth (holds the ball). Keep the north axis of the Earth pointed at the North Star at all times. Choose another person to represent the Sun (holds flashlight).

7. The student holding the "Earth" should walk around the student holding the "Sun", while spinning the "Earth" on its axis, keeping the north axis pointed to the North Star. Students should model both the Earth's revolution around the Sun and rotation on its axis. The Earth's tilt is always about a 23.5 degree tilt away from its median, and always in the same direction. The student modeling the Earth's rotation and revolution must be sure to demonstrate this as well.

Demonstrating the Earth's tilt



8. Students develop a hypothesis for the following question: "When the Earth is in this position (refer to the graphic below), which hemisphere has longer daylight? North or South?" **Students can record their hypothesis on the data sheet provided**.

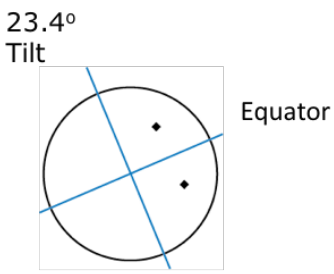


Answer: *Northern Hemisphere*

9. Students test this hypothesis by spinning the Earth one full rotation and observing which pushpin (north or south) stays in the light longer with the Earth tilted.

   Students can record their observations using the data sheets provided.

10. Repeat steps 7 & 8, except this time place the student holding the Earth in the opposite position, where the southern hemisphere is pointed towards the Sun (as shown below).



Ask: *"Which hemisphere has longer daylight now?"*

Ask: *Where is Hawaii? (close to the equator) how does length of daylight compare to somewhere like Alaska? (further from the equator)*

Check for Understanding

Question: What are the two main reasons for the difference in length of daylight between each hemisphere?

Answer: The tilt of the Earth's axis and its revolution around the Sun.

Enrichment

Do other planets in our solar system have seasons? Do they show differences in how long daylight periods are throughout their revolution around the Sun?

Have students brainstorm answers to these questions and follow-up with a research assignment on the tilts, revolutions, and seasons of other planets within our solar system.

Additional Activities

For more activities addressing questions like:

"Why are summers warmer?" and "Why are there differences in periods of sunlight between polar and equatorial regions?"

We recommend: LHS GEMS "The Real Reasons for the Seasons" curriculum book.

Student Data Sheet

Name:

Data Sheet - Earth Position 1

Study Question:

When the Earth is in this position (see picture below), which hemisphere has longer days? North or South?

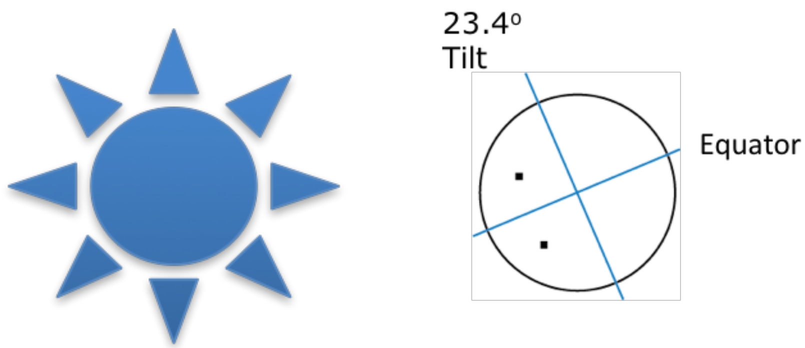


Figure 1. Earth Position 1

Hemisphere	Time (seconds)	Notes
Pushpin in the Northern Hemisphere		
Pushpin in the Southern Hemisphere		

Hypothesis: ____________________________________

____

Test your hypothesis:

1. Position the flashlight “Sun” and the styrofoam ball “Earth” as you see in figure 1.
2. Slowly spin the Earth one full rotation while observing which pushpin (north or south) stays in the light longer with the Earth tilted.
3. Using two timers, measure the amount of time, during one full rotation, that each pushpin stays in the light. Be sure to measure both pushpins simultaneously to ensure that the speed of “Earth’s” rotation remains the same when testing for both pushpins.
4. Record your findings in the data table.

Name: Data Sheet - Earth Position 2

Study Question:

When the Earth is in this position (see picture below), which hemisphere has longer days? North or South?

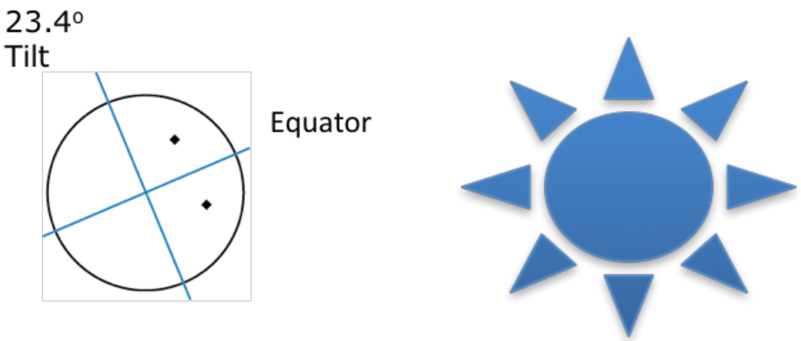


Figure 2. Earth Position 2

Hemisphere	Time (seconds)	Notes
Pushpin in the Northern Hemisphere		
Pushpin in the Southern Hemisphere		

Hypothesis: ______________________________

____

Test your hypothesis:

1. Position the flashlight "Sun" and the styrofoam ball "Earth" as you see in figure 2.
2. Slowly spin the Earth one full rotation while observing which pushpin (north or south) stays in the light longer with the Earth tilted.
3. Using two timers, measure the amount of time, during one full rotation, that each pushpin stays in the light. Be sure to measure both pushpins simultaneously to ensure that the speed of "Earth's" rotation remains the same when testing for both pushpins.
4. Record your findings in the data table

NAME:

CONCLUSIONS

1. Does the Earth's tilt ever change? Explain. ____

2. If the Earth is in this position (Figure 1.) during its revolution around the Sun, and you live in the USA (northern hemisphere), are you experiencing summer or winter? Explain your answer.

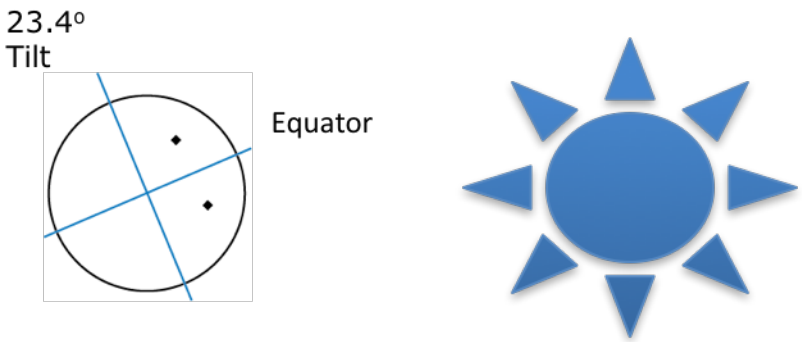


Figure 1.

____
____
____
____
____
____
____

3. What are two main reasons for differences in sunrise and sunset times between each hemisphere? Explain.

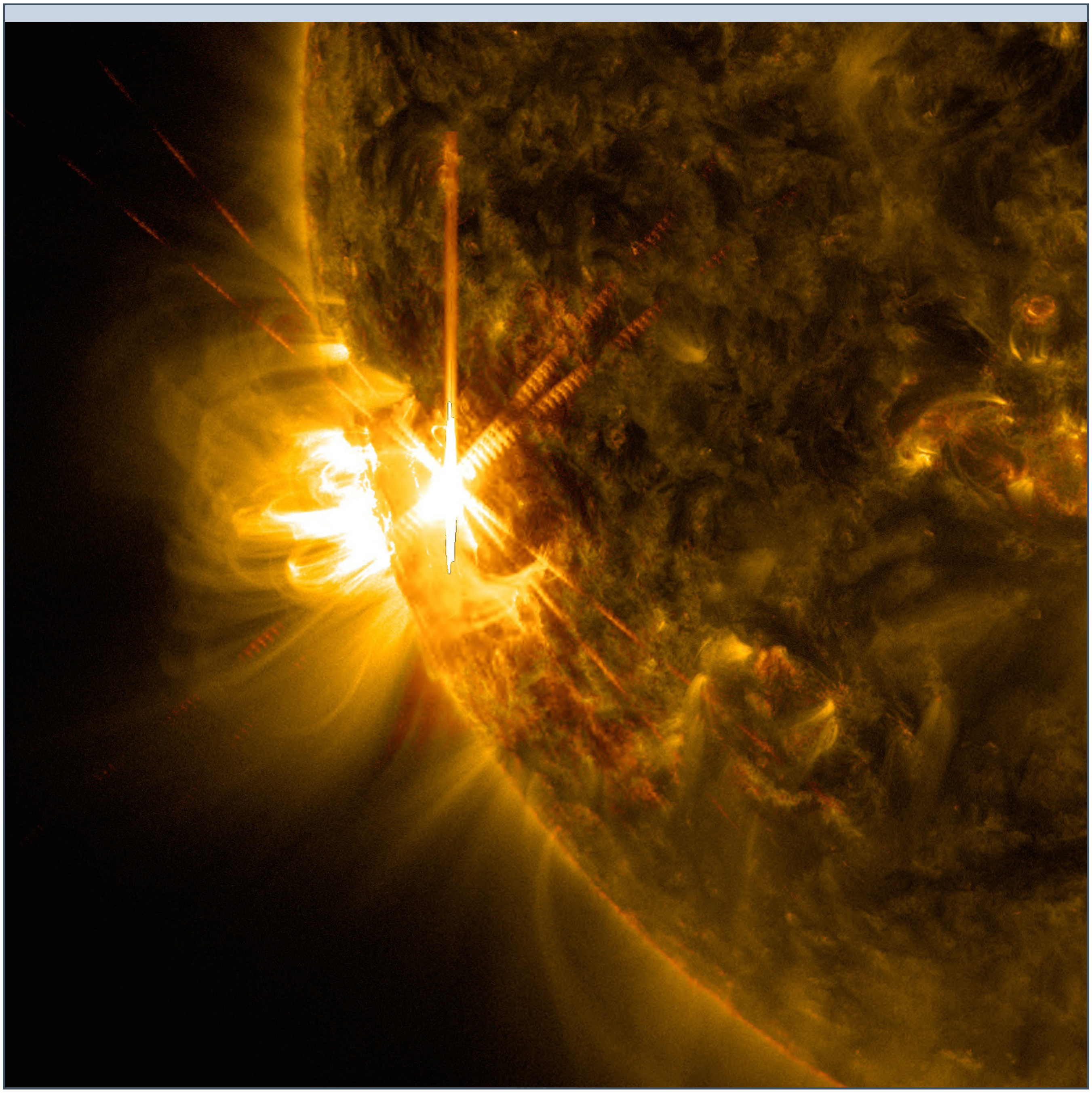
____
____

4. Hawaii is close to the equator. How do you think length of daylight during summer in Hawaii would compare to length of daylight in Alaska, which is further from the equator? Would there be a difference? Why or why not? What about during winter? Move the pushpins in your model to the approximate locations of Hawaii and Alaska to test your hypotheses.

____
____

Journey To The Sun Teacher Guide Lesson 3

Grades: 6 - 8
Duration: 1 class period
Standards: MS-ESS1-2
MS-PS4-2
MS-ESS3-5



The Sun as a Star

Funded by the National Science Foundation

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Objectives

At the end of this lesson, students will be able to:

1. Identify infrared as a form of light energy.
2. Describe the Sun as a star with a magnetic field.
3. Describe properties of stars and how they are formed.
4. Explain fusion and gravity, including the roles they play in a star's life cycle.

Standards

MS-ESS1-2
Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

MS-PS4-2
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-ESS3-5
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Key Vocabulary

Atoms

Electrons

Fusion

Gravity

Infrared

Ions

Magnetic Field

Plasma

Materials

- ☐ Lesson Packet: www.nso.edu/educators/jtts-curriculum
- ☐ Slideshow: "*The Sun as a Star*"
- ☐ Video *A Star is born.mp4*
- ☐ Activity Materials (see activity sheet)

Background

This lesson is an introduction to the Sun as a star. What is a star? What are they made of? How do they shine? Why are they hot? These are questions that will be answered throughout this lesson. Students interact with the presentation as they learn about ***fusion*** and ***gravity*** and the roles they play throughout a star's life cycle. An informational video is included by the "How the Universe Works" series, published by the Science Channel on YouTube, to engage students in the processes involved in star formation. Lastly, students learn of the Sun's magnetic fields as responsible for space weather and the solar events that affect us here on Earth, which will be covered in more detail during lesson 4: "The Dynamic Sun".

Directions

As students enter the classroom, have Slide 1 on display. This will give them a chance to ponder the questions: "What is the Sun?" "What are Stars?" "What are they made of?"

Slide #

2. Reveal the answers to the questions on slide 1. The Sun is a star made of hot plasma. Because of the Sun's intense heat, electrons are stripped from it's atoms, leaving free electrons and positively charged ions. This ionized substance is called plasma.

3-4. Using the images provided, lead a discussion on vocabulary terms: ***atoms***, ***electrons***, ***plasma***, and ***protons***.

5-6. Why do the Sun and other stars shine? It shines because it's hot. All hot objects give off light, although not all objects give off visible light. It's only when objects are really hot, like the Sun for example, that they glow in light that is visible.

*<u>Example</u>: When animals and humans have warm body temperatures, they give off invisible light called **infrared.***

7. Use the images provided to lead a discussion of infrared radiation and how special cameras, like telescopes, can be used to detect the infrared energy (heat) coming off of objects. These two pictures were taken simultaneously. Compare and contrast what you see in each.

8-10. Why is the Sun hot? It's hot due to ***gravity*** and ***fusion***. The Sun is made up of huge amounts of matter. The more matter, the more gravitational force. Gravity compresses matter; as matter is compressed, it heats up.

11. Play the simulation demonstrating how galaxies are pulled together by gravity.

12. Play the embedded movie "How a star is born". In the movie, scientists describe how gravity, pressure, and time work together to form a star like our Sun. The star will then use hydrogen and helium throughout its life as fuel for nuclear fusion. Nuclear fusion is responsible for creating the heavier elements (i.e. oxygen, carbon, etc.) necessary for us to survive. Fusion also releases heat and allows stars to shine.

13-16. Discuss the process of fusion. Use the images and fusion gif as visual aids. As atoms fuse to form heavier elements, light and heat energy are released.

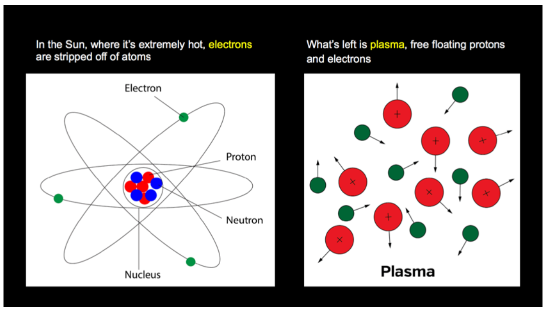
Fun Solar Fact: *The Sun radiates enough energy to melt a bridge of ice 2 miles wide, 1 mile thick, and extending the entire way from the Earth to Sun in 1 second!*
Fact provided by Dr. Louis Barbier (reference included on last slide).

17. Review questions from the video "How a Star is Born".

"The Sun as a Star" Guided Notes

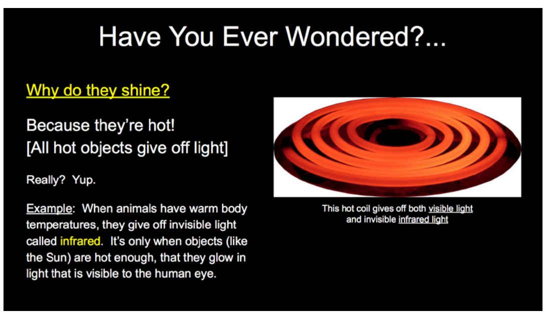
The Sun is a ________. It's made of really _______ plasma.

The ______ is made of _________!



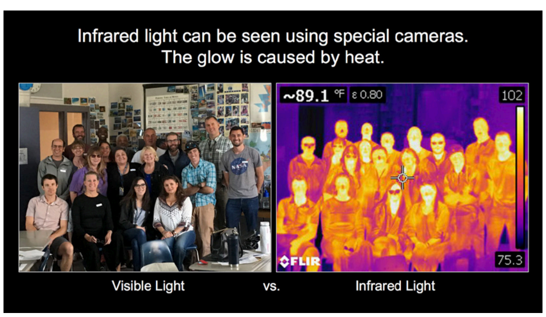
In the Sun, where it's extremely _______, _________ are stripped off of _________.

Plasma is made of free floating _______ and _________



The sun and other stars shine because they're _______.

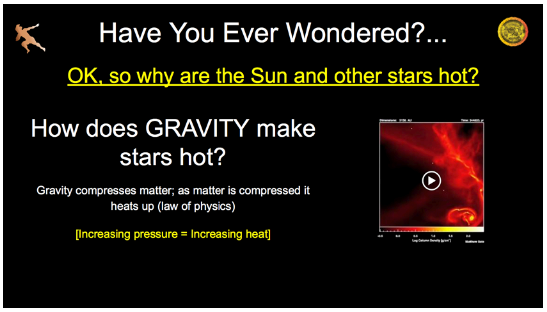
Example: When animals have warm body temperatures, they give of invisible light called ___________.



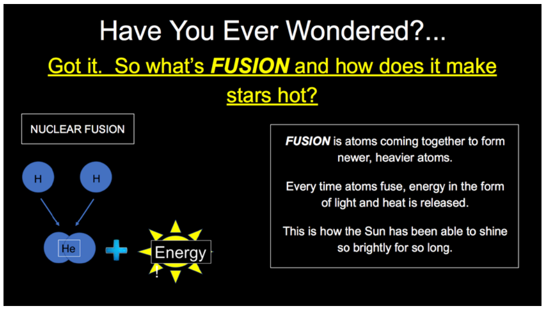
_________ light can be seen using special ________.

The glow is caused by _______.

The Sun and other stars are hot due to: _____________ and ____________



Gravity makes stars ________. Gravity __________ matter; as matter is _____________, it ________ up.



_______ is atoms coming together to form heavier atoms.

Every time atoms fuse, ________ in the form of _______ and _______ is released.

Stars - A Review

- ☐ What are stars made of?
- ☐ How are they born?
- ☐ Why are they important?
- ☐ Remember, the Sun is a star, why is the sun important to us?

Activity - Electromagnetic Spectrum Poster

Adapted by NSO from "EM spectrum poster project guidelines" © 2014 Florida State University. cpalms.org

Objective

Become familiar with the electromagnetic spectrum.

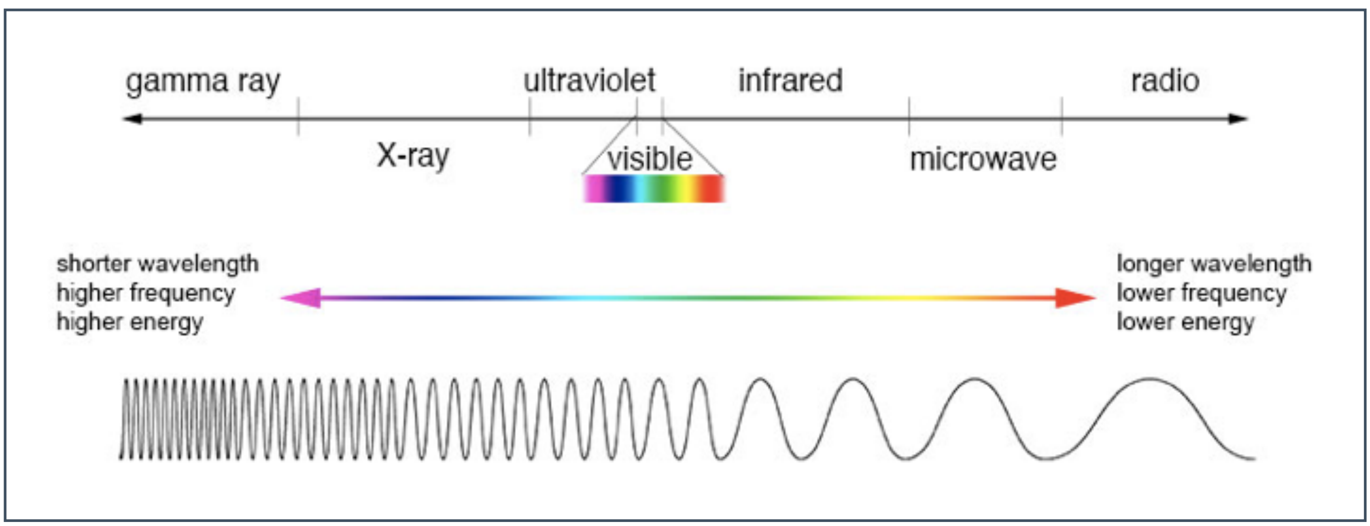
This activity is an optional pre-requisite to lessons 4 and 5, which incorporate topics requiring knowledge of electromagnetic energy waves and their properties.

Materials

- ☐ Poster paper
- ☐ Markers
- ☐ Internet access or alternative source for information

Background

The Electromagnetic (EM) Spectrum is the range of wavelengths and frequencies of electromagnetic radiation. The EM spectrum includes frequencies lower than the low radio frequencies used in radio communication and extends to gamma radiation, a short-wavelength, high-frequency radiation. The wavelengths covered in the EM Spectrum span from lengths smaller than an atom to those measuring thousands of kilometers long. Radiation energy falling within specific ranges of the EM spectrum are used for multiple purposes, including radio communication, medical diagnostics, reheating food, and night vision technology to name a few.



EM Spectrum - https://imagine.gsfc.nasa.gov/Images/science/EM_spectrum_compare_level1_lg.jpg . Retrieved 7/24/17

Directions

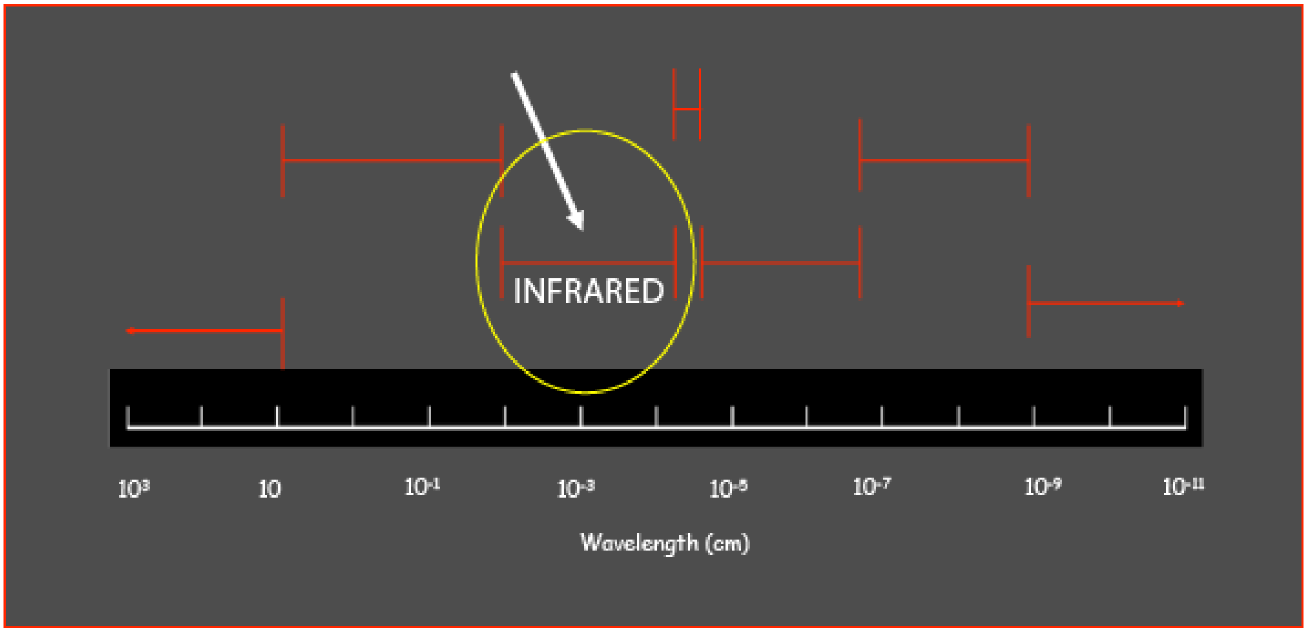
1. Assign students working in groups of 2 or 3 a specific region of the electromagnetic spectrum (i.e. radio, microwaves, infrared, visible, ultraviolet, x-ray, gamma).
2. Students will then research their assigned area of the Electromagnetic Spectrum and create a poster or other means of presenting their research. Posters must include the following information:
   a. Title and assigned region of Electromagnetic Spectrum
   b. Where is this type of radiation located on the EM Spectrum? What properties of the energy wave define its location in the spectrum?
   c. Key characteristics of the assigned radiation type (i.e. wavelength, frequency, key information, etc.)
   d. How is the assigned radiation type used or found in everyday life and/or industry? Identify and explain at least 3 uses.
   e. Is the radiation type harmful, beneficial, or both? Provide evidence to support your argument.
   f. At least 3 references, cited in a format designated by the teacher.

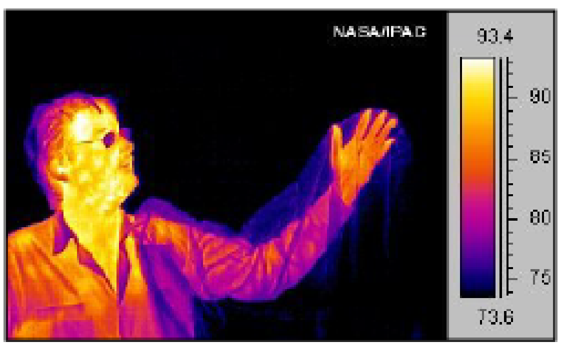
Assessment

1. Have students participate in a gallery walk in order to learn about the different types of radiation energy from the work of their classmates.
2. See the slideshow presentation titled “Interactive EM Quiz”. This is an interactive quiz on the electromagnetic spectrum, where students identify the type of radiation energy that is displayed on each slide.

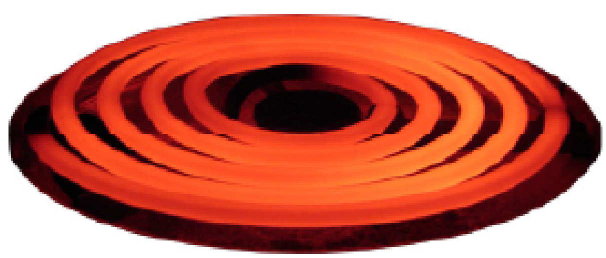
Sample Student Poster

Infrared Radiation





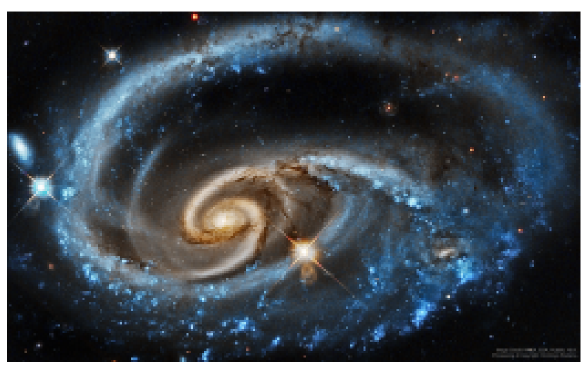
Night Vision &
Heat Sensing



Cooking and Heating

Can be both Harmful and Beneficial!

Harmful - too much can cause burns
Helpful - night vision, cooking, scientific discovery



Studying complex structures in galaxies and nebulae

Wavelengths: 0.0010 cm to 0.1 cm
Frequencies: 3 GHz to 400 THz

Activity - "The Herschel Experiment"

Discovery of Infrared Light in the Electromagnetic Spectrum

Adapted by NSO from Cool Cosmos "The Herschel Experiment".
Published online: 2014. Cool Cosmos is an IPAC website: http://coolcosmos.ipac.caltech.edu

Objective

In this activity, students learn about Herschel's discovery of infrared light by completing an experiment similar to the one Herschel conducted in the 1800s. Students use thermometers and prisms to note the temperature differences between visible light colors, and invisible light just beyond red (infrared).

Materials

- ◻ Glass Prisms
- ◻ Thermometers
- ◻ Black paint or permanent marker
- ◻ Scissors
- ◻ Cardboard Box
- ◻ Blank white paper
- ◻ Video ***Herschel Experiment - Frantisek Plasil.mp4***

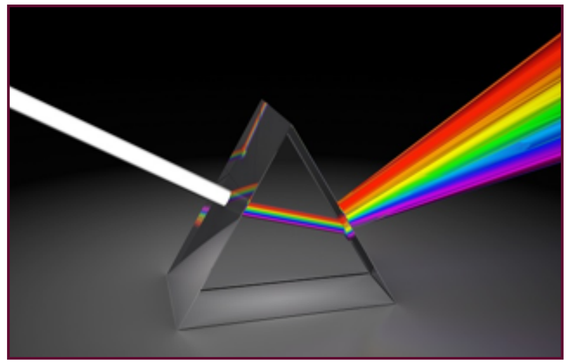


Image Credit: Mmaxer/Shutterstock.com.
Retrieved 11/29/17

Background

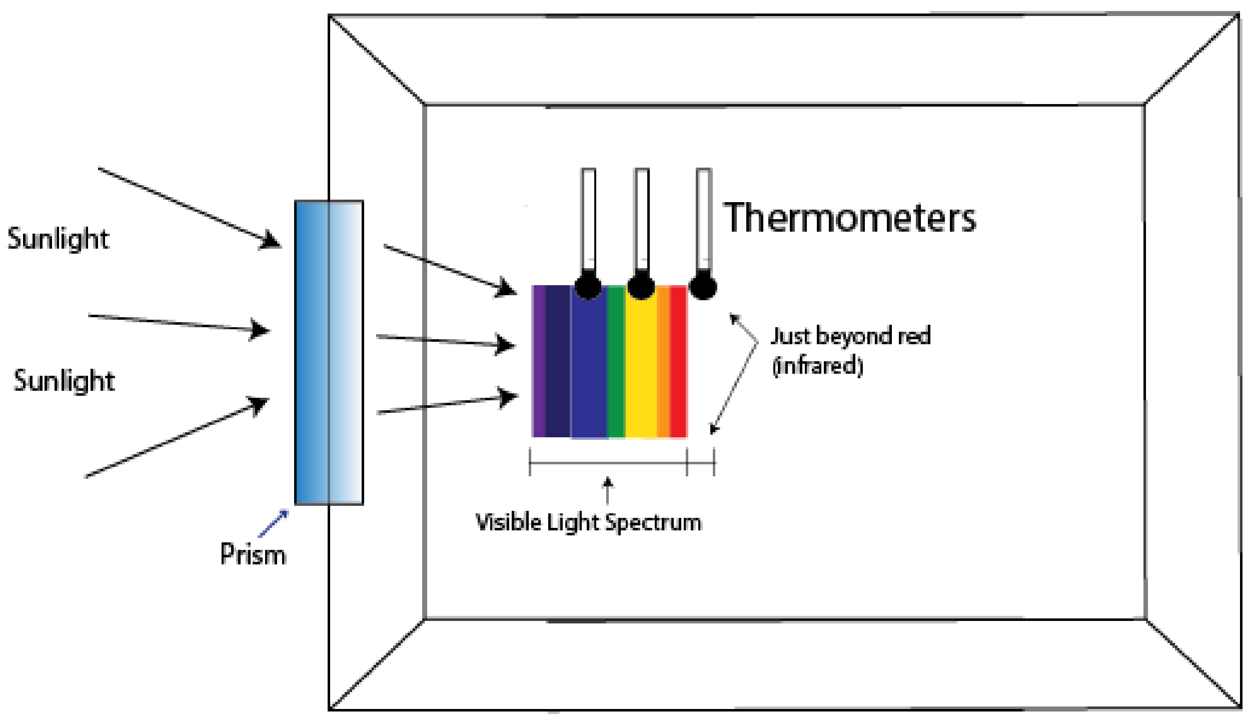
Herschel was an astronomer and musician. In 1800, he experimented by passing sunlight through a glass prism and dispersing the light into a rainbow of colors called the visible light spectrum. He investigated whether the colors had different temperatures by placing a thermometer in each color of light, and recording his results. All of the colors had temperatures higher than a thermometer in the shade. Additionally, he found that the temperatures increased from the violet to the red end of the spectrum. He then measured the region just beyond the red and found that the temperature was even higher! Herschel was the first to show that there are types of light that we can't see. What Herschel discovered was infrared light.

Optional:

Play the "***Herschel Experiment - Frantisek Plasil.mp4***" included in this lesson packet for students before beginning this experiment, to build excitement and provide background.

Directions

1. Prepare three thermometers by blackening their bulbs with either black paint or black permanent marker. This is so that they absorb heat better.
2. Place a blank, white sheet of paper in the bottom of the cardboard box.
3. Cut out an area at the top edge of the box facing the sun. This notch holds the prism while still allowing the prism to be adjusted to produce the widest possible spectrum on the white paper. It is important that the spectrum falls on the shaded portion of the white sheet of paper at the bottom of the box.
4. Once the prism is secured in place, put the thermometers in the shade and record their temperatures. These are your control temperatures.
5. Next, place the thermometers in the color spectrum, one each in the blue and yellow regions. Tape them to the box to secure them if necessary. The third thermometer is placed just beyond the red region, where no colored light is visible.
6. Record the temperatures measured by each thermometer at 1 minute intervals until final temperatures are reached after 5 minutes. Record your results in the data sheets provided. Do not move the thermometers or block the light spectrum while reading your measurements.



Experimental Set Up

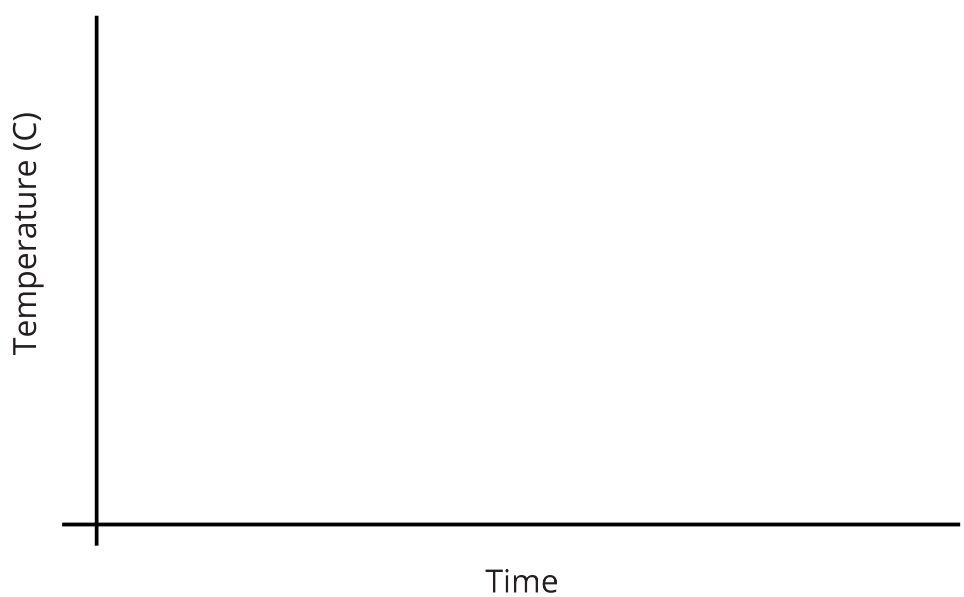
Student Data Sheet

Observations

	Thermometer 1	Thermometer 2	Thermometer 3
Control Temperature (in the shade)			

Temperature in the spectrum	Thermometer 1 (Blue)	Thermometer 2 (Yellow)	Thermometer 3 (beyond red)
1 minute			
2 minutes			
3 minutes			
4 minutes			
5 minutes			

Graph your measurements



Calculations

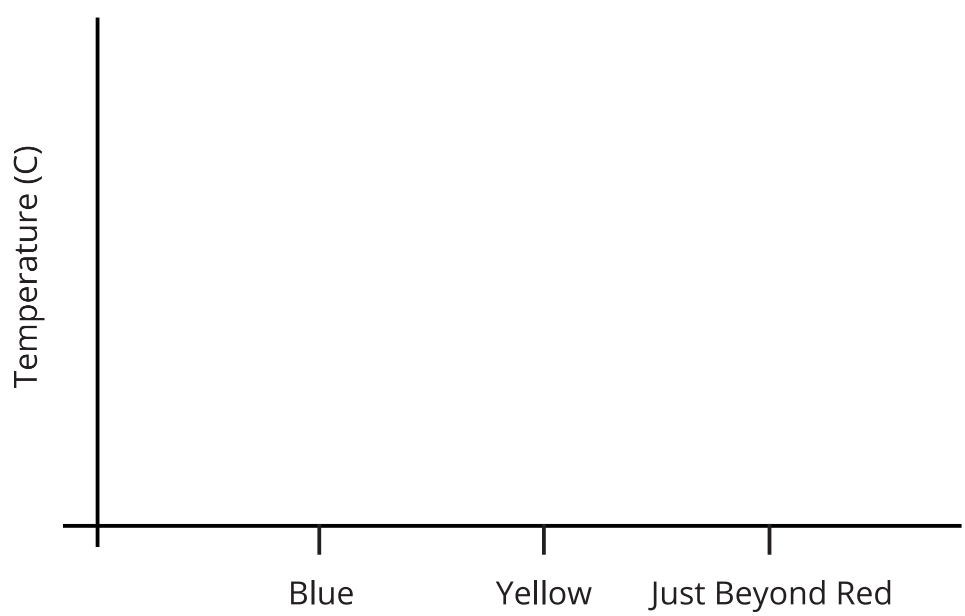
Calculate the average final temperatures measured by the class in each part of the spectrum

	Sum of final Temps (X)	Total number of final measurements (Y)	Class average (X / Y)
Blue at 5 minutes			
Yellow at 5 minutes			
Just beyond red at 5 minutes			

Calculate the difference between the control temperature and the class average final temperature for each part of the spectrum

Blue: __________ °C Yellow: __________ °C Just Beyond Red: __________ °C

Graph the temperature difference between the control and each part of the spectrum



Conclusions

1. What are your thoughts on the temperature measurements? Did you notice anything interesting? If so, what? Explain.

2. Did you see any trends in your data? Explain.

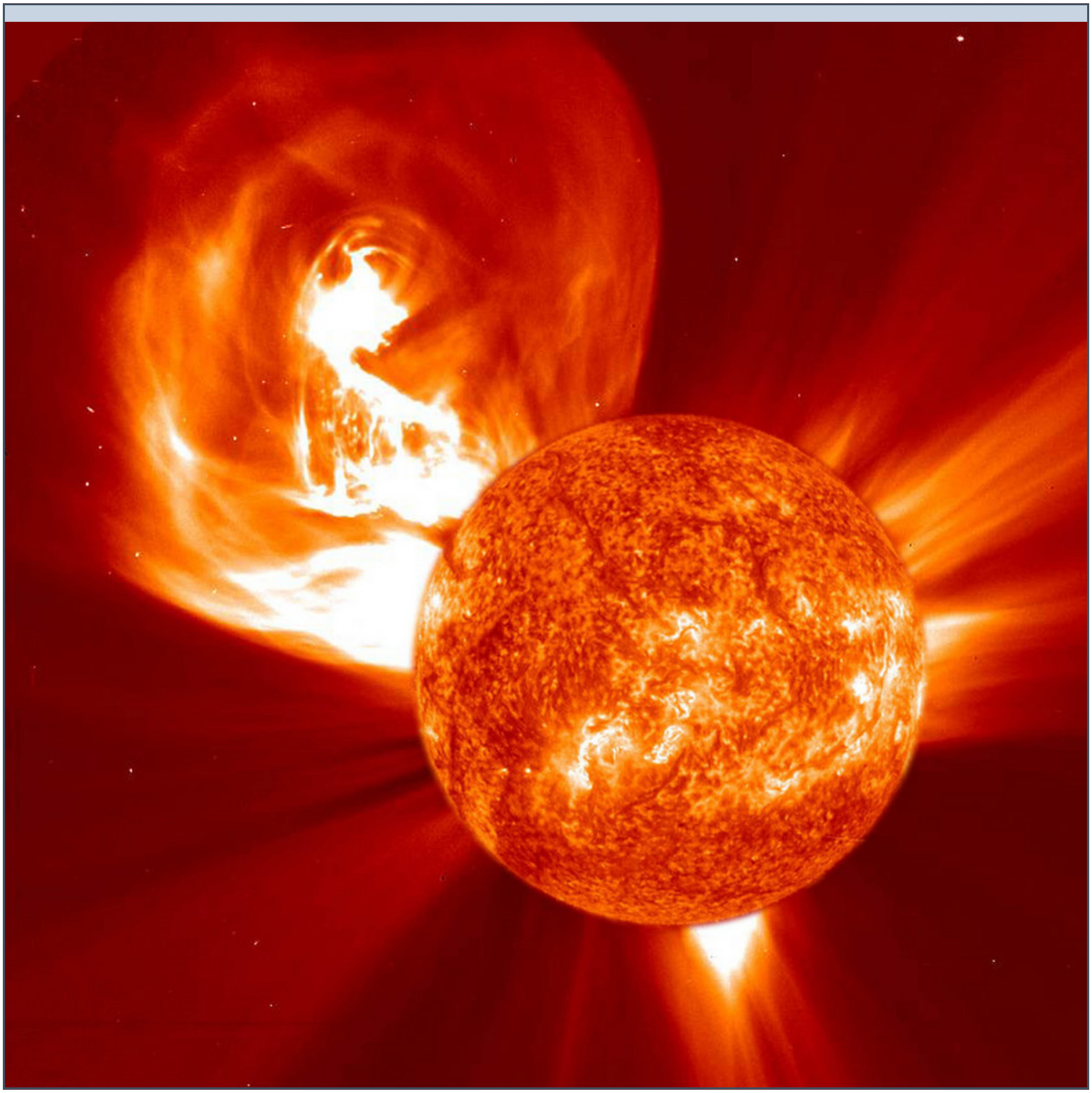
3. Which portion of the spectrum had the highest temperature after 5 minutes? Why do you think this portion had the highest temperature?

4. What do you think exists just beyond the red light, where there was no color? What do you think caused this area to increase in temperature?

5. Was there anything that went “wrong” during this experiment that you think may have affected your results? If so, discuss them here.

Journey To The Sun Teacher Guide Lesson 4

Grades: 6 - 8
Duration: 1-2 class periods
Standards: MS-ESS1-1
MS-PS2-3
MS-PS2-5
SC.8.2.1



The Dynamic Sun

Funded by the National Science Foundation

www.nso.edu

Objectives

At the end of this lesson, students will be able to:

1. Identify and describe solar events (i.e. solar flares, coronal mass ejections, etc.)
2. Describe how the electromagnetic spectrum can be used to observe different features of the Sun.
3. Describe the Sun as a star on which major events occur that can affect Earth.

Standards

MS-ESS1-1
Patterns of the apparent motion of the sun, moon, and stars in the sky can be observed, described, predicted, and explained with models.

MS-PS2-3
Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5
Conduct an investigation to provide evidence that fields exist between objects exerting forces on each other.

SC.8.2.1
Describe significant relationships among society, science, and technology and how one impacts the other.

Key Vocabulary

Coronal Mass Ejection

Filament

Prominence

Solar Flare

Sunspot

Materials

- ◻ Lesson Packet: www.nso.edu/educators/jtts-curriculum
- ◻ Slideshow: "***The Dynamic Sun***"
- ◻ Activity Materials (see activity sheet)

Background

***Note: This lesson will be most effective if taught after students have a basic understanding of radiation energy and the electromagnetic spectrum. Please see the following activities as optional prerequisites to this lesson: Electromagnetic Spectrum Poster, Interactive EM Quiz, and The Herschel Experiment.**

The Sun is a dynamic star. It's a moving, changing, ball of plasma and energy. Events that occur on the Sun such as sunspots, coronal mass ejections, and solar flares are the result of the Sun's structure, processes, and magnetic fields. These events can potentially impact life on Earth and thus, solar scientists learn about these events in order to better predict them and understand their impacts in the future.

In this lesson, students are introduced to these solar events. They learn what each is and observe them through videos and potentially through the solar telescope.

The main objective of this lesson is for students to learn to identify and describe 5 main solar events (sunspots, filaments/prominences, solar flares, coronal mass ejections).

In the next lesson, students will draw connections between these events and their effects on Earth.

Directions

Using the slideshow provided, review with students the information provided on each slide.

Slide #

1. Have students share their thoughts on the color of the Sun. Many may say yellow or white. Suggestion: Have students write ideas on the board or draw interpretations in their notebook.

2. Reveal the answer to the question on slide 1. The Sun emits light in all colors, which is perceived as "white light". Prisms split white light into a rainbow of colors. The Sun is the opposite, as it contains the rainbow of colors combined into white light.

3. The Sun does not just emit visible light, it emits across all wavelengths. Mention that different telescopes used for viewing the Sun, have special filters to view the Sun in different wavelengths. This allows scientists to see details in one wavelength that may not be visible in another wavelength.

   Examples: *DKIST telescope views the Sun in visible light wavelengths and SDO views the Sun in ultraviolet wavelengths.*

4. Ask the following critical thinking question, which can be used as a lead into EM spectrum review, or as a formative assessment of EM spectrum understanding:

   Question: *"If these images aren't taken using visible light wavelengths, why can we see color in the pictures?"*

Directions Cont...

5. Students should know that if wavelengths other than those in the visible range were used to capture the images, then they should not see color in the pictures. This is correct because in fact, the images were originally black and white. Scientists add color in order to better see details, much like biologists stain cells to see different structures within the cell.

6. Have students think-pair-share, or use another strategy, to describe the details that they see in the picture.

7. Point out that the streaming lines coming off of the Sun resemble magnetic field lines coming off of a bar magnet. In fact, these streaming lines are made up of plasma tracing the Sun's magnetic field.

8-12. What causes the Sun to vary? Its magnetic field. The Sun's magnetic field is responsible for the features of the Sun that can be seen through solar telescopes. The corona looks like lines streaming off from around the Sun. These lines are the result of plasma tracing the Sun's magnetic field lines, much like iron shavings trace the field lines of a magnet.

13. Begin the Activity: "Exploring Magnetism - visualizing magnetic field lines of the Sun". The activity sheet is provided in this lesson package.

14-20. Review the photos and videos included on these slides to introduce students to Sunspots. Have students take notes from slide 18.

21-26. Review the photos and videos included on these slides to introduce students to filaments and prominences. Have students take notes from slide 24 & 25.

27-31. Review the photos and videos included on these slides to introduce students to Solar Flares. Have students take notes from slide 31.

32-36. Review the photos and videos included on these slides to introduce students to Coronal Mass Ejections (CMEs). Have students take notes from slide 36.

37-38. Students practice what they've learned by matching the correct term with what is seen in each photo (A-D). See answers on slide 38.

39. We rely on our knowledge of the Sun. Point out that all of the solar events student have just learned (i.e. Sunspots, filaments, solar flares, CMEs, etc.), can affect the people living on Earth. In the next lesson, they'll find out how.

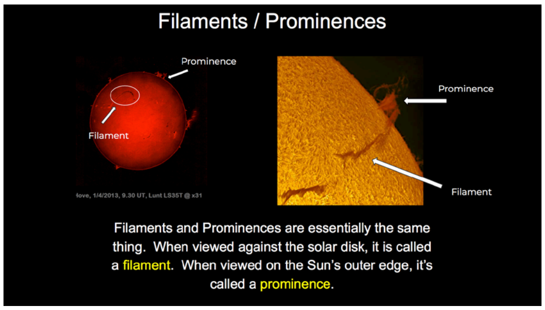
Begin the Activity: "Solar Observations Practice". The activity sheet is provided in this lesson package.

"The Dynamic Sun" - Guided Notes

Sunspots are caused by the Sun's __________ ________ bursting through the surface.

Draw each feature in the box provided

Sunspot

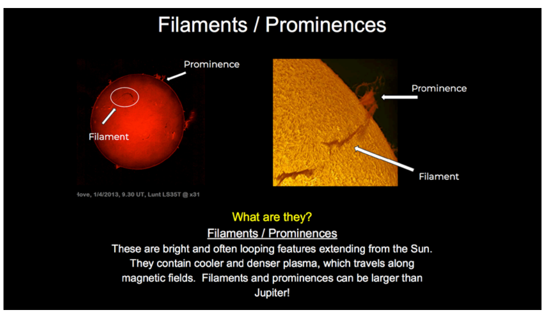


___________ are viewed against the solar disk

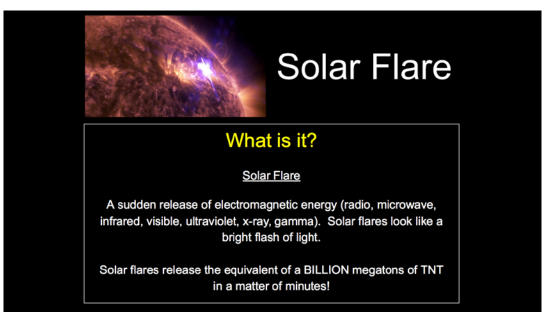
___________ are viewed on the Sun's outer edge.

Filament

Prominence

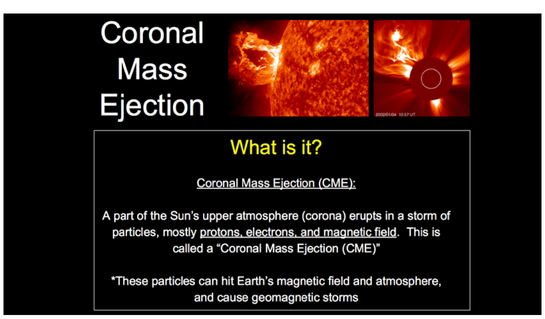


Filaments and Prominences extend from the ________. They contain __________, which travels along _____________ ___________.



A solar flare is a sudden release of ___________ ________. They look like _________________.

Solar Flare



A Coronal Mass Ejection is an eruption of _________, __________, and ____________ _________.

These _________ can hit _________ and cause ____________

CME

Activity - Exploring Magnetism

Visualizing magnetic field lines of the sun

Adapted by NSO from NASA's "Exploring Magnetism: A Teacher's Magnetism Activity Guide" © 2005 Regents of the University of California.
http://cse.ssl.berkeley.edu/SEGwayed/lessons/exploring_magnetism/exploring_magnetism/index.html

Objective

Students learn about the magnetic field of the Sun by exploring bar magnets.

Materials

- ◻ 1 magnetic compass per student (ones with transparent faces work best)
- ◻ 1 long Alnico bar magnet
- ◻ 1 large sheet of white paper or several sheets of regular paper and scotch tape
- ◻ A pencil or marker

Background

The Sun has a magnetic field like the Earth, Jupiter and magnets on your refrigerator. While there are many intricacies to the behavior of the Sun's magnetic field, its overall structure is just like that of any bar magnet you might have at home. What causes an object to have a magnetic field? All magnetism in the universe ultimately derives from the motion of charged particles. Permanent magnets like the ones on our fridge do this on a quantum mechanical level, but there are other types of magnetism that are easier to explain and all involve a moving charge (also known as a current). For example, junk yards can lift and move cars weighing several tons using electromagnetic cranes. These devices run a very large electric current around in big circles, creating a magnetic field. Similarly, the rotation and convection of negatively charged electrons inside the Sun causes it to have a "magnetic dynamo," which is the name for a magnetic field created by a rotating astronomical body. How does this happen? The Sun rotates, electrons rotate with it, the flow of electrons is an electric current, electric currents generate electric fields.

The Sun's magnetic field has a North and a South pole, just like a bar magnet. Magnetic fields are typically shown by drawing lines that represent the direction a positive charge would move if it were introduced into the magnetic field. These electrons flow from negative to positive and from North to South. The closer together the magnetic field lines are, the stronger the magnetic field is in that region. One of the mysterious things about the Sun's magnetic field, is that it switches orientation every 11 years. Solar scientist are currently trying to figure out the exact mechanisms behind this swap.

Directions

1. Discuss with students that the Sun has a magnetic field and it acts almost like a bar magnet.

2. Have students arrange their compasses around one of the bar magnets. Note how the heads of the compass needles point toward the magnetic south pole and away from the magnetic north pole of the bar magnet.

3. Use the large sheets of paper (or have the students tape together several sheets) and place the bar magnet on top and in the middle of the paper. Tell the students that they will now trace the magnetic field around the bar magnet. Ask them to hypothesize what they think the magnetic field will look like.

4. To make the tracings, draw a dot somewhere near the magnet and place the center of a compass over the dot.

5. Draw a dot at the location of the arrow head (or tail) of the compass needle.

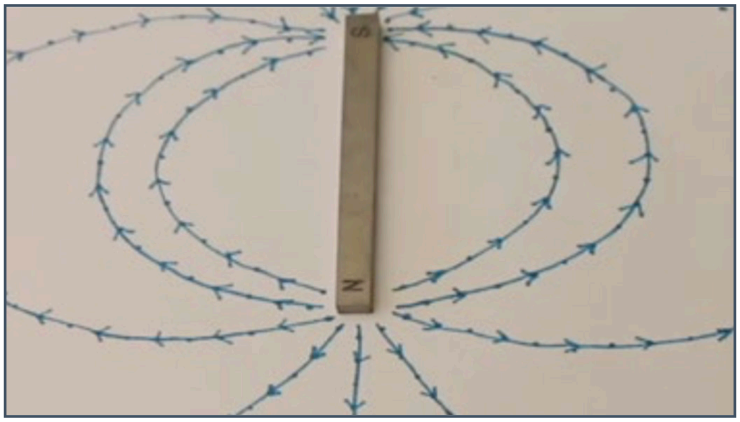
6. Move the compass center to this new dot, and again draw a dot at the location of the compass needle head (or tail).

7. Remove the compass from the paper and draw lines connecting the dots with arrows indicating the direction that the compass points.

8. Continue making new dots until the line meets back up with the magnet or you reach the edge of the paper.

9. Connect the dots with a line and draw in some arrow markers to show the direction of the magnetic field, from North to South.

10. Pick another spot near the magnet and repeat steps 4-9. Continue until the lines are surrounding the magnet, making a dipole pattern of magnetic field.



Watch a video tutorial of this activity on YouTube:
http://bit.ly/ExploringMagnetism

Watch our solar magnetism webcast:
http://bit.ly/Webcast2-TheLayersOfTheSun

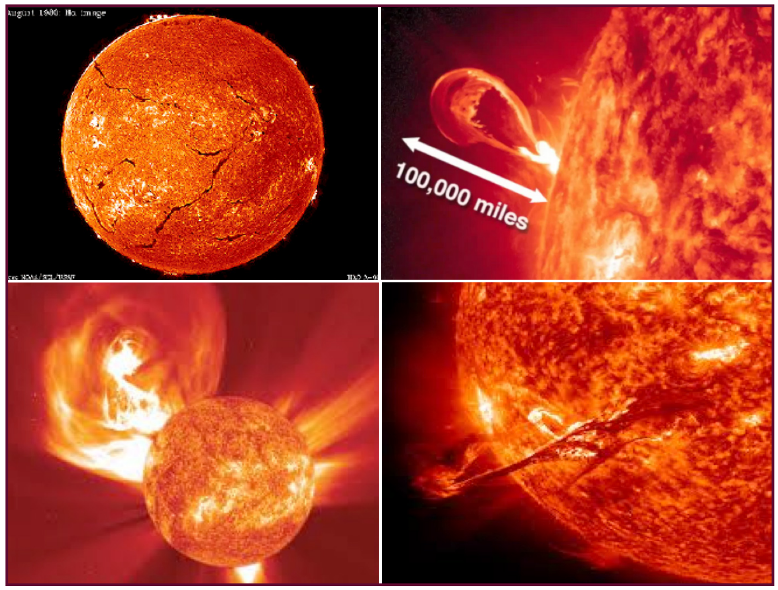
Activity - Solar Observations Practice

Objective

In this activity, students practice making and recording solar observations. They'll be required to identify the solar events and features shown in the videos provided. This practice is meant to prepare students for making solar observations in real time using the Meade Coronado Personal Solar Telescope.

Materials

- ☐ Sunspot.mp4
- ☐ Filaments.mp4
- ☐ Prominence.mpg
- ☐ Solar Flare1.mp4
- ☐ Solar Flare2.mp4
- ☐ CME.mp4



Background

Sunspots are caused by the Sun's magnetic field bursting through the surface, which can push glowing surface matter out of the way. That's why sunspots look dark. They come and go, and so are considered temporary.

Filaments and ***Prominences*** are essentially the same thing. When viewed against the solar disk, it's called a filament. When viewed on the Sun's outer edge, it's called a prominence. These are bright and often looping features extending from the Sun. They contain cooler and denser plasma, which is trapped along magnetic fields.

A ***Solar Flare*** is a sudden release of electromagnetic energy. Solar flares look like a bright flash of light. They release the same energy as a billion megatons of TNT of energy into the solar system on an almost daily basis.

Sometimes, solar flares cause part of the Sun's upper atmosphere (corona) to erupt in an explosion of particles, mostly protons, electrons, and magnetic field. This is called a "***Coronal Mass Ejection (CME)***". These particles can hit Earth and cause technology disruptions.

Directions

1. Watch the provided videos. In each video, students sketch what they observe.

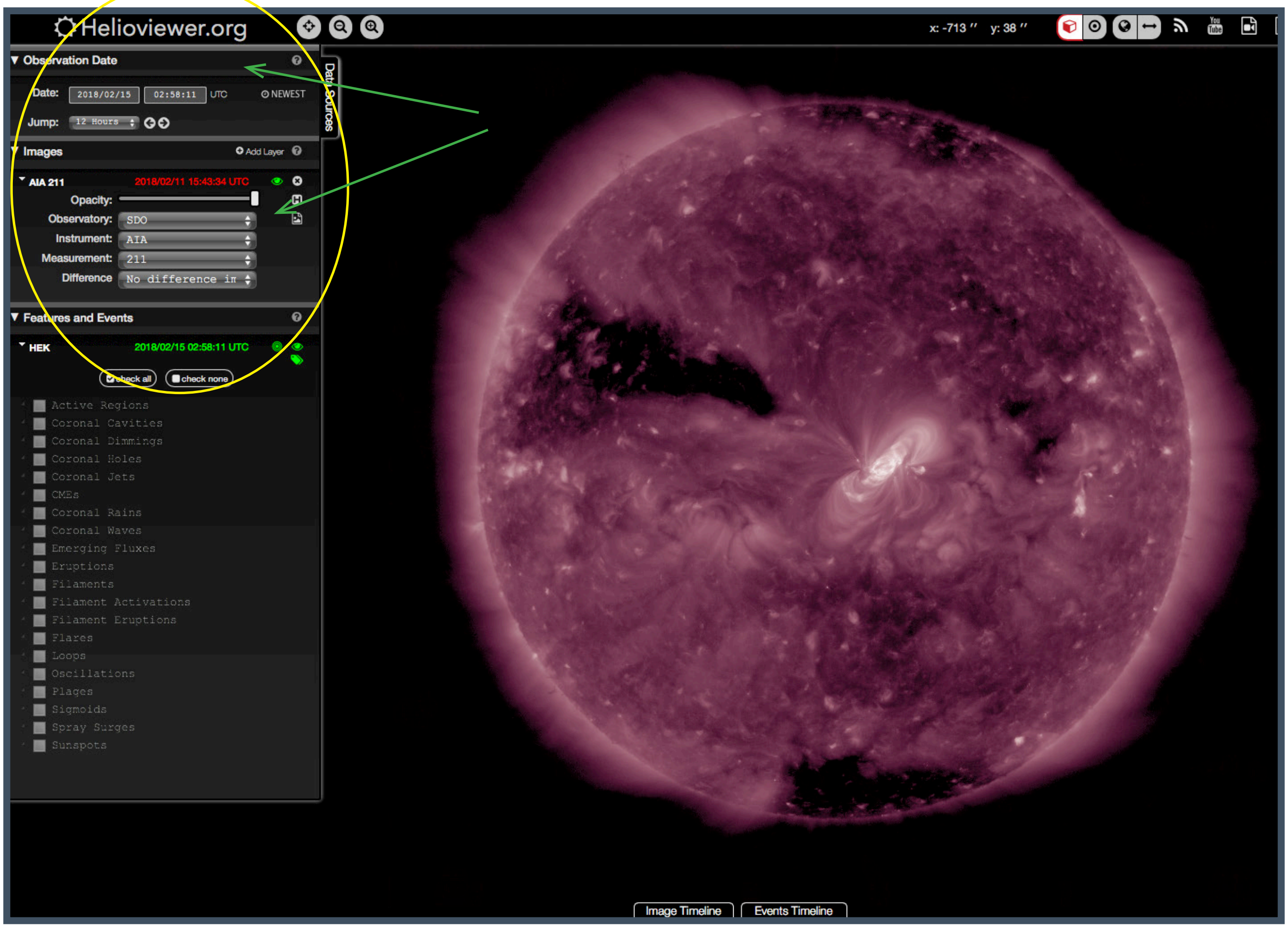
2. Next, students identify solar events or features (i.e. Sunspots, filaments, etc.), which they will then circle in their sketches.

3. Lastly, students record notes on anything specific that they observe.

   For Example: *How many sunspots are there? How many filaments? Were there any differences observed between similar features in different videos?*

4. To create solar movies of your own, visit helioviewer.org. Helioviewer is a free solar and heliospheric image visualization tool that allows users to create images and movies using near real-time images and data taken from professional solar observatories. Toggle between different dates, observatories, instruments, wavelength channels, and measurements to customize your movie.

   Helioviewer User Guide: wiki.helioviewer.org/wiki/Helioviewer.org_User_Guide_3.1.0



Helioviewer Selection Guide

To see → Select ↓	Sunspots	Filamemts/ Prominances	Coronal Loops	Flares	CMEs Zoom out!
Observatory	SDO	SDO	SDO	SDO	SOHO
Instrument	AIA	AIA	AIA	AIA	LASCO
Measurement	1600, 1700, 4500	304	171, 193, 335	94, 131, 211, 195	C2, C3
Observatory	SDO	SOHO	PROBA2	PROBA2	STEREO-A or -B
Instrument	HMI	EIT*	SWAP	SWAP	SECCHI → COR1 or COR2
Measurement	Continuum, magnetogram	304	174	174	White light
Observatory	SOHO	STEREO-A or -B	STEREO-A or -B	STEREO-A or -B	
Instrument	MDI*	SECCHI →EUVI	SECCHI →EUVI	SECCHI →EUVI	
Measurement	Continuum, magnetogram	304	171, 195, 284	171, 195, 284	

*EIT and MDI have been turned off since 2013 and 2011 respectively. No data is available from these instruments after these dates.

Student Data Sheet

Identify the solar events!
Find the solar features!

(circle and label what you find, or draw each in a specific ink color)

Notes:

____

____

____

____

____

____

Identify the solar events!
Find the solar features!

(circle and label what you find, or draw each in a specific ink color)

Notes:

____

____

____

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____

Student Data Sheet

Identify the solar events!
Find the solar features!

(circle and label what you find, or draw each in a specific ink color)

Notes:

Identify the solar events!
Find the solar features!

(circle and label what you find, or draw each in a specific ink color)

Notes:

Student Data Sheet

Identify the solar events!
Find the solar features!

(circle and label what you find, or draw each in a specific ink color)

Notes:

____

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____

Identify the solar events!
Find the solar features!

(circle and label what you find, or draw each in a specific ink color)

Notes:

____

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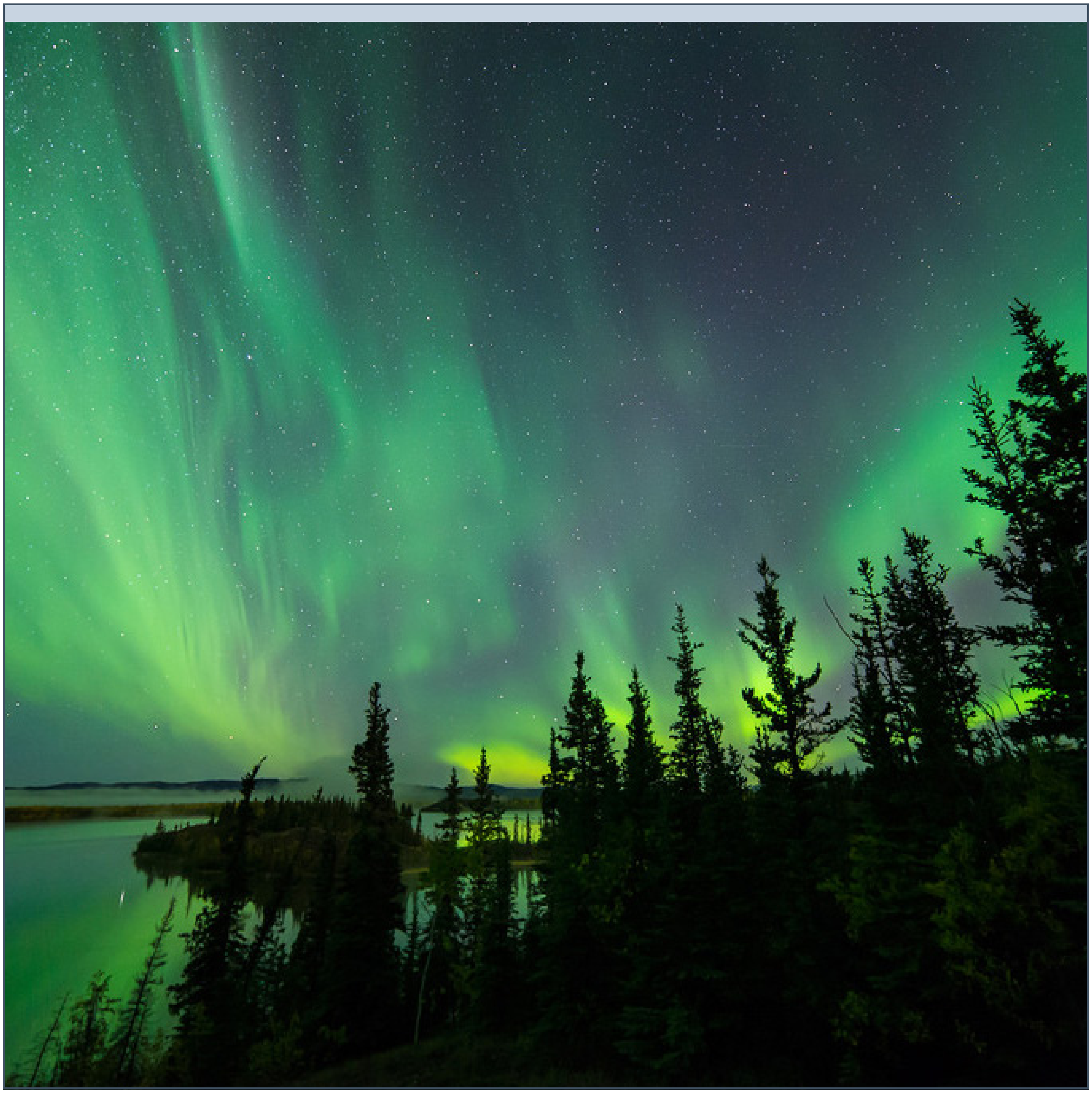
Journey To The Sun Teacher Guide Lesson 5

Grades: 6 - 8
Duration: 1-2 class periods
Standards: MS-ESS1-1
SC.8.2.1
SC.8.8.10



How the Sun Affects Earth

Funded by the National Science Foundation

www.nso.edu

Objectives

At the end of this lesson, students will be able to:

1. Compare and contrast the effects of solar flares vs. coronal mass ejections.
2. Investigate the solar cause of mysterious events that could impact society.
3. Explain how solar events and space weather affect Earth and society.
4. Plot Coronal Mass Ejection (CME) locations and map their paths from the Sun.

Standards

MS-ESS1-1
Patterns of the apparent motion of the sun, moon, and stars in the sky can be observed, described, predicted, and explained with models.

SC.8.2.1
Describe significant relationships among society, science, and technology and how one impacts the other.

SC.8.8.10
Compare the characteristics and movement patterns in our solar system.

Key Vocabulary

CMEs

Electrons

Light Energy

Particles

Protons

Solar Flares

Materials

- ☐ Lesson Packet: www.nso.edu/educators/jtts-curriculum
- ☐ Slideshow: "***How the Sun Affects Earth***"
- ☐ How the Sun Affects Earth.mp4 (For Teachers)
- ☐ Activity Materials (See activity sheets)

Background

***Note:** This lesson will be most effective if taught after students have a basic understanding of radiation energy and the electromagnetic spectrum. Please see the following activities as optional pre-requisites to this lesson: Electromagnetic Spectrum Poster, Interactive EM Quiz, and The Herschel Experiment.

In lesson 4, students learned of the different events such as solar flares and CMEs occuring on the Sun. In this lesson, students get to make valuable connections between these events and how they affect our society. Additionally, students are re-introduced to the importance of solar science and how it is applied to keep the public prepared in the event that important societal technologies, such as radio communications and power grids, are disrupted.

Directions

Using the slideshow provided, review with students the information provided on each slide.

Slide #

2. Allow students to brainstorm, think-pair-share, etc. on the reasons for why solar scientists study the Sun. Why is solar science important?

3. Remind students that the solar events they learned of in the previous lesson can affect human society on Earth.

4. Informational slide displaying how CMEs and Solar Flares compare and contrast in terms of the material they release, the speed at which their effects reach Earth, and the disruptions they may cause. This information will become useful as students complete the included activities.

5. Real-world example of a CME impacting Earth: On March 10th 1989 astronomers observed a powerful explosion on the Sun. Three days later on March 13th, the entire province of Quebec, Canada suffered an electrical power blackout as a result. The blackout lasted 12 hours. This meant 12 hours without light, heat, elevators, etc. Additionally during this time, other "mysterious" problems arose, including space satellites temporarily losing control. These problems went away as the solar storm subsided.

   For more information on "The Day the Sun Brought Darkness" visit: https://www.nasa.gov/topics/earth/features/sun_darkness.html

6. CMEs happen all the time. This is a simulation of a real event from 2012 that narrowly missed Earth. Had this been directed at Earth, it could have had very severe consequences

7. ***Enrichment Option:*** Have students research this phenomenon and present their findings. Real-world example of solar flare impacts on Earth: Solar flares can increase radiation exposure to flight crews and passengers flying at high altitudes where there is less atmospheric protection. They can also impact long-wave radio communications, rendering them unreliable.

8. Introduction to the student activity "Calling all Hawai'i Solar Scientists". In this activity, students use the artifacts provided on the worksheet to investigate the solar causes of mysterious events. This worksheet may be used as a formative assessment.

9. Introduce students to the "CME Plotting Activity" (activity sheet provided). In this activity, students plot CME locations over time and map their paths to determine how likely they are to hit Earth.

Activity - Calling All Hawaiʻi Solar Scientists

Adapted by NSO from: NASA. 2003. Living with a Star-GEMS Teacher's Guide for Grades 6-8. University of California, Berkley, CA.

Objective

In this activity, students investigate a series of mysterious events on Earth, and build a hypothesis to explain what happened. This activity is based on real events with fictionalized emergencies.

Materials

- ☐ Student activity sheets
- ☐ Pen or pencil

Background

Solar events such as coronal mass ejections and solar flares, also known as space weather, can cause technological disruptions and mishaps when they hit Earth. In this lesson, students are the solar scientists who determine the solar causes of mysterious events that have the potential to affect thousands of people. Similar real-life events like the ones described in this activity have occured and impacted the lives of many.

In our present day society, we are heavily dependent on modern technologies such as radio wave communications, satellites, global positioning systems, and electrical power grids. In the event that a solar storm powerful enough to cause large-scale damage to these sytems occurs, early prediction and preparedness will make all the difference in how society's technologies will recover.

Calling all Hawaiʻi Solar Scientists!

Student Activity Sheet

There have been a series of mysterious events here on Earth. Figure out what's caused these events and use your knowledge to keep the public safe in the future.

Mysterious Events

September 6

Rescue services lost communication fishermen out of Kahului port when their radios stopped working at 12:01pm.

September 8

Night time security guards recorded red and green lights on the horizon around 11:50pm.

September 8

A sudden impulse was observed at several of Earth's magnetic field instruments (magnetometers) at 3:48am.

September 6

NASA's SoHO satellite suffered radiation damage at 12:00pm.

September 8

10:30pm: UHMC students out stargazing in Waihee reported unusual clouds and colors in the sky in the north and northeast directions.

September 6

12:01pm: Astronauts on the International Space Station detected a sudden increase in X-rays and Gamma-rays and were directed to take cover immediately.

September 8

Voltage irregularities registered across Hawaiʻi electrical grid through the day.

September 6

The number of dropped cell phone calls increased drastically throughout the day.

Mysterious Events Continued

September 7

Television broadcasts interrupted temporarily across the USA. Effect most noticeable with satellite television channels.

September 7

Department of Defense issued a memo regarding poor GPS reliability for drone operators for the next 24-36 hours.

September 6

Federal Aviation Authority has announced delays in flights from Hawai'i to Europe. Airlines are forbidden from flying over the north or south poles due to concern about radio communication stability until further notice.

September 8

Scientists at Antarctica's Amundsen-Scott South Pole Station noted irregularities in the location of the magnetic south pole today.

September 5

The National Solar Observatory observe highly complex sunspots near the center of the Sun.

September 9

Verizon, AT&T and T-Mobile have announced that cell phone services have returned to normal as of noon today.

September 6

The National Weather Service have issued a warning to electricity companies regarding possible nationwide outages for the next 24-36 hours.

September 9

Scientists at Antarctica's Amundsen-Scott South Pole Station report that magnetic south has returned to its normal position.

September 6

11:59pm: Astronauts report X-ray and Gamma-ray radiation levels returned to normal.

September 9

Federal Aviation Authority has declared flights from Hawai'i to Europe may resume flightpaths over the poles.

Directions

1. Catalogue the mysterious events using the calendar below.
2. Use the calendar of events, along with the artifacts below to find evidence for what may have caused the mysterious events. Use the hints provided to guide you along the way.

September 6	September 7
September 8	**September 9**

Artifacts

Artifact #1: "Internet Research"

You've done some research and have come across the following chart:

Coronal Mass Ejections	Solar Flares
Release explosions of magnetic field, protons and electrons (matter)	Release electromagnetic radiation
Particles take 2-3 days to reach Earth	Travels at the speed of light; takes 8 minutes to reach Earth
Carries a magnetic field that can interact with Earth's magnetic field.	Increase in EM radiation can cause disruptions in radio communications and GPS

Evidence :

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____

____

____

Hint: How long does it take CME particles and Solar Flare energy to reach Earth?

Artifact #2: "Military Satellite Report"

Sept. 5 - Normal

Sept 6 - Alert

12:01pm - Increase in X-ray and gamma ray levels detected. Defense system on alert: Def Con 3.
12:11pm - Increased X-rays and gamma rays identified as not coming from Earth. Defense system taken off alert.
12:34pm - Communications with all other nuclear powers confirm that no detonation of nuclear weapons occured.
11:59pm X-ray and Gamma-ray levels returned to normal

Sept. 7 - Normal

Sept. 8 - Normal

Evidence :

____

Hint: On what day and times did the alert occur? When was the increase in rays detected?

Artifact #3: "Hourly Record of Sept 6th Solar Flares and CMEs"

S = small

M = Medium

L = Large

Time	Solar Flares			Coronal Mass Ejection		
	S	M	L	S	M	L
00:00 - 00:59	1					
01:00 - 01:59		1			1	
02:00 - 02:59						
03:00 - 03:59		1				
04:00 - 04:59		1			1	
05:00 - 05:59						
06:00 - 06:59						
07:00 - 07:59	1					
08:00 - 08:59						
09:00 - 09:59		1				
10:00 - 10:59	1					
11:00 - 11:59			1			1
12:00 - 12:59	1					
13:00 - 13:59	1					
14:00 - 14:59						
15:00 - 15:59						
16:00 - 16:59	1			1		
17:00 - 17:59	1	1			1	
18:00 - 18:59						
19:00 - 19:59						
20:00 - 20:59	1					
21:00 - 21:59						
22:00 - 22:59						
23:00 - 23:59						

Flare Data from www.solarmonitor.org/?date=20170906

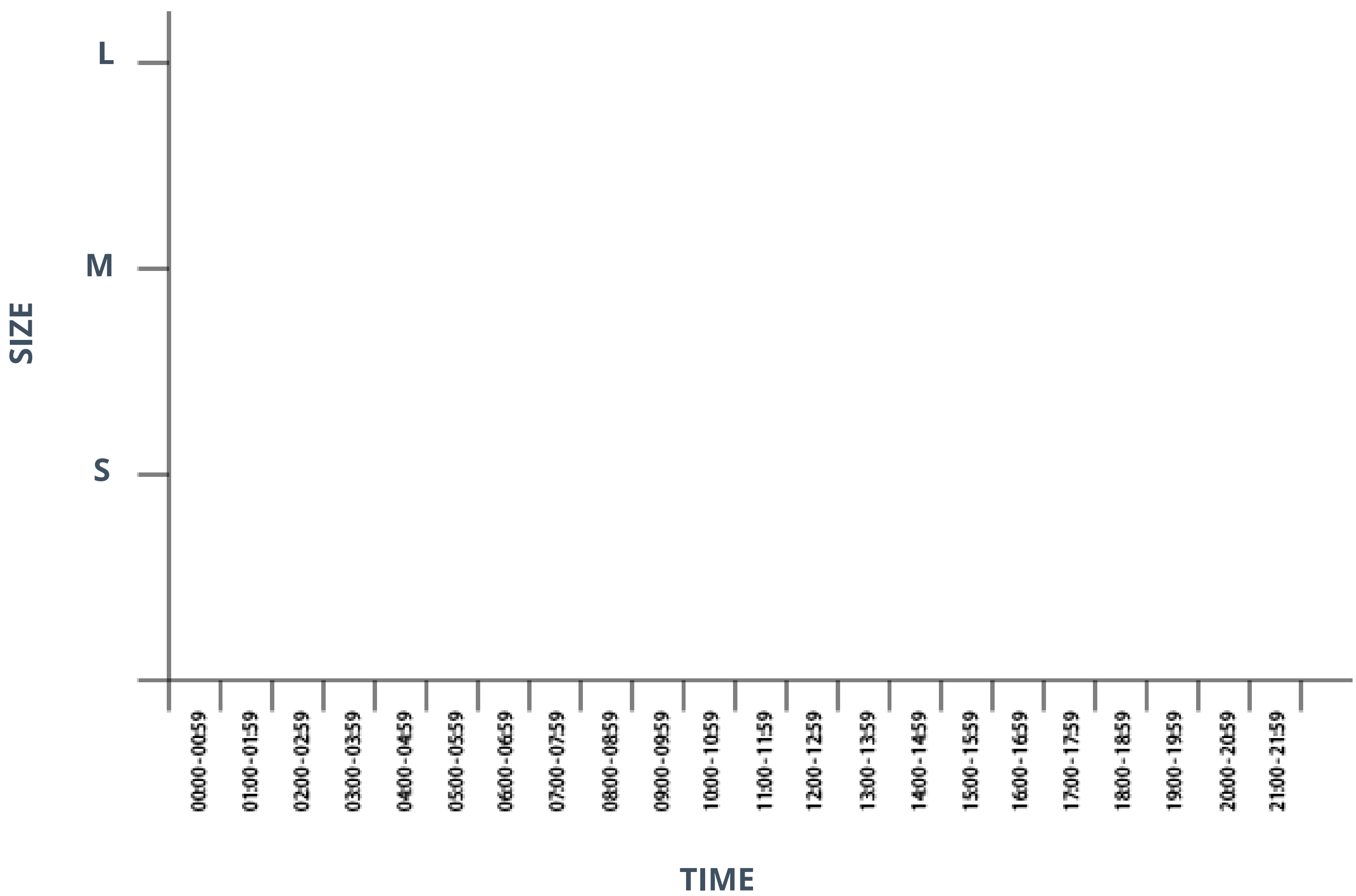
Evidence :

____

Hint: At what time did the largest CME and Solar Flare occur?

Graph the Data from Artifact #3

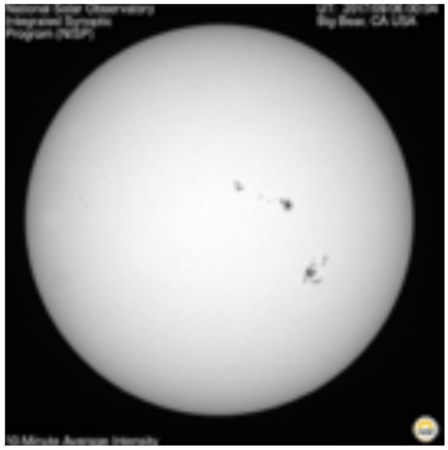
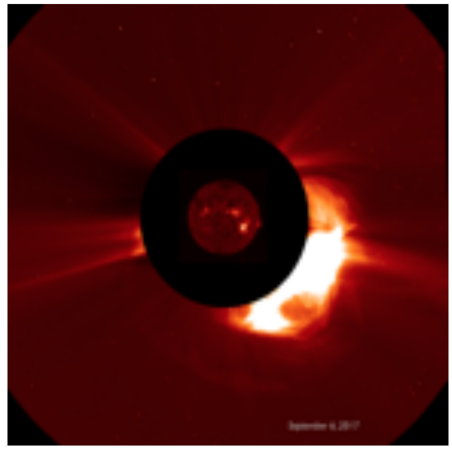
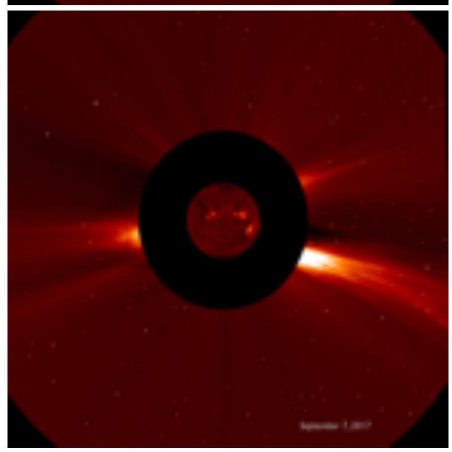
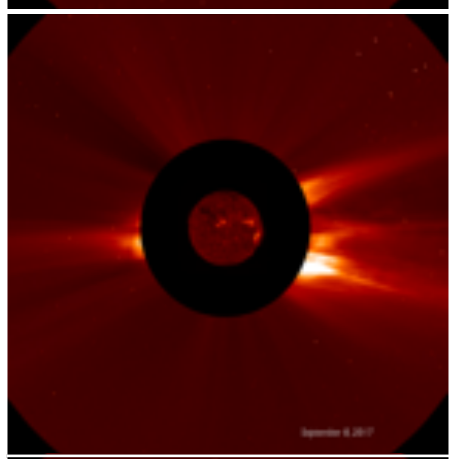
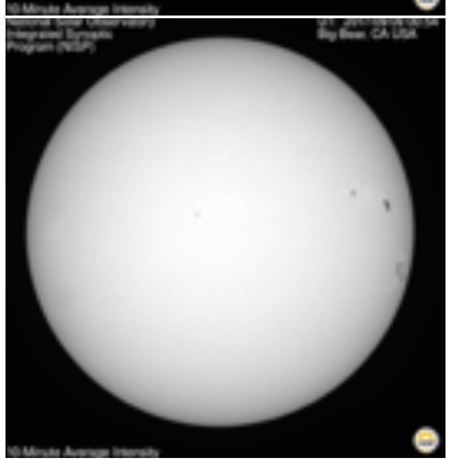
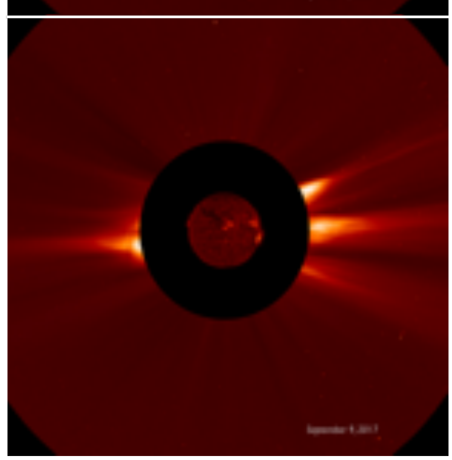
Graph Title ______________________________



□ = Solar Flare

○ = Coronal Mass Ejection

Artifact #4: Sunspot and CME observations

Date	Sunspot activity	CME activity
Sept. 6		
Sept. 7		
Sept. 8		
Sept. 9		

Evidence :

Hint: On what day does the CME activity look different?

Conclusions

Questions:

1. What was the cause of all of these disruptions?

2. The largest solar flare on Sept 6th happened at 11:53am. Why did the loss of radio communications at Earth not happen until 12:01pm?

3. If the largest solar flare and CMEs occured on Sept 6th, what explains the disturbances that happened on Sept 8th?

Write your conclusions in the space below. Be sure to explain what caused the events and provide specific examples of evidences that validate your conclusions. Use what you know about solar flares and CMEs in your explanation.

Teacher Answer Key

Artifact #1: "Internet Research"

You've done some research and have learned that it takes 8 minutes to travel from the Sun to Earth at the speed of light.

You've learned that it takes CME gusts two to three days to reach the Earth from the Sun.

Evidence :

It takes light energy 8 minutes to get from the Sun to the Earth.

It takes protons and electrons from CME gusts 2-3 days to reach Earth.

Artifact #2: "Military Satellite Report"

Sept. 5- Normal

Sept 6 - Alert

12:01pm - Increase in X-ray and gamma ray levels detected. Defense system on alert: Def Con 3.
12:11pm - Increased X-rays and gamma rays identified as not coming from Earth. Defense system taken off alert.
12:34pm - Communications with all other nuclear powers confirm that no detonation of nuclear weapons occured.
11:59pm X-ray and Gamma-ray levels returned to normal

Sept. 7 - Normal

Sept. 8 - Normal

Evidence :

Increased X-ray and Gamma rays, which can be released by solar flares, were detected on Sept. 6 @ 12:01pm

Hint: On what day and times did the alert occur?
When was the increase in rays detected?

Artifact #3: "Hourly Record of Sept 6th Solar Flares and CMEs"

S = small

M = Medium

L = Large

Time	Solar Flares			Coronal Mass Ejection		
	S	M	L	S	M	L
00:00 - 00:59	1					
01:00 - 01:59		1			1	
02:00 - 02:59						
03:00 - 03:59		1				
04:00 - 04:59		1			1	
05:00 - 05:59						
06:00 - 06:59						
07:00 - 07:59	1					
08:00 - 08:59						
09:00 - 09:59		1				
10:00 - 10:59	1					
11:00 - 11:59			1			1
12:00 - 12:59	1					
13:00 - 13:59	1					
14:00 - 14:59						
15:00 - 15:59						
16:00 - 16:59	1			1		
17:00 - 17:59	1	1			1	
18:00 - 18:59						
19:00 - 19:59						
20:00 - 20:59	1					
21:00 - 21:59						
22:00 - 22:59						
23:00 - 23:59						

Flare Data from www.solarmonitor.org/?date=20170906

Evidence :

The largest solar flare and CME both occured on Sept. 6th between 11am and noon

Hint: At what time did the largest CME and Solar Flare occur?

Questions:

1. What was the cause of all of these disruptions?

A large solar flare occurred on Sept. 6th between 11am and noon. There was a large CME that happened at the same time.

2. The largest solar flare on Sept 6th happened at 11:53am. Why did the loss of radio communications at Earth not happen until 12:01pm?

Solar flares release light energy. It takes light 8 minutes to reach Earth from the Sun.

3. If the largest solar flare and CMEs occured on Sept 6th, what explains the disturbances that happened on Sept 8th?

These issues could have been caused by increased magnetic field and particles ejected from the sun interfering with the Earth's magnetic field. The protons and electrons and magnetic field released in the large CME take 2-3 days to reach Earth from the Sun. This is why it took 2 days after the big CME for these disturbances to happen..

Write your conclusions in the space below. Be sure to explain what caused the events and provide specific examples of evidences that validate your conclusions. Use what you know about solar flares and CMEs in your explanation.

These events seem to have been caused by a large solar flare and CME that occurred on Sept 6th at 11:53am. Evidence to support solar flare involvement include increased x-ray and gamma rays detected at Earth on Sept. 6th @ 12:01pm. Solar flares release large amounts of light energy such as x-rays and gamma rays. These types of light energy take approximaely 8 minutes to reach Earth from the Sun. Thus, a large solar flare occuring at 11:53am, was likely the source of the increase in energy rays detected on Earth at 12:01pm (8 minutes later). This is what caused interference with radio waves and communications. [Note to teachers: Flare radiation doesn't directly interefere with radio waves. The actual cause of radio interference is as a result of solar flare radiation ionizing the Earth's outer atmosphere, making our ionosphere thicker. Radio waves bounce off the ionosphere to travel long distances, so unexpected changes in that layer of the atmosphere can cause radio signals to be lost.]

CMEs release protons and electrons along with magnetic field. These protons and electrons take 2-3 days to reach Earth (evidence from artifact #1) and can sometimes interfere with Earth's magnetic field. This explains why disturbances continued to happen until Sept. 8th. CMEs can also excite the atoms in our atmosphere, causing them to glow (i.e. Aurora Borealis). Although it would be extremely rare to see aurora in Hawaiʻi, it would be possible if the CME was large enough. This would explain the unusual colors in the sky that were observed by the UHMC students.

Activity - Coronal Mass Ejection Plotting

Adapted by NSO from the NASA IMAGE/POETRY Teacher and Student Consortium.
https://image.gsfc.nasa.gov/poetry/activities.html

Objective

In this activity, students map the paths of Coronal Mass Ejections (CMEs) by plotting their positions over the course of a few days.

Materials

- ◻ Student activity sheet
- ◻ Ruler
- ◻ Protractor
- ◻ Pen or pencil

Background

A Coronal Mass Ejection (CME) is a storm of particles ejected from the Sun. These particles can shoot out from any of the 360° around the Sun. Therefore, the probability of a CME being directed towards Earth is relatively small. Students will plot CME locations and map their paths in order to spot trends and draw conclusions on CME behavior. As students add more CMEs to their activity sheets, it becomes apparent that in order for a CME to hit Earth, it must be ejected from a specific region of the Sun facing Earth.

Assuming that every 12 hours or so, a CME with an initial width of 0.5 million kilometers, will:

- Travel a distance of approximately 20 million kilometers
- Move approximately 7° counter clockwise
- Spread over a width of approximately 6.5 million kilometers.

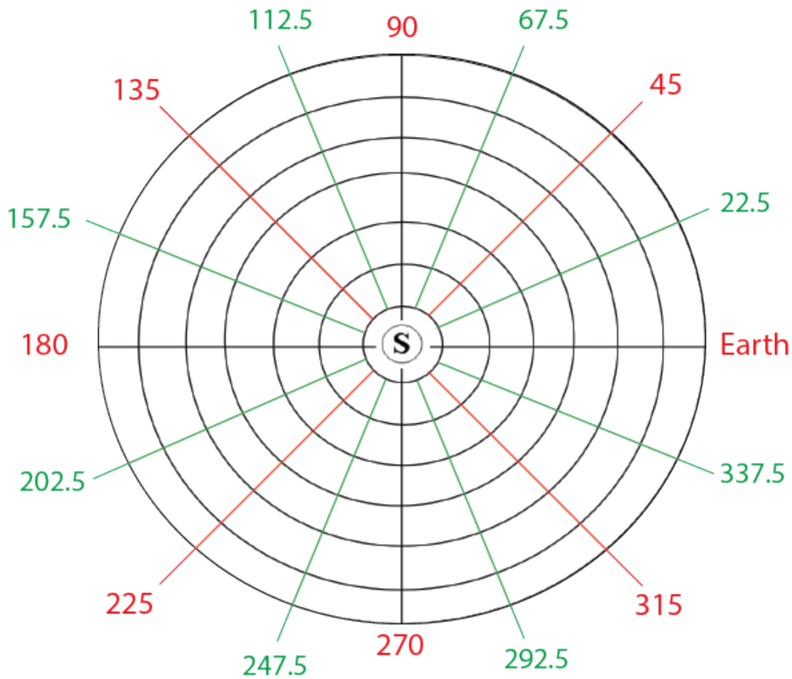
Students can generate and map other probable paths of CMEs ejected from the Sun at many different angles from 0° to 360°.

Note: Different CMEs travel at different speeds, which affect the distance that they travel over time, among other factors. The assumed values above are provided to simplify this activity for students.

Teacher Directions

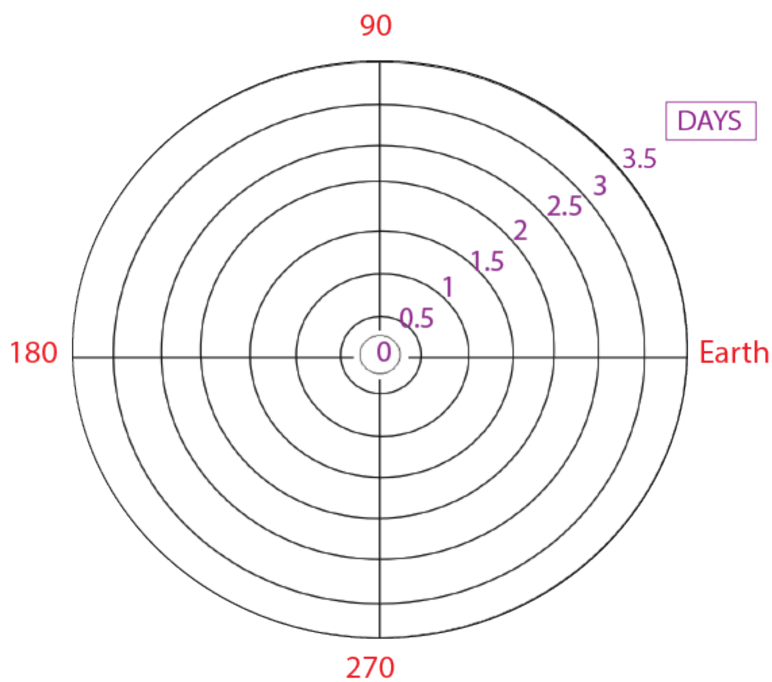
1. Label each angle on the grid using degrees as your unit. Draw and label additional angle lines between each 90º interval for more precise plotting

Example:



2. Because the provided CMEs' distances from the Sun increase linearly in approximate intervals of 20 million kilometers per 0.5 day, it is possible to label each circle as time in days, starting from Day 0 and increasing in 0.5 day intervals for each concentric circle.

Example:



Teacher Directions Cont...

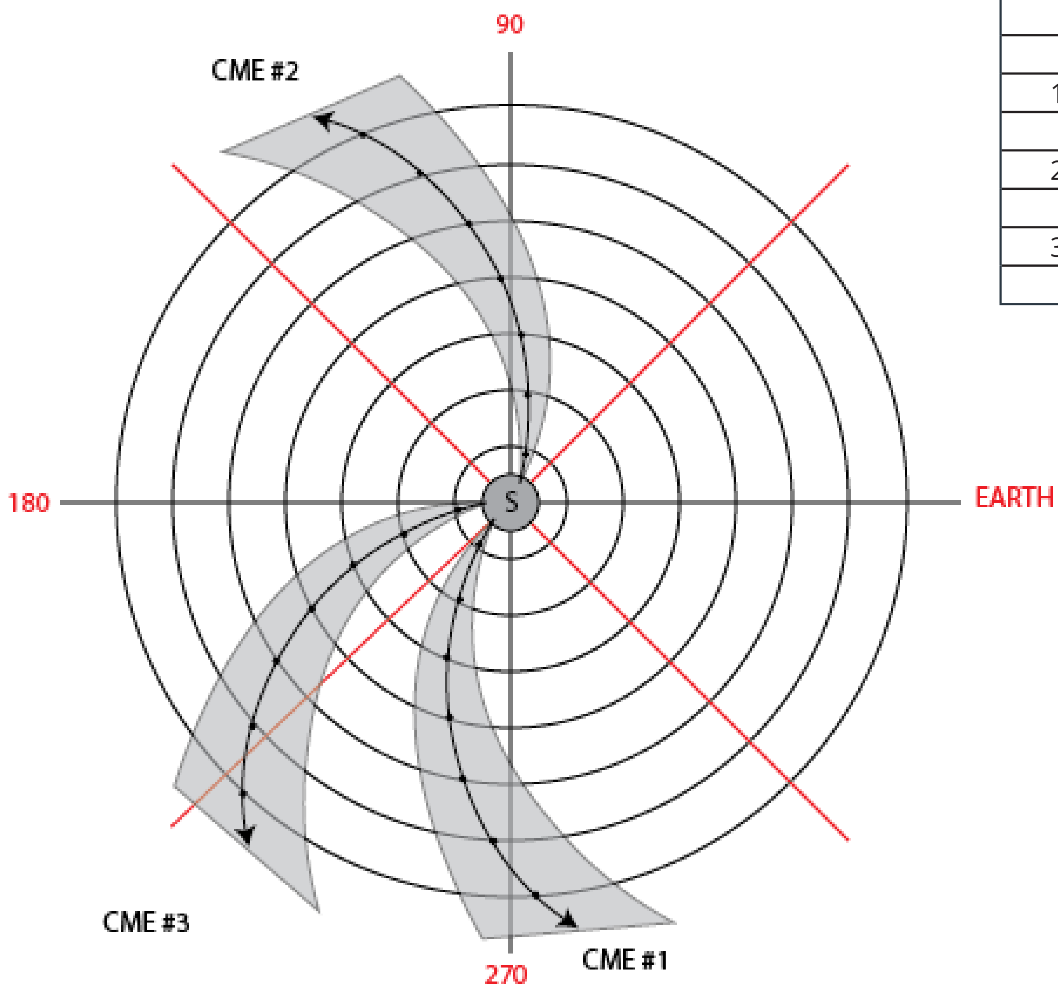
3. Now that the grid is ready, start plotting CME locations over time, using the data table provided. You will use the data in the "Day" and "Angle" columns to plot your points.

4. Once each location is plotted, draw to scale the width of the CME as indicated in the "Width" column of the data table. *Distances and widths are given in millions of kilometers. Students can calculate their own scale for drawing width measurements, or you can give them the conversion:

5. 20 million kilometers = 1 centimeter = 10 millimeters

6. Hand sketch the path of each CME and complete the shape by shading in between the width measurements.

Teacher Answer Key:



Key for Student Activity Sheet width scale

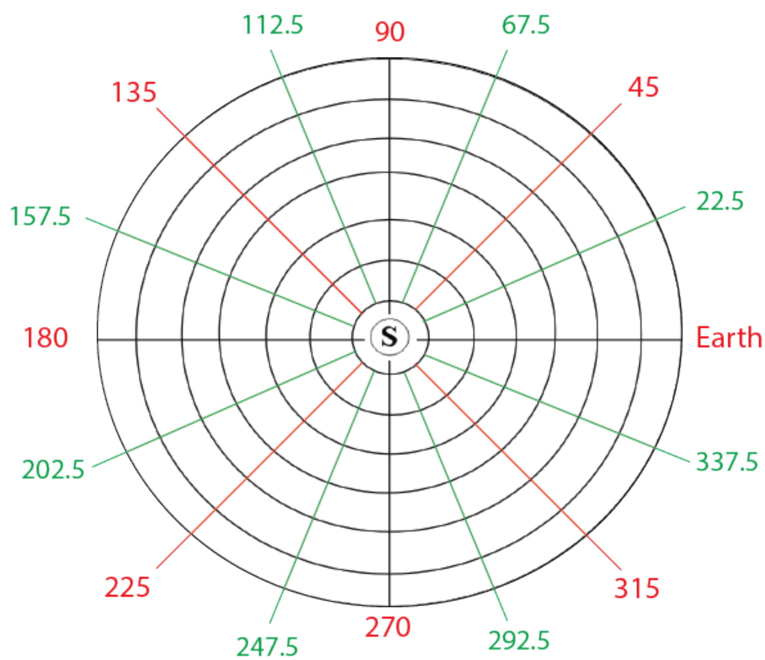
WIDTH (millions of kilometers)	WIDTH TO SCALE (MM)
0.5	0.25
7	3.5
13.5	6.75
20	10
26.5	13.25
33	16.5
39.5	19.75
46	23

CME Plotting - Student Activity Sheet

Directions

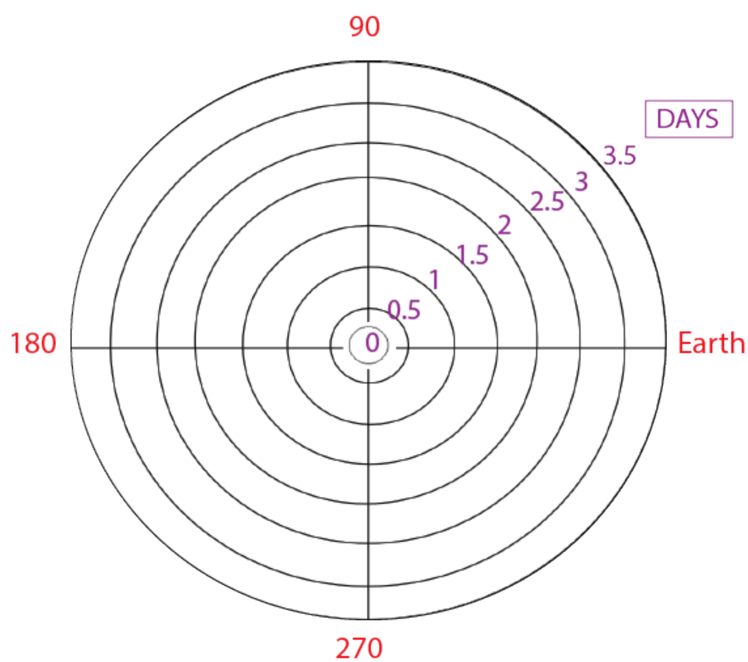
1. Label each angle on the grid using degrees as your unit. Draw and label additional angle lines between each 90° interval for more precise plotting.

Example:



2. Because the provided CMEs' distances from the Sun increase linearly in approximate intervals of 20 million kilometers per 0.5 day, it is possible to label each circle as time in days, starting from Day 0 and increasing in 0.5 day intervals for each concentric circle.

Example:



CME Plotting - Student Activity Sheet

Directions Cont...

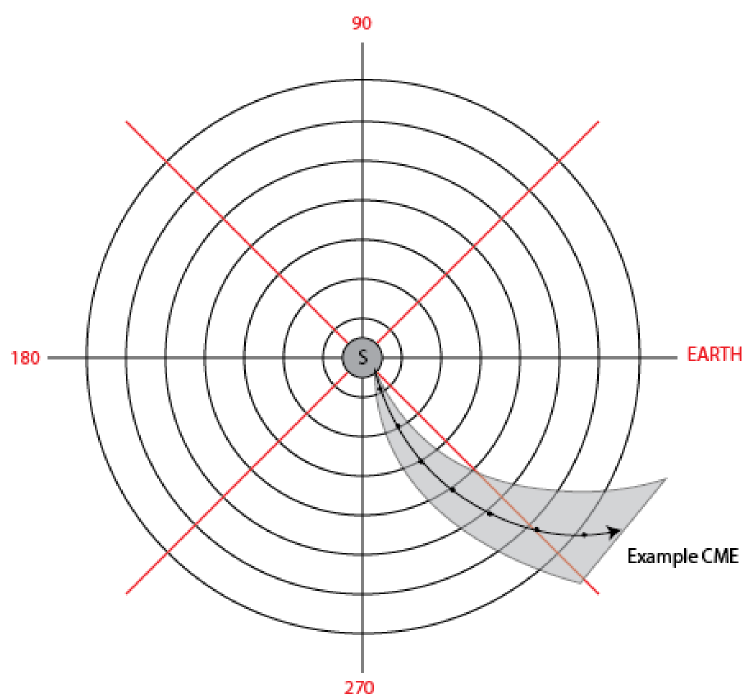
3. Calculate the scale width of each CME and record the values in the "WIDTH TO SCALE (mm)" column of each data table provided. Use the map grid provided to calibrate your measurements. Hint: the distance between concentric rings represent 20 million kilometers and measure 10 millimeters apart.

4. Using the data tables provided, plot the path of CME #1, CME #2, and CME #3 as they leave the Sun during their 3.5-day journey. You will use the data in the "DAY" and "ANGLE" columns to plot your points.

5. Using a ruler, draw to scale the width of each CME indicated in the "WIDTH TO SCALE (mm)" column.

6. Hand sketch the path of each CME by connecting your location points and drawing an arrow to indicate the direction that the CME is moving (away from the Sun). Complete the shape of the CME by shading in your width measurements.

Example:



7. Use the data provided for CMEs 1, 2, and 3, to determine at which angle a CME can emerge from the Sun and hit Earth. Then, fill in the "ANGLE" and "WIDTH TO SCALE (mm)" columns in the data table provided for "CME that hits Earth". Lastly, plot the path of this CME on your map grid and label it CME #4.

Student Activity Sheet - Data Tables

CME #1

DAY	DISTANCE (millions of kilometers)	ANGLE (degrees)	WIDTH (millions of kilometers)	WIDTH TO SCALE (MM)
0	0	225	0.5	
0.5	20	232	7	
1	40	239	13.5	
1.5	60	246	20	
2	80	253	26.5	
2.5	100	260	33	
3	120	267	39.5	
3.5	140	274	46	

CME #2

DAY	DISTANCE (millions of kilometers)	ANGLE (degrees)	WIDTH (millions of kilometers)	WIDTH TO SCALE (MM)
0	0	67.5	0.5	
0.5	20	74.5	7	
1	40	81.5	13.5	
1.5	60	88.5	20	
2	80	95.5	26.5	
2.5	100	102.5	33	
3	120	109.5	39.5	
3.5	140	116.5	46	

CME #3

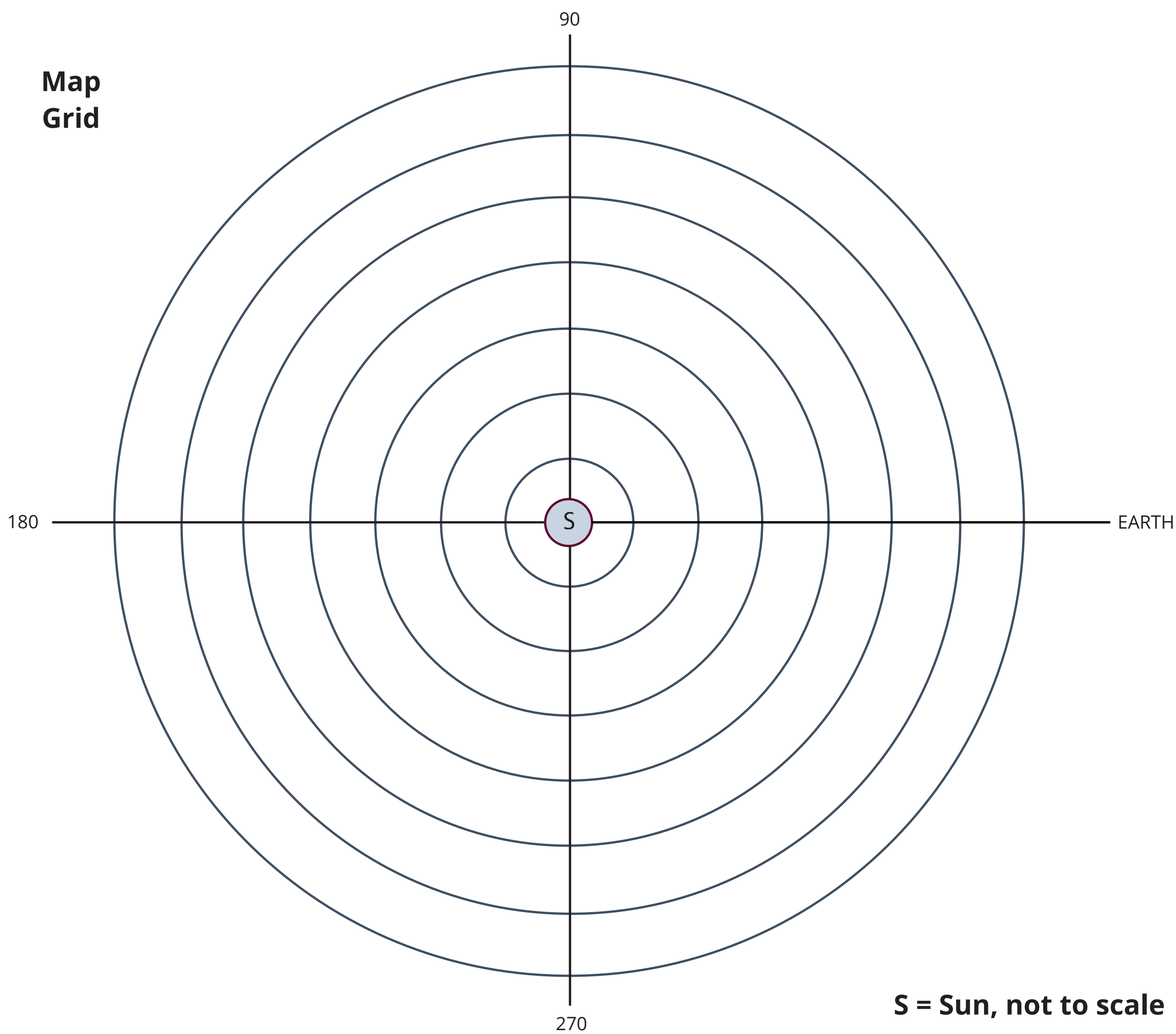
DAY	DISTANCE (millions of kilometers)	ANGLE (degrees)	WIDTH (millions of kilometers)	WIDTH TO SCALE (MM)
0	0	180	0.5	
0.5	20	187	7	
1	40	194	13.5	
1.5	60	201	20	
2	80	208	26.5	
2.5	100	215	33	
3	120	222	39.5	
3.5	140	229	46	

Student Activity Sheet - CME Plotting

CME that hits Earth:

DAY	DISTANCE (millions of kilometers)	ANGLE (degrees)	WIDTH (millions of kilometers)	WIDTH TO SCALE (MM)
0	0		0.5	
0.5	20		7	
1	40		13.5	
1.5	60		20	
2	80		26.5	
2.5	100		33	
3	120		39.5	
3.5	140		46	

Map Grid



S = Sun, not to scale

Conclusions

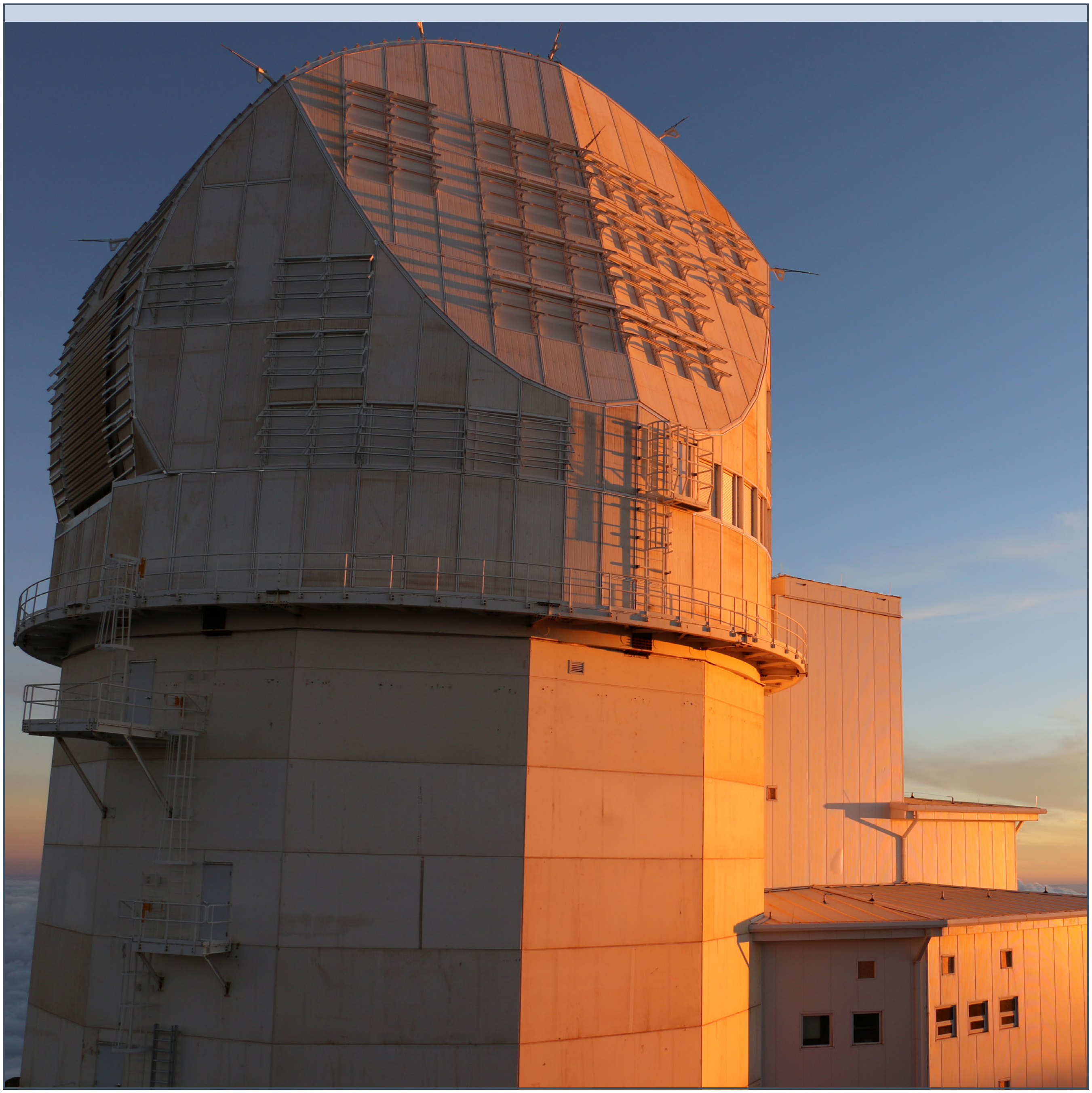
1. Based on your CME plot, do most Coronal Mass Ejections (CMEs) hit Earth? Why or why not?

2. The points in the tables were calculated for an assumed CME speed of 450 km/sec. How do you think CME paths or shapes might change if traveling at a speed twice as fast (900 km/sec.)? Challenge yourself by re-calculating the table entries for different speeds.

3. What are the limitations of this plotting activity? In other words, what other factors might be missing or not accounted for in this exercise. How might your results be different if you were tracking "real-life" CMEs? Explain.

Journey To The Sun Teacher Guide Lesson 6

Grades: 6 - 8
Duration: 1-2 class periods
Standards: MS-ETS1-3.4.1
SC.8.2.1



Observing the Sun

National Solar Observatory

Funded by the National Science Foundation

www.nso.edu

Objectives

At the end of this lesson, students will be able to:

1. Describe the scientific tools used in observing the Sun
2. Differentiate between types of telescopes and their abilities
3. Explain how lens or aperture size is related to image quality
4. Explain trade-offs and why they occur so often in science and society decision making

Standards

MS-ETS1-3.4.1
Analyze and interpret data to determine similarities and differences in findings.

SC.8.2.1
Describe significant relationships among society, science, and technology and how one impacts the other.

Key Vocabulary

Aperture

Lens

Refractor

Reflector

Telescope

Trade-off

Materials

- □ Lesson Packet: www.nso.edu/educators/jtts-curriculum
- □ Slideshow: "***Observing the Sun***"
- □ How Telescopes Work.mp4 (included)
- □ Activity Materials (See activity sheets)

Background

The invention of modern reflector telescopes has changed the ways in which scientists observe the Sun and space in a revolutionary way. In this lesson, students learn the basics of light collection, optics, and technologies involved in seeing the most distant objects on the Sun and in space. Following this interactive lesson, students practice tracking sunspots and graphing real data from professional telescopes. See the follow-up activities: "Sunspot Tracking" and "Sunspot Graphing Practice".

Directions

Using the slideshow provided, review with students the information provided on each slide.

Slide #

2. Students think critically to answer the question "Why do your pupils get bigger in the dark?" Students can share out their ideas in a number of ways, including think-pair-share, small group sharing, or writing answers on the board.

3. Facilitate the quick demonstration outlined on the slide. Students sit in the dark (or cover their eyes), then observe each other's pupils as the light is turned on.

4. Explain that the bigger your pupils get, the more light photons are captured. This is why pupils get bigger in the dark. This is the same reason for larger lenses and apertures in cameras and telescopes.

5. Lead a short discussion comparing images captured by human eyes vs images captured by cameras. Be sure to draw attention to the size of a human pupil vs camera lens size and how this relates to image quality.

6. In order to see very faint, very distant objects in space, large telescope mirrors and lenses are required.

7. Interactive slide / check for understanding. Students match lens sizes with images of different qualities. If students understand the content thus far, they will match the largest lens size with the best quality image.

8. Answers to the matching activity on the previous slide.

9. The black and white picture is the surface of the Sun at the level of detail as would be observed through a telescope with a 4m aperture or mirror. Be sure to point out that the image taken is of an area of the Sun comparable to the size of Earth.

10. Introduce the two basic types of telescopes: Refractor and Reflector.

11. Compare and contrast refractor and reflector telescopes.

12. Most professional telescopes are reflectors because they can be built larger. Thus, they provide brighter, clearer images.

13-22. Students identify refractor and reflector telescopes. Suggestion: convert these slides into an electronic survey or quiz using kahoot.it, where students can "buzz in" their answers.

23. Not only are there different types of telescopes (i.e. mirror vs lens), but different telescopes also observe different wavelengths of light.

Directions Cont...

Slide #

24. Point out that NASA's Fermi Gamma-ray observatory observes light in the gamma ray wavelength range of the electromagnetic spectrum.

25. Ask students to discuss the differences they observe between the solar images taken at different wavelengths by different telescopes.

26. Introduce students to the concept of "Space-Based" and "Ground-Based" telescopes

27. This infographic details the limitations of ground-based or space-based telescopes when observing different wavelengths of light. The higher the atmospheric opacity, the less observable the wavelength is through Earth's atmosphere. For example, Earth's upper atmosphere blocks gamma rays, x-rays, and UV light. These are best observed in space using space-based telescopes.

28-30. Discuss the differences and trade-offs between ground-based and space-based telescopes.

31. Introduce students to the concept of "trade-offs". A trade-off is like a compromise. If one thing increases, some other thing must decrease. Slides 28-30 detailed trade-offs between ground-based and space-based telescopes. For example: Space based telescopes can observe images in x-ray and gamma-ray more clearly than ground based telescopes, the trade-off is that they are more expensive to launch and repair.

32. Have students demonstrate their understanding of trade-offs by thinking of as many as they can, either regarding telescope technology or any other general topic, like doing homework for example.

33-39. Belief Circle. Give students the opportunity to identify and discuss their beliefs about a number of topics in science and society. Each slide gives a statement and students are to choose whether or not they agree with it. After a statement is given, have each thumbs up student pair with a thumbs down student and allow them to discuss and analyze their differences of opinion.

40. Introduce the follow-up activities: "Sunspot Tracking" & "Sunspot Graphing Practice", where students analyze data obtained by real, professional, telescopes and observatories. In the activity "Student Solar Observations", students gather, record, and analyze their own data using the Coronado Personal Solar Telescope.

Activity - Sunspot Tracking

Adapted by NSO from NASA and the European Space Agency (ESA).
https://sohowww.nascom.nasa.gov/classroom/docs/Spotexerweb.pdf / Retrieved on 01/23/18.

Objectives

In this activity, students determine the rate of the Sun's rotation by tracking and analyzing real solar data over a period of 7 days.

Materials

- ☐ Student activity sheet
- ☐ Calculator
- ☐ Pen or pencil

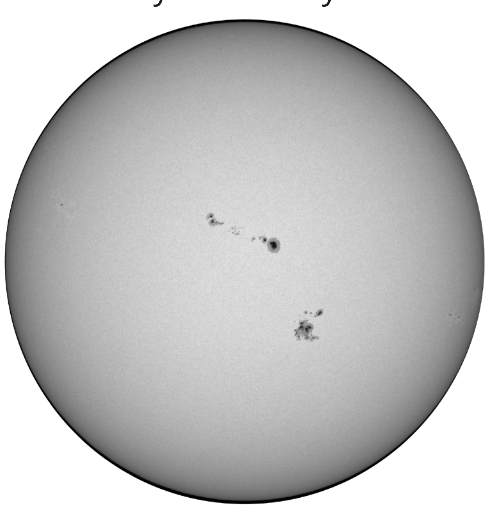
Background

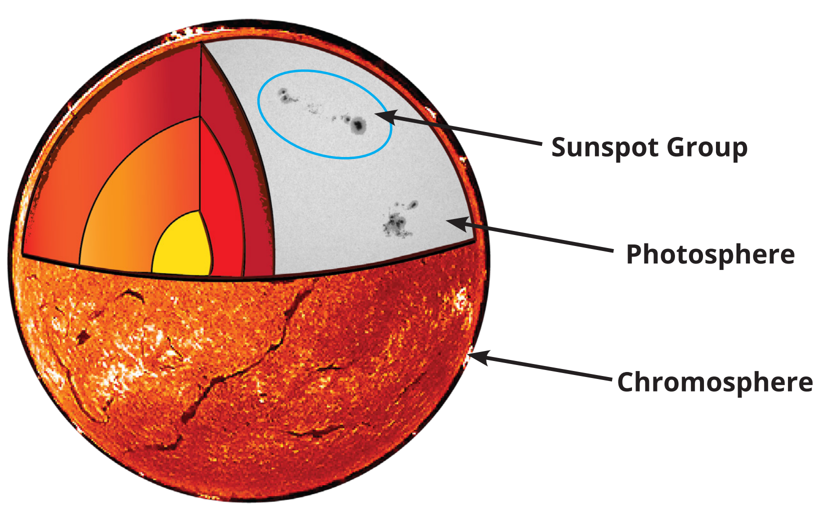
In this activity, you'll observe and track sunspots across the Sun, using real images from the National Solar Observatory's: Global Oscillation Network Group (GONG). This can also be completed with data students gather using www.helioviewer.org. See lesson 4 for instructions.

GONG uses specialized telescope cameras to observe different layers of the Sun in different wavelengths of light. Each layer has a different story to tell. For example, the chromosphere is a layer in the lower solar atmosphere. Scientists observe this layer in H-alpha light (656.28nm) to study features such as filaments and prominences, which are clearly visible in the chromosphere.

For the best view of sunspots, GONG looks to the photosphere. The photosphere is the lowest layer of the Sun's atmosphere. It's the layer that we consider to be the "surface" of the Sun. It's the visible portion of the Sun that most people are familiar with. In order to best observe sunspots, scientists use photospheric light with a wavelength of 676.8nm.

The images that you will analyze in this activity are of the solar ***photosphere.*** The data gathered in this activity will allow you to determine the rate of the Sun's rotation.





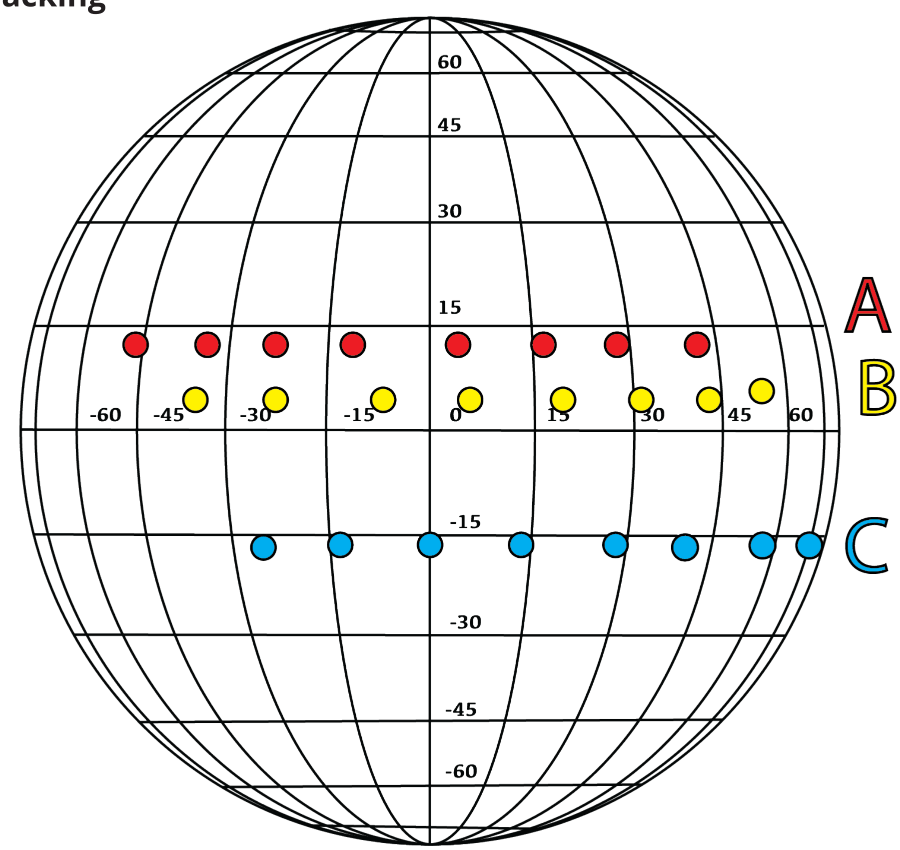
Directions

This activity can be completed individually or in groups of 3. Each student in a group will track one of the 3 visible sunspot groups (A, B, or C). If a student works individually, they will track all 3 sunspot groups.

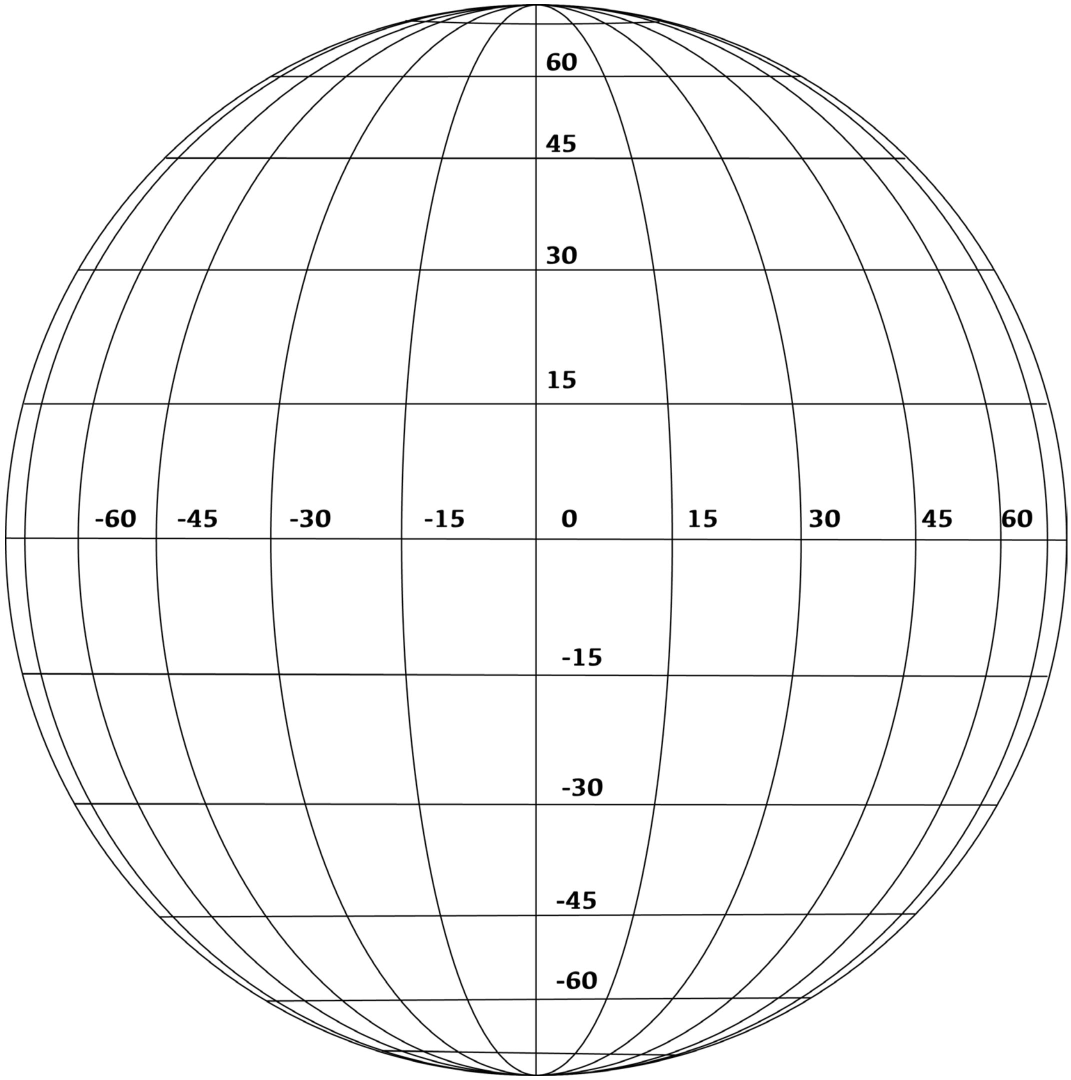
1. Print out the Sunspot Tracking Data Sheet. Each student or group of students will need one.
2. Observe the sunspot images from September 1st to September 8th.
3. For each day, mark where the sunspots appear on your mapping grid. Note the date and any changes in shape or size. Also, write down each sunspot's position in terms of longitude.

This activity is meant to simulate stepping outside at the same time each day and observing sunspots with a solar telescope. NSO images are provided to use in the event that there are no actual sunspots present on the sun at the start of this activity.

Sample Tracking Grid

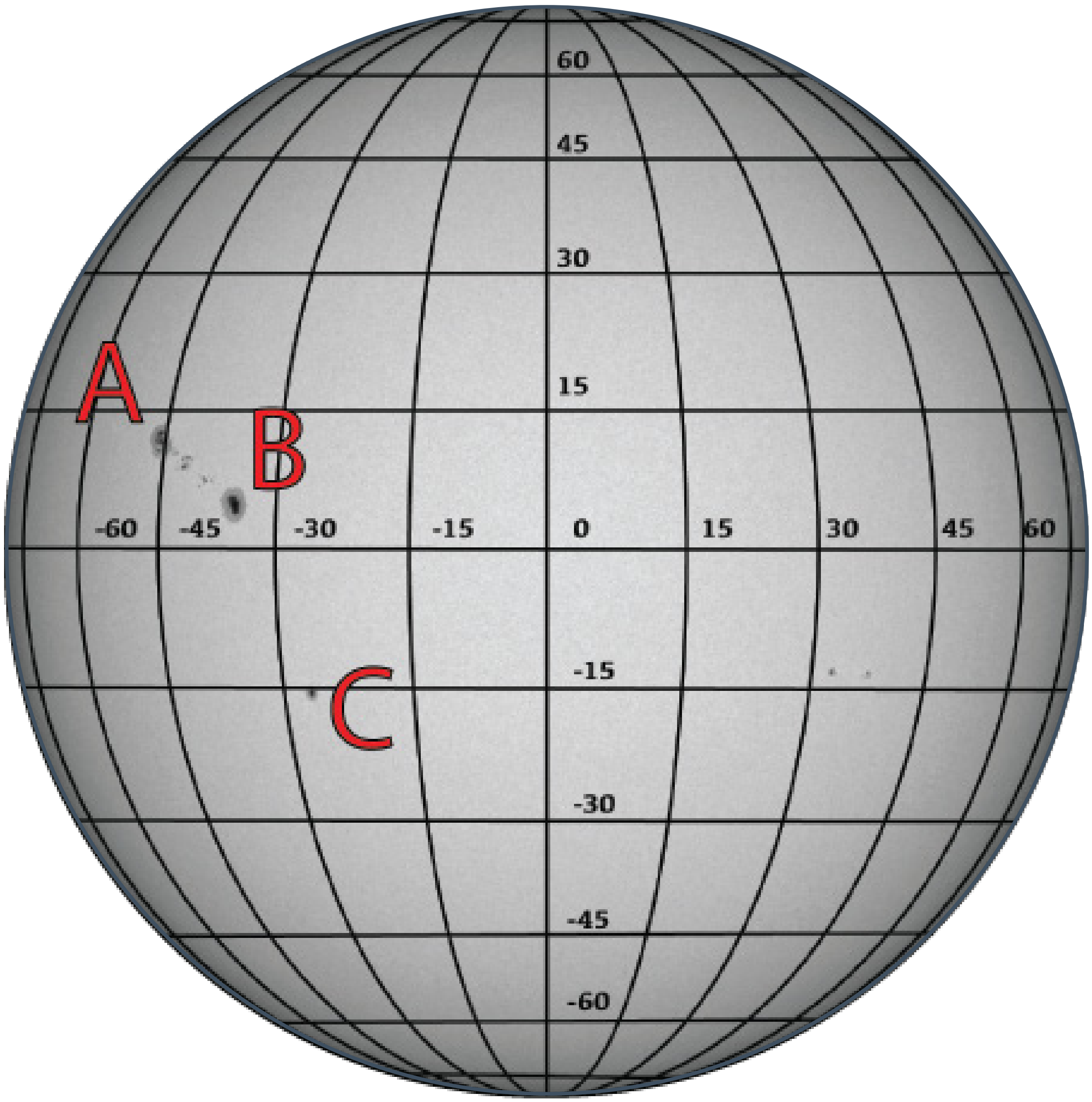


Sunspot Tracking - Student Data Sheet

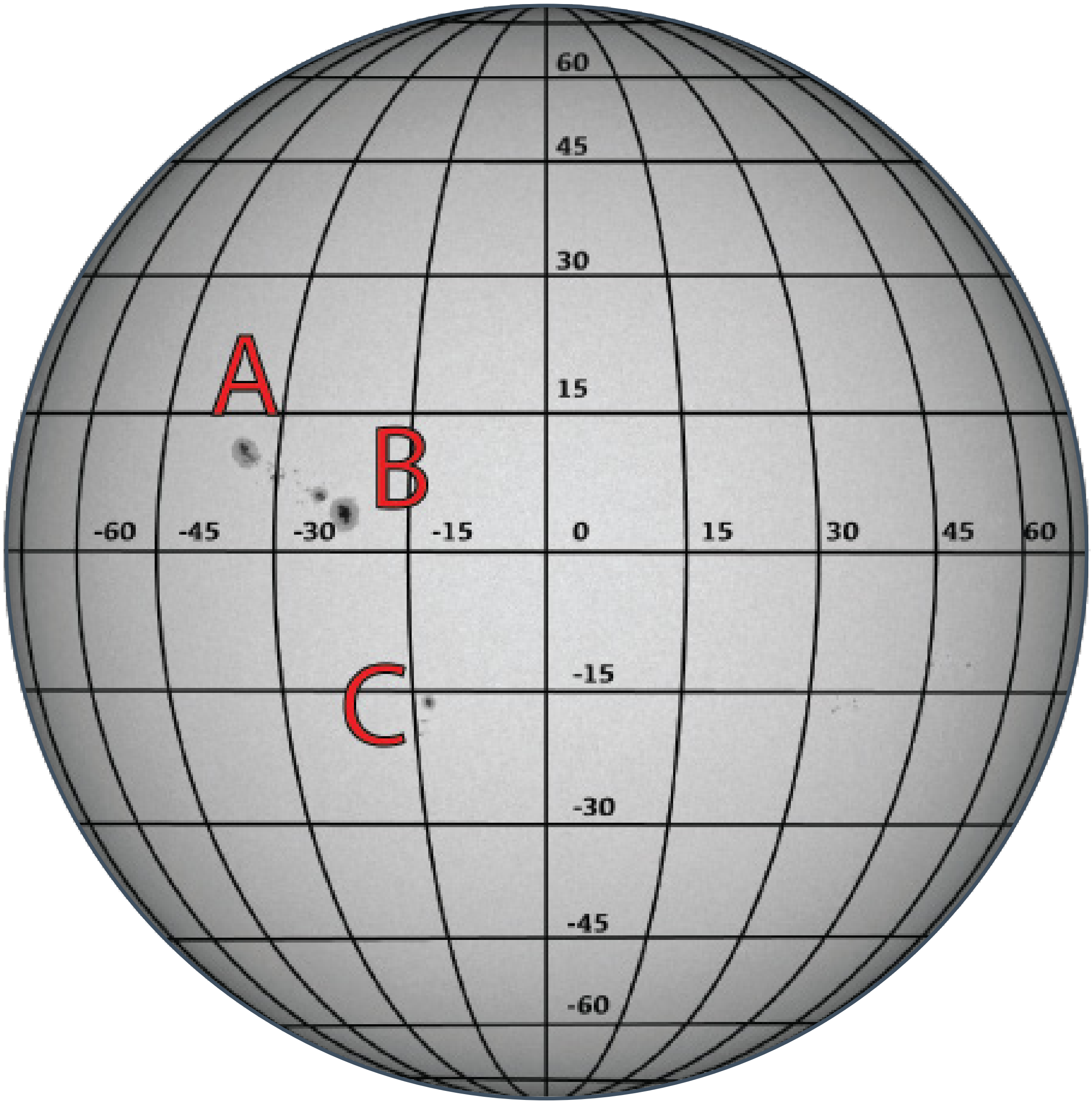


DAY	Sunspot Longitude (degrees)			Number of degrees sunspots moved from previous day		
	A	B	C	A	B	C
1						
2						
3						
4						
5						
6						
7						
8						

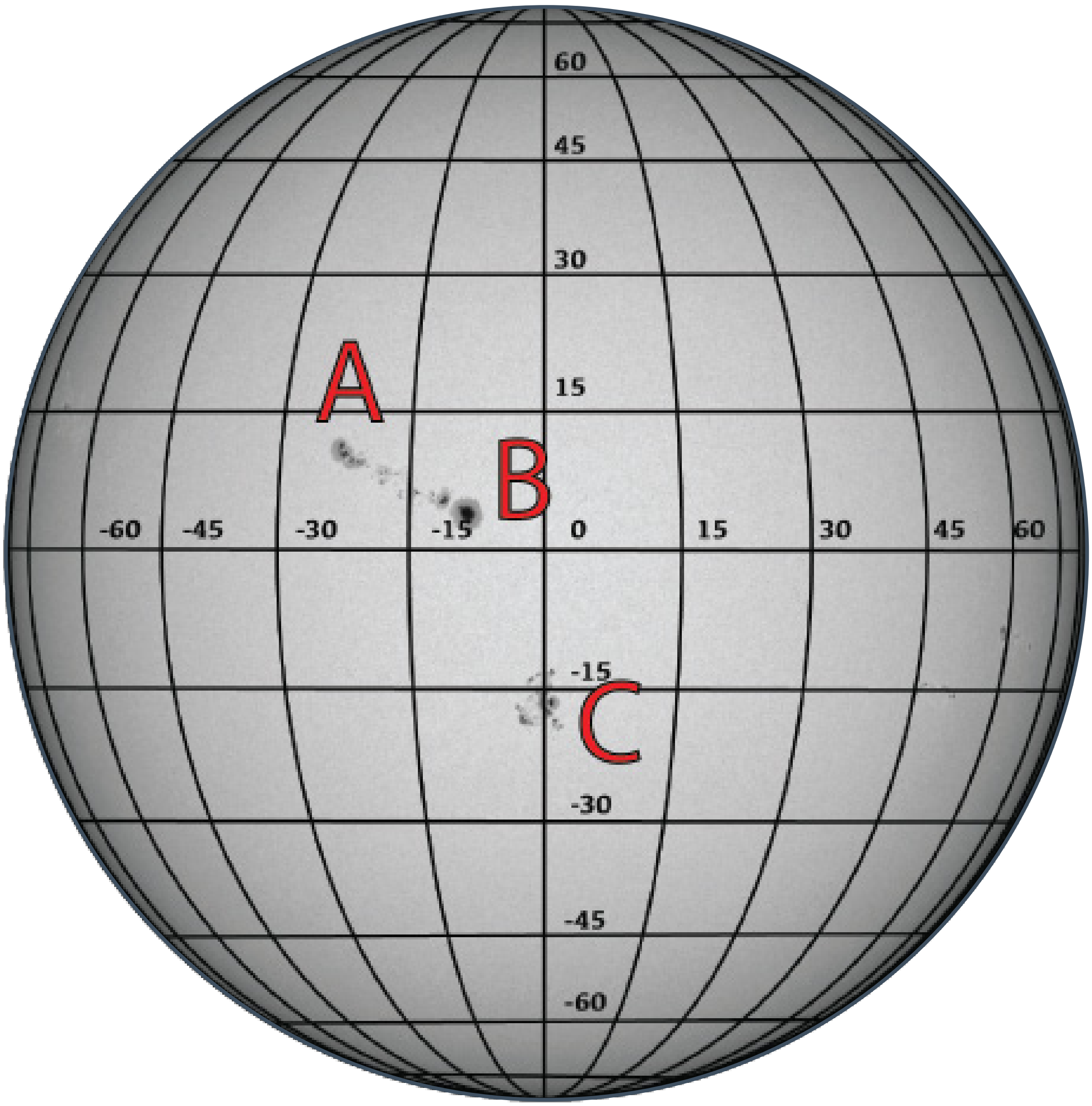
September 1st



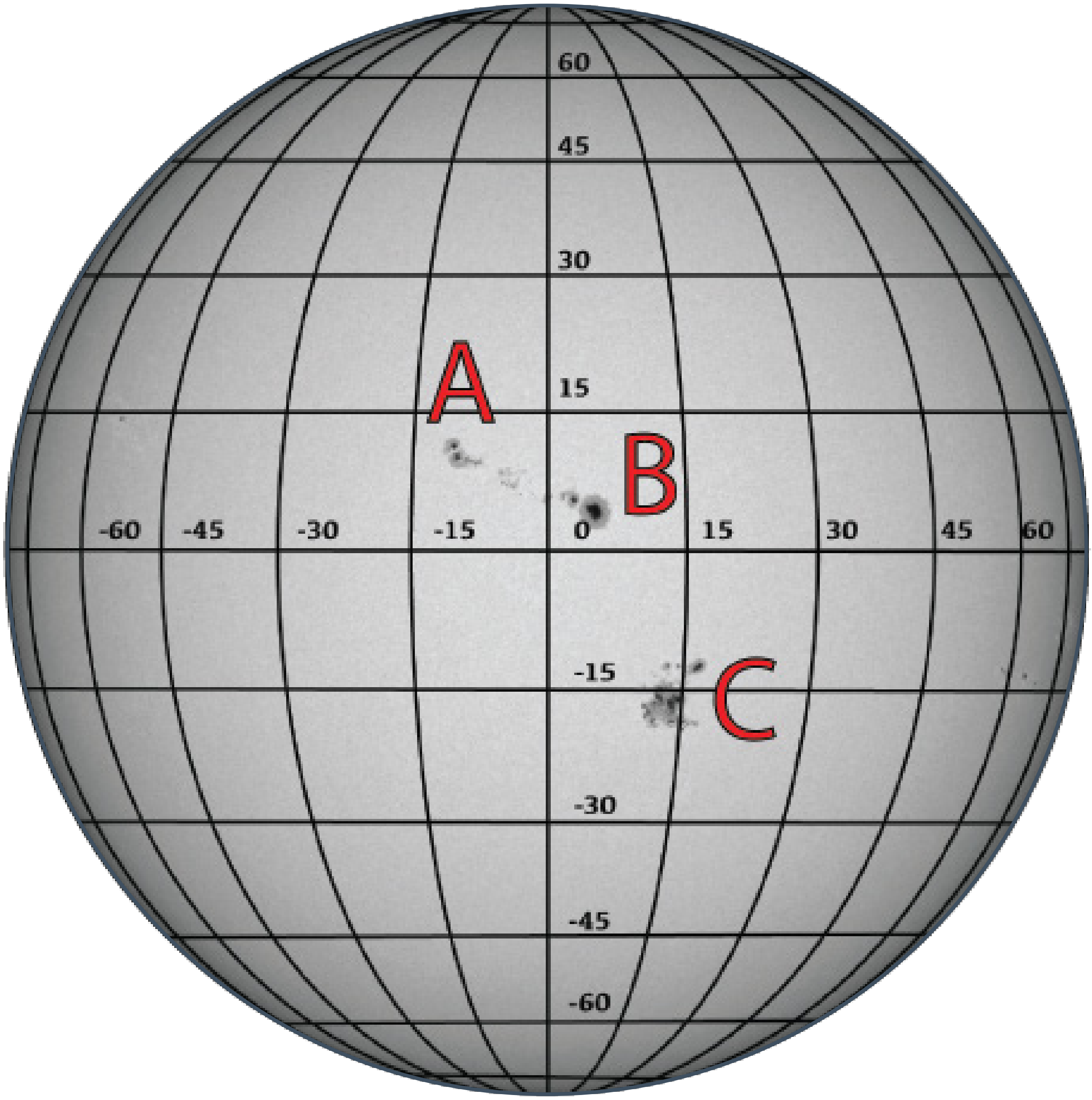
September 2nd



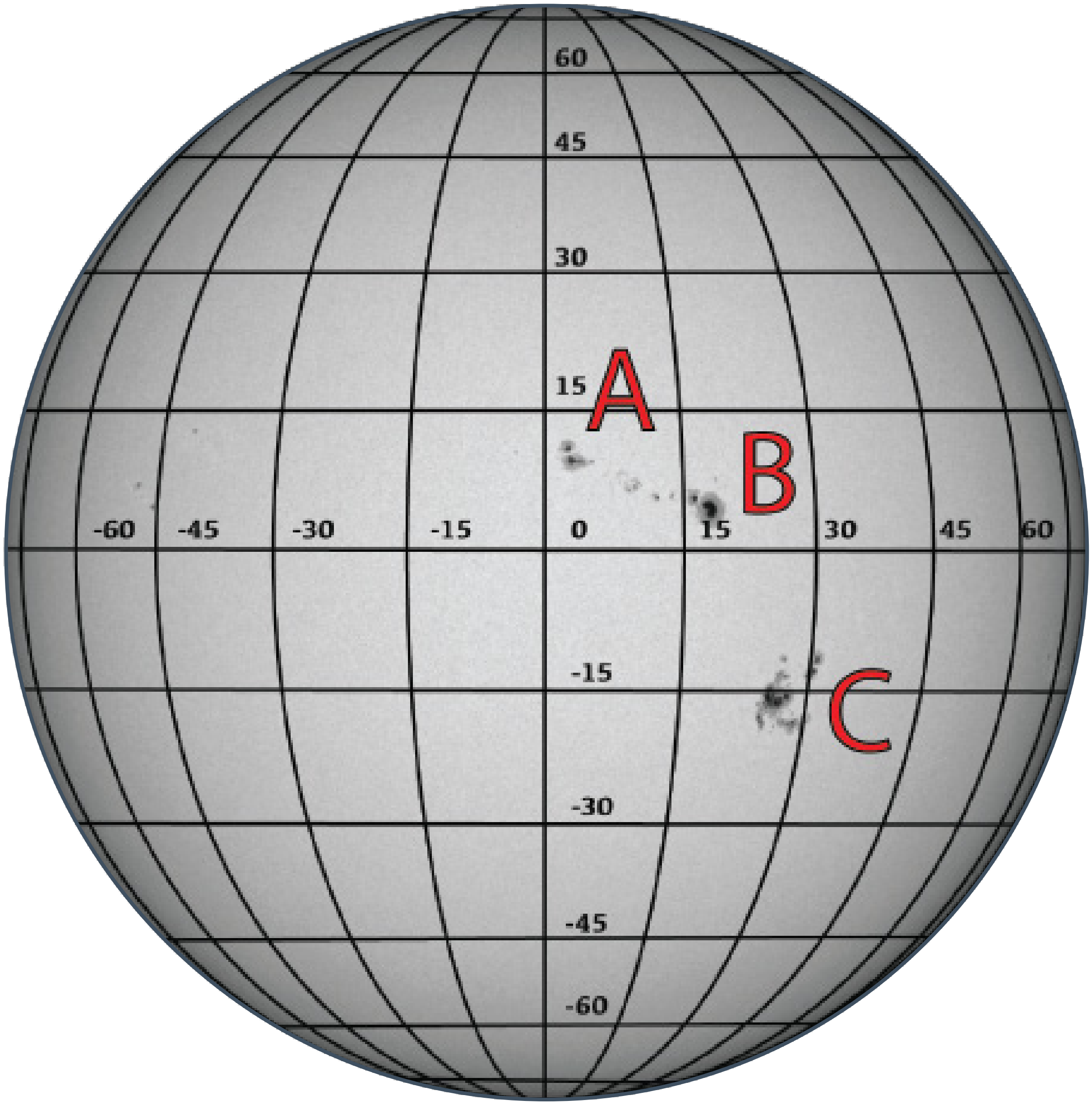
September 3rd



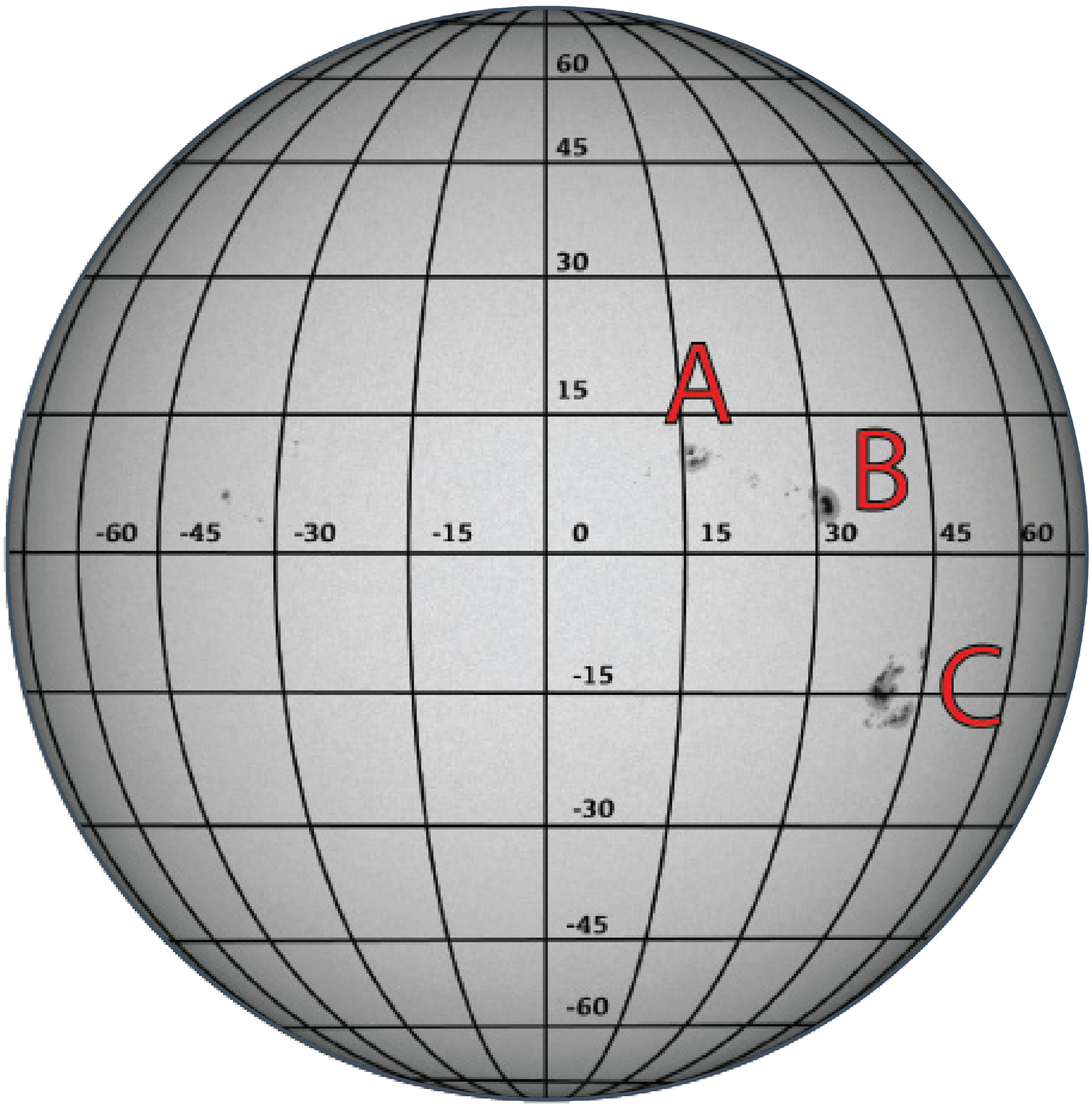
September 4th



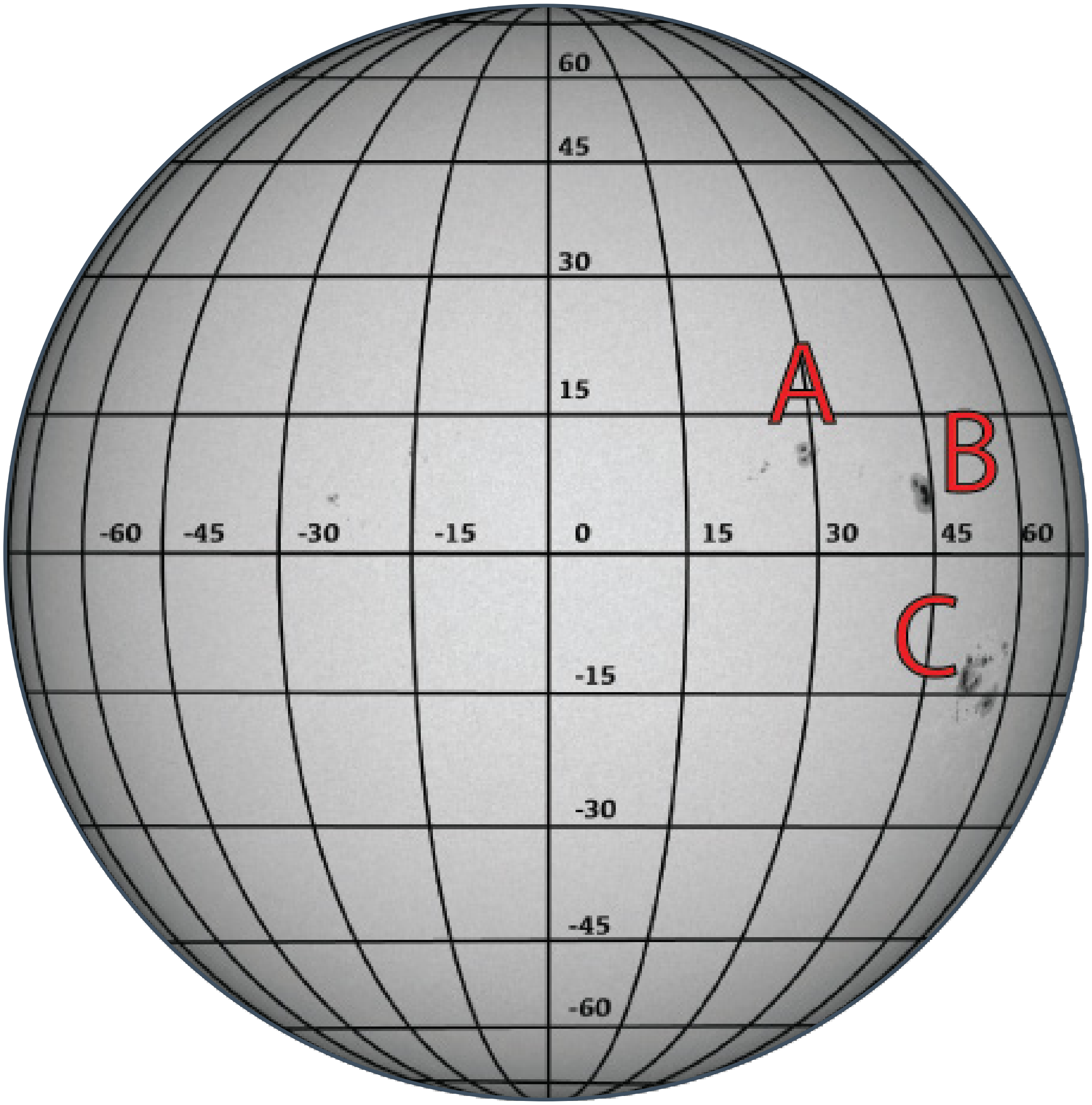
September 5th



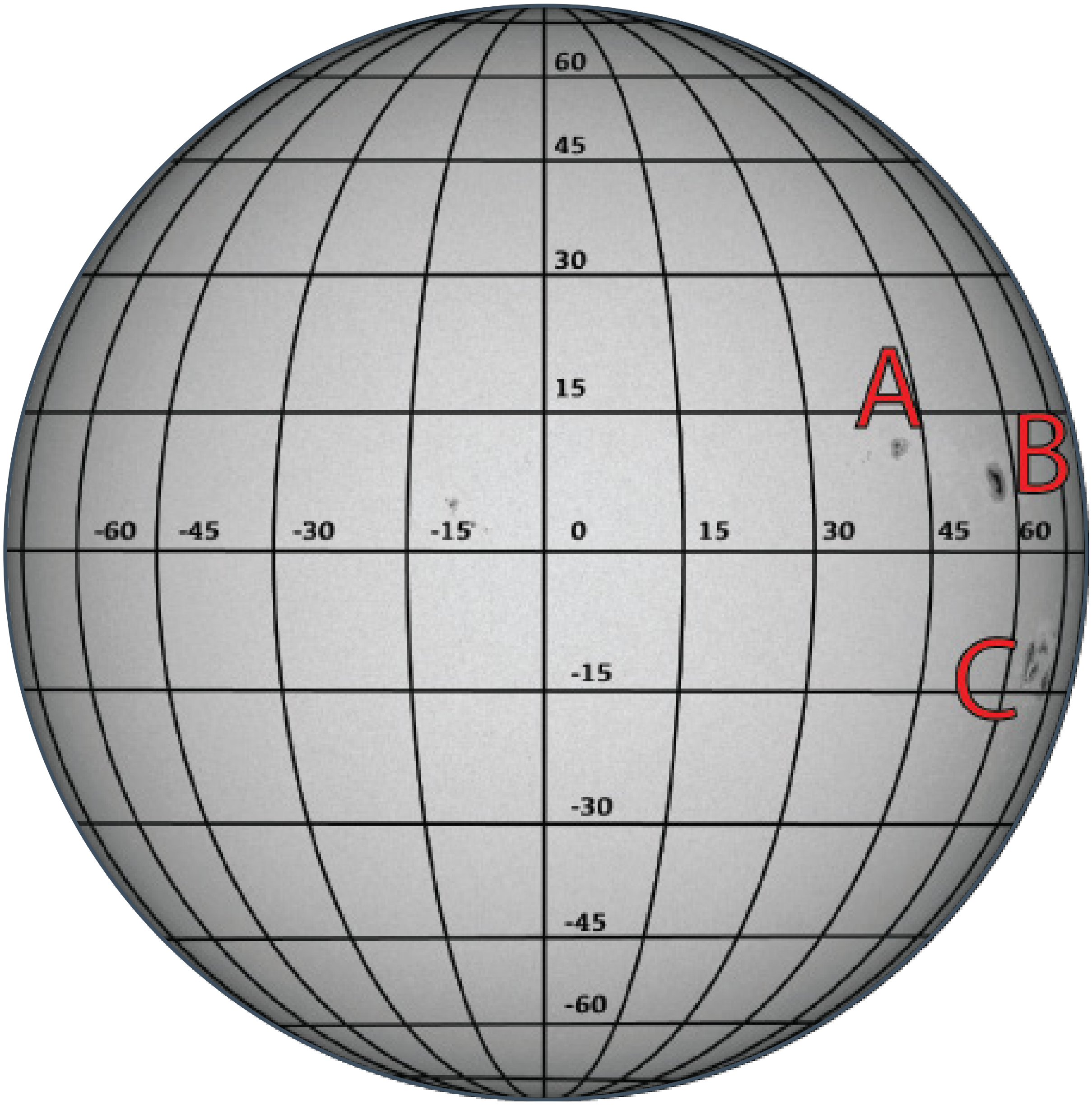
September 6th



September 7th



September 8th



Analysis

What is the average daily rate of sunspot movement?

To answer this, determine the total degrees of change from one day to the next. For example, if you noted the sunspot at -60° on Monday, than at -45° at the same time on Tuesday, then you can conclude that the sunspot moved 15° in one day. Repeat this calculation for each 24-hour period. Then, add the daily movement values together and divide by the total number of days (24-hour periods) over which the changes took place.

Example:

DAY	Sunspot Longitude (degree)	Number of degrees sunspot moved from previous day
Day 1	-60	
Day 2	-50	(60-50) = 10
Day 3	-40	(50-40) = 10
Day 4	-30	(40-30) = 10

Total number of degrees moved = (10+10+10) = 30

Total number of observation days = (4-1) = 3 days

Average rate of sunspot movement = 30 degrees / 3 days = 10 degrees per day.

**Remember, this is just an example, Sunspots do NOT actually move at a rate of 10 degrees per day. You will calculate the actual rate using the data that YOU gather.*

Fill in with your ACTUAL data:

Total Number of Degrees Moved from Day 1 to Day 8 =

A:____ B:____ C:____

Total Number of Days (24-hr. periods between day 1 and day 8) = 7

Rate of Sunspot movement =

A: ______ degrees per day

B: ______ degrees per day

C: ______ degrees per day

Average Rate of Sunspot Movement between groups A, B, and C:

__________________ degrees per day

How long does it take the Sun to make one full rotation of 360°?

To answer this, first we need to recognize that the Earth moves around the Sun in the same direction at about 1° per day:

Earth revolves 360° around the Sun in about 365 days.

Thus:

360/365 = 0.99° per day (approximately 1 degree per day)

Therefore, because our telescopes are located on Earth, it seems like the Sun is rotating slower than it really is. We have to correct for this; we must add 1° per day to our initial calculation.

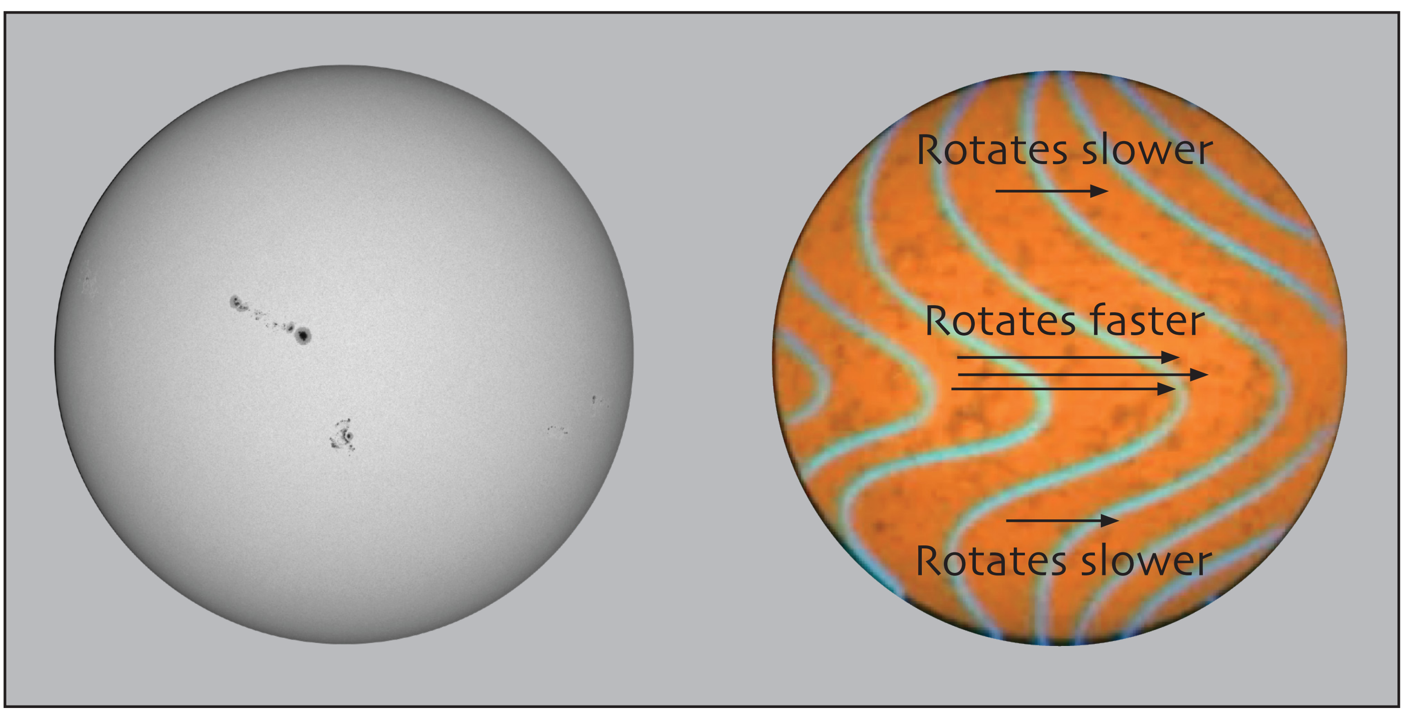
For example: If your initial calculation gave you a sunspot rate of 12° per day, the corrected rate would be 13° per day.

Lastly, use this information to draw your conclusion.

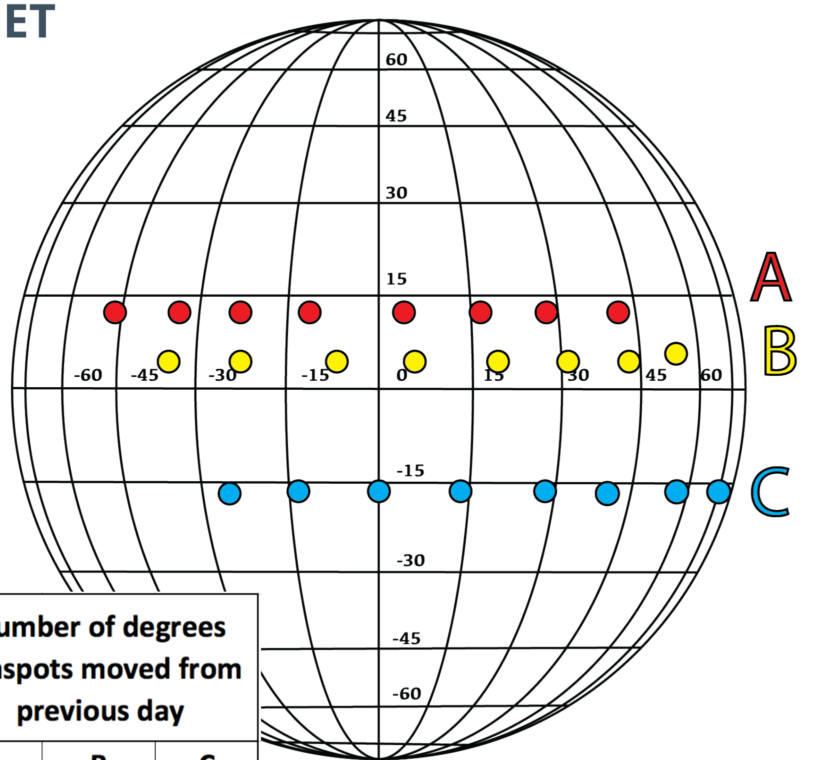
How long does it take the Sun to rotate 360°?

The Sun rotates once every ____ days

Note the Sun isn't a solid object, therefore it does not rotate at the same rate everywhere on its surface. The Sun rotates slightly faster at the equator than it does near the poles.



Sample Answer Sheet



DAY	Sunspot Longitude (degrees)			Number of degrees sunspots moved from previous day		
	A	B	C	A	B	C
1	-46	-35	-24			
2	-34	-23	-13	12	12	11
3	-24	-7	0	10	16	13
4	-12	5	14	12	12	14
5	3	17	29	15	12	15
6	16	31	40	13	14	11
7	28	38	59	12	7	19
8	41	49	75	13	11	16

Total Number of Degrees Moved from Day 1 to Day 8 =
A: 87 B: 84 C: 99

Total Number of Days (8-1) = 7

Rate of Sunspot movement =
A: (87/7) = 12.43 degrees per day
B: (84/7) = 12 degrees per day
C: (99/7) = 14.14 degrees per day

<u>How long does it take the Sun to rotate 360 degrees?</u>
Average degrees per day = (12.43 + 12 + 14.14) / 3 = 12.86
Account for the Earth's revolution (12.86 + 1 = 13.86)
360 degrees / 13.86 degrees per day = 26 days

*Remember, this is not a precise measurement. The Sun rotates at different speeds between the poles and equator.

Activity - Student Solar Observations

Objective

In this activity, students gather, record, and analyze their own data using the Coronado Personal Solar Telescope.

SAFETY WARNING

Never look at the Sun through an ordinary telescope without a solar filter. This can lead to severe eye damage and blindness. Only specialized SOLAR telescopes/filters should be used to view the Sun.

Materials

- ☐ Coronado Personal Solar Telescope
- ☐ Observation Data Sheets (included)
- ☐ Camera or cell phone for taking pictures (optional)
- ☐ Internet access (to verify observations)
- ☐ Pen or pencil

Background

NEVER TRY TO OBSERVE THE SUN WITHOUT EYE PROTECTION, IT CAN LEAD TO BLINDNESS!

The Sun radiates so much light that in order to observe it safely, we must use telescopes with special filters that only let some of the light through. The filter you will be using is called a "Hydrogen-alpha" filter, which only lets wavelengths of approximately 656nm (red light) through. This filter should allow you to see solar prominences, filaments, flares, and even sunspots!

In the activity, you will:

1. Observe the Sun using a Coronado Personal Solar Telescope, which uses an H-alpha filter.
2. Sketch images of the Sun either daily, weekly, or monthly.
3. Demonstrate that the Sun rotates, by recording sunspot positions over time.
4. Record the number of sunspots visible on the Sun on any given day.

Telescope Make: Meade Coronado
Telescope Model: Personal Solar Telescope (PST)
Aperture Size: 40mm
Focal Length: 400mm

Directions

1. Determine where the Sun rises. Find a reference point where you will know to look when trying to find the Sun on its path. What times did the Sun rise and set on the day of your observation?
2. Observe through a solar telescope
3. How many sunspots can you see? What are their locations?
4. How many filaments can you see? What are their locations?
5. How many prominences can you see? What are their locations?
6. List some differences between what you observed yesterday and today. Sketch what you see.
7. Verify your observations. Visit National Solar Observatory's H-Alpha Monitor:

   halpha.nso.edu

8. Write a quick journal entry about the day's observations.
   - Did you notice anything different or special?
   - What was your favorite observation?
   - Make predictions about what you'll see the next day, week, year...
9. Record your responses on the observation data sheets provided.

Student Data Sheet

Date: ______________

Time: ______________

Scientist (student name): ____________________

Weather conditions ________________________

Sky conditions ____________________________

Telescope make & model:

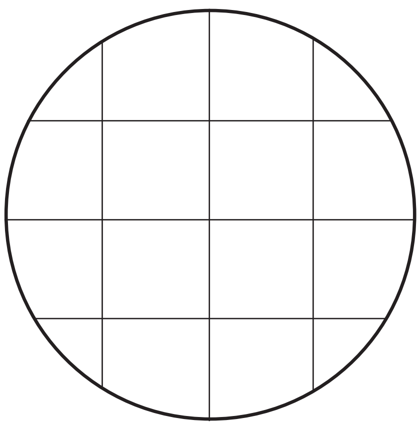
____

Aperture size: _______________________

Focal Length: _______________________

Observe the Sun:

Carefully sketch what you observe through the telescope. Draw as many features as you can.



# of Sunspots visible: _____

# of Filaments visible: _____

# of Prominences visible: _____

Written description of observations:

(colors, sizes, and locations of features) ___________________________

____

____

____

____

Verify your observations with the following websites:

http://halpha.nso.edu
www.helioviewer.org

Does what you observed through the telescope match what you found online? Explain.

Additional observations from the online resources:

Journal Entry:

____

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The National Solar Observatory (NSO) is the national center for ground-based solar physics in the United States and is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation Division of Astronomical Sciences.

The National Science Foundation (NSF) is an independent federal agency created by Congress in 1950 to promote the progress of science. NSF supports basic research and people to create knowledge that transforms the future. Please refer to www.nsf.gov.

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