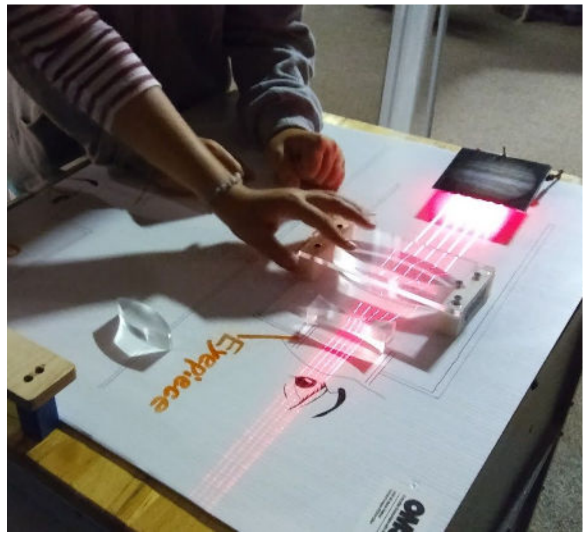
Lenses on the Sky

Educator Guide



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Introduction to the Project

The *Lenses on the Sky* project encourages people to think about the "big idea" that humans across time and around the world have used tools to observe and understand the sky. Audiences explore this topic through three main "lenses" or frames: a NASA lens, a tools lens, and a cultural lens. The goals of the project are for participants to:

- Understand the big idea
- Recognize the relevance, value, and scientific achievements of NASA missions
- Be inspired to learn more about topics related to space science, STEM careers, and NASA

To achieve these goals, the Oregon Museum of Science & Industry (OMSI) created a bilingual (Spanish/English) exhibition outside OMSI's planetarium, a Star Party program for rural areas, and this Educator Guide for classroom teachers and informal educators.

The focus of the *Lenses on the Sky* project is to introduce a resource that we all share—the sky. While celestial bodies and phenomena are not always visible, most people have at least some means of observing the sky. Even urbanites in cloudy Portland, Oregon (where OMSI is located) can occasionally see the Sun, the Moon, stars, and perhaps even a meteor by simply stepping outside.

To connect with that shared skywatching experience, we chose to focus on the celestial objects and phenomena that people can see with their naked eyes and simple, accessible tools. The purpose of the project is not for audiences to learn facts about astronomical objects, though. We want to help people understand how we as humans observe and understand the sky. Therefore, the activities in this guide highlight the observational technologies, stories, artwork, calendars, and other human tools that help us relate to what we can see in the sky. We worked closely with the diverse communities and leaders who hold this information, as well as referencing documented resources. Our key audiences are Hispanic, African American, and Native American youth, so the team worked with advisors and partners to identify content from Africa and Native North, Central, and South America, as well as highlighting NASA projects that involve personnel from diverse backgrounds.

Content Background

The interplay of the Sun*, Moon, stars, and Earth gives us the cycles that mark space and time. The length of a day, the ebb and flow of the tides, and the demarcation of east and west are prime examples of how the interplay of the Sun, Moon, and Earth define our world.

Cultures around the world track these celestial cycles and marvel at spectacular celestial events such as eclipses darkening the Sun and meteors blazing across the night sky. Similarly, every culture has a story to explain these phenomena. The stories, whether of gods or gravitational forces, help us understand our place in the universe. The stories, captured in words or artwork, allow us to observe and draw relationships between the heavenly bodies and ourselves.

The activities in this guide introduce a variety of tools that people have used to observe and understand the sky. The tools include the physical objects we use to track the sky such as telescopes and solar observatories, as well as cultural tools that help us see the patterns and relationships in the sky such as constellations and calendars. Here are some of the types of tools that we include in the *Lenses on the Sky* activities.

**** Confused about capitalization?*** *We have capitalized sun, moon, and earth when they refer to the Sun (star closest to Earth), Moon (Earth's moon), and Earth (the planet we live on). If the term is used as a sun (center point of another solar system), a moon (planetary body orbiting another planet), or earth (soil), we do not capitalize.*

Eyes & Hands
The most basic observational tools that people use to observe the sky are their eyes and hands. For example, Polynesian canoe voyagers (past and present) travel across the ocean for hundreds of miles measuring their latitude using just their hands, the horizon, and the North Star (Exploratorium n.d.). Similarly, if a Tuareg herder's GPS dies as they navigate their camel herds across the great expanse of the Sahara Desert, the skilled travelers rely on their knowledge of the stars to reach their destination.

Buildings & Monuments
People around the world have used buildings and monuments to mark the passage of the Sun, Moon, planets, and stars. The Maya people of Central America are particularly keen observers of the heavens. Temples, monoliths, and wells were built to mark the

zenith passage of the Sun, solstices, and other celestial phenomena. Today, Maya Day Keepers continue to track the precise Maya calendar for their communities (Smithsonian National Museum of the American Indian 2017).

Quadrants

In the Islamic Golden Age (eighth to fifteenth centuries CE) astronomers invented and used new tools, including quadrants, to make precise measurements of the stars and planets. These measurements led Islamic astronomers to form new models for how the universe and celestial bodies worked. Three hundred years later European scientists used the Islamic astronomers' measurements to argue for a heliocentric (Sun-centered) model of the solar system (King 1996, Stirone 2017, BBC 2017).

Telescopes

Galileo Galilei was one of the first people to use a telescope to observe and study the Moon and other celestial bodies. His ingenuity and enthusiasm for the telescope ushered in a long history of technological advances in observational tools (Penphase 2011). Today, there are giant optical and radio telescopes on Earth as well as complex instruments such as the *Hubble Space Telescope* beyond Earth's atmosphere (NASA 2017a, Thompson 2009).

NASA Missions & Instruments

NASA has sent exploratory spacecraft to many corners of the solar system. Some of the most important NASA missions include (https://www.nasa.gov/missions):

- Curiosity, a Mars rover, touched down on the Red Planet at Gale Crater in 2012. The rover has studied the chemical composition of Mars's thin atmosphere. Several future missions to Mars, including sending humans, are currently in development.
- The *Hubble Space Telescope*, a telescope orbiting the Earth, sends us spectacular pictures of planets, stars, and galaxies in ultraviolet, optical, and infrared light.
- The International Space Station, a human habitat orbiting nearly 250 miles above the Earth, serves as a platform for science experiments in microgravity.

Calendars & Holidays

Calendars and holidays are often directly linked to the sky. Days mark one rotation of Earth on its axis. A month is based on one lunar cycle (29.5 days). The Gregorian calendar (365.2425 days) lasts the length of one revolution of the Earth around the Sun (Penphase 2011). Calendars in many cultures use a combination of lunar and solar cycles to determine the year (Penphase 2011). Therefore, holidays such as new year celebrations (e.g., Jewish Rosh Hashanah, Tibetan Losar) tie directly to the movement of the Sun and Moon (Penphase 2011). Other holidays are linked to the position of the Sun in the sky or phase of the Moon. For example, Easter is the first Sunday after the first full Moon after the spring equinox in the Northern Hemisphere (United States Naval Observatory 2016).

Ancient Maya astronomers created precise calendars to track the solstices, equinoxes, cross-quarter days (midpoints between solstices and equinoxes), and other celestial events. Contemporary Maya Day Keepers still follow these calendars to inform the lives of their communities (Exploratorium 2017). For example, Day of the Dead takes place at the nadir* passage of the Sun as experienced in Southern Mexico, and marks a time when the worlds of the living and the dead are connected. (*The nadir passage is when the Sun appears to pass directly below Earth at that latitude). (Mendez n.d., Smithsonian National Museum of the American Indian 2017).

Constellations & Sky Stories

Cultures from every corner of the globe see pictures in the scatter of the stars. Constellations often illustrate a community's most important stories. The combination of image and story also creates a dynamic map of the stars that narrates their apparent movements throughout the year.

The International Astronomical Union (IAU) bases its map of the sky on ancient Greek and Roman constellations, but every culture connects the stars in its own way (Penphase 2011). The Diné (Navajo) three-part constellation around Polaris (the North Star) exemplifies how a constellation can reflect a deep understanding of the sky and its cycles. Náhookǫs Bi'áád, the Female Revolving One (IAU constellation Cassiopeia), is considered to be a mother representing strength, motherhood, and regeneration. She reflects stability and peace and also provides food and nutrition for her family. Náhookǫs Bi'ką', the Male Revolving One (the Big Dipper (part of IAU constellation Ursa Major), is considered to be a warrior, leader, and father. He provides for and protects his family and community. Náhookǫs Bikǫ', the Central Fire (the North Star, or Polaris), sits between the man and woman like a fire would in the center of a traditional Navajo home (hogan). The central role of Polaris reflects how the star appears to be the center of the sky that all of the other stars revolve around. The Central Fire adds stability, security, peace, warmth, and light. This constellation helps people navigate (by locating the North Star) and track time as the Male and Female Revolving Ones rotate around their fire during the year (Begay and Maryboy 2005).

Other cultures also use constellations to mark time. For example, in parts of Africa, observation of the Pleiades signals to knowledgeable skywatchers the coming of the rainy season.

Please note we must be very careful when telling sky stories from cultures other than our own. Some stories are only meant to be told at certain times of the year or by certain people. For example, our Diné and Grand Ronde advisors explained that in their communities, stories are only told in the wintertime. If stories are referenced at other times, they should be told in abbreviated forms.

Artwork

Like stories, there are examples from many cultures of how people reflect a deep knowledge and connection to the sky through art. For example, ancient Egyptians in Northern Africa drew images of the fourteen ascending and fourteen descending gods and goddesses to match each day of the lunar cycle (Hooper 2012). Eleventh-century astronomer Al-Biruni drew diagrams to explore why the Moon changes shape (Nasr 1996). Maya scribes illustrated the relationship between the Moon and Sun as fraternal twins—similar but each with its own qualities (Smithsonian National Museum of the American Indian 2017). When Galileo first saw the Moon through his telescope, he reached for his sketch pad to document what he saw (Penphase 2011). Young Lakota and Dakota women sent to boarding schools at the turn of the nineteenth century replaced dwindling bison hides with shining star quilts to honor their community (Termin 1997). Today, artist Al Bean paints to capture the feelings he experienced as an astronaut walking on the Moon (Bean 2017). Margaret Nazon, an artist from Canada's Northern Territories, translates the beauty in *Hubble Space Telescope* images into beaded artwork (Nazon 2016). Even scientists use a combination of complex data and artistic inspiration to create the beautiful NASA images of faraway places in space (NASA 2017a). For all of these artists, art is or was their tool for capturing their fascination and understanding of the sky.

Connections to Standards

The *Lenses on the Sky* team developed the activities with Next Generation Science Standards (NGSS) for elementary and middle school students in mind (listed below). All of the included lesson plans list the Next Generation Science Standards supported by the activity. Many of the lessons also support Common Core Math and Common Core English Language Arts standards. While there are no national social studies and arts standards to list, educators are also encouraged to link the cultural, historical, arts, and storytelling content to their social studies and arts curricula.

Grade Band Endpoints for Space Systems

Grade Band Endpoints for ESS1.A

https://ngss.sdcoe.net/Disciplinary-Core-Ideas/DCI-Earth-and-Space-Sciences/ESS1A-The-Universe-and-Its-Stars

By the end of grade 2. Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted. At night one can see the light coming from many stars with the naked eye, but telescopes make it possible to see many more and to observe them and the Moon and planets in greater detail.

By the end of grade 5. The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their size and distance from Earth.

By the end of grade 8. Patterns of the apparent motion of the Sun, Moon, and stars in the sky can be observed, described, predicted, and explained with models. The universe began with a period of extreme and rapid expansion known as the Big Bang. Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

Grade Band Endpoints for ESS1.B

https://ngss.sdcoe.net/Disciplinary-Core-Ideas/DCI-Earth-and-Space-Sciences/ESS1B-Earth-and-the-Solar-System

By the end of grade 2. Seasonal patterns of Sunrise and Sunset can be observed, described, and predicted.

By the end of grade 5. The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the Moon; and different positions of the Sun, Moon, and stars at different times of the day, month, and year.

Some objects in the solar system can be seen with the naked eye. Planets in the night sky change positions and are not always visible from Earth as they orbit the Sun. Stars appear in patterns called constellations, which can be used for navigation and appear to move together across the sky because of Earth's rotation.

By the end of grade 8. The solar system consists of the Sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the Sun by its gravitational pull on them. This model of the solar system can explain tides, eclipses of the Sun and the Moon, and the motion of the planets in the sky relative to the stars. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of Sunlight on different areas of Earth across the year.

Space-Related Disciplinary Core Ideas for 1st and 5th grades.

Grade 1—Space Systems: Patterns and Cycles

http://www.nextgenscience.org/topic-arrangement/1space-systems-patterns-and-cycles

Disciplinary Core Ideas

ESS1.A: The Universe and its Stars

- Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted (First Grade 1-ESS1-1).

ESS1.B: Earth and the Solar System

- Seasonal patterns of Sunrise and Sunset can be observed, described, and predicted. (1-ESS1-2)

Crosscutting Concepts

Patterns: Patterns in the natural world can be observed, used to describe phenomena, and used as evidence (1-ESS1-1), (1-ESS1-2).

Connections to Nature of Science—Scientific Knowledge Assumes an Order and Consistency in Natural Systems**:**

- Science assumes natural events happen today as they happened in the past (1-ESS1-1).
- Many events are repeated (1-ESS1-1).

Grade 5—Space Systems: Stars and the Solar System

http://www.nextgenscience.org/topic-arrangement/5space-systems-stars-and-solar-system

Disciplinary Core Ideas

PS2.B: Types of Interactions

- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center (5- PS2-1).

ESS1.A: The Universe and Its Stars

- The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth (5-ESS1-1).

ESS1.B: Earth and the Solar System

- The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun, Moon, and stars at different times of the day, month, and year (5-ESS1-2).

Crosscutting Concepts

Patterns: Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena (5-ESS1-2).

Cause and Effect: Cause and effect relationships are routinely identified and used to explain change (5-PS2-1).

Scale, Proportion, and Quantity: Natural objects exist from the very small to the immensely large (5-ESS1-1).

Middle School—Space Systems

http://www.nextgenscience.org/topic-arrangement/msspace-systems

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- 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-ESS1-1).
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe (MS-ESS1-2).

ESS1.B: Earth and the Solar System

- The solar system consists of the Sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the Sun by its gravitational pull on them (MS-ESS1-2), (MS-ESS1-3).
- This model of the solar system can explain eclipses of the Sun and the Moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of Sunlight on different areas of Earth across the year (MS-ESS1-1).
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity (MS-ESS1-2).

Crosscutting Concepts

Patterns: Patterns can be used to identify cause-and-effect relationships (MS-ESS1-1).

Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small (MS-ESS1-3).

Systems and System Models: Models can be used to represent systems and their interactions (MS-ESS1-2).

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems (MS-ESS1-3).

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems: Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation (MS-ESS1-1), (MS-ESS1-2).

Overview of the Activities

The nine *Lenses on the Sky* activities in this guide include the following:

1. ***Art Matching***
   Description: Students explore how artists from different cultures have used art to represent space-related phenomena.
   Program Type: Demonstration or classroom activity
   Topics: Moon, space travel, art, stars, sky-watching

2. ***Stories of the Moon***
   Description: Students investigate the stories and pictures that different cultures have used to describe the Moon. Students also conduct activities to explore the scientific principles embedded in the cultural stories that explain the Moon's relationship to Earth and the Sun.
   Program Type: Set of demonstrations or classroom activities
   Topics: Moon, astronomy, culture, sky

3. ***Constellation Puzzle***
   Description: Students learn how people have used star patterns to map the sky by completing a constellation puzzle and learning stories from different cultures.
   Program Type: Demonstration or classroom activity
   Topics: Stars, constellations, patterns, culture, Earth's place in the universe

4. ***Laser Telescope***
   Description: Students use lenses and mirrors to understand how light travels through reflecting and refracting telescopes.
   Program Type: Demonstration
   Topics: Astronomy, light, optics, lens, mirrors.

5. ***Moon Phase Flipbook***
   Description: Students assemble a flipbook of Moon phases and discuss why the Moon appears to change shape over the course of a month.
   Program Type: Demonstration or classroom activity
   Topics: Moon phases, Moon, Earth, Sun, astronomy, patterns

6. ***Measure the Sky***
   Description: Students assemble a quadrant, a tool for measuring the positions of objects in the sky.
   Program Type: Demonstration or classroom activity
   Topics: Sky, observation, astronomy

7. ***Observing the Sun***

   Description: Students learn how to safely observe the Sun and how different cultures have observed the Sun around the world.

   Program Type: Demonstration or classroom activity.

   Topics: Astronomy, the Sun, solar observing, Sunspots, math

8. ***Star Quilts***

   Description: Students learn the cultural significance of star quilts for Native peoples of the Northern Plains. Then, students create and dedicate their own geometric star quilt pattern.

   Program Type: Demonstration or classroom activity

   Topics: Sky-watching, astronomy, Native American culture, art, patterns

9. ***Window Constellations***

   Description: Students learn about constellations from different cultures and create constellation-inspired artwork.

   Program Type: Demonstration or classroom activity

   Topics: Astronomy, constellations, patterns, stories, stars.

Additional Educator Resources

Online Exhibits and Interactive Experiences

NASA for Students website hosts interactive experiences sorted by age range.
https://www.nasa.gov/audience/forstudents/index.html

African Cosmos: Stellar Arts by the Smithsonian's National Museum of African Art includes interactive experiences, videos, a family guide, and lesson plans.
https://africa.si.edu/exhibits/cosmos/

Never Lost by the Exploratorium uses a multimedia platform to share how Polynesian navigators use the sky to travel across the ocean.
https://annex.exploratorium.edu/neverlost/

Living Maya Time by the Smithsonian's National Museum of the American Indian introduces youth to the science and math embedded in the Maya calendar and architecture. The website includes several videos, activities, and lesson plans.
https://maya.nmai.si.edu/

Lesson Plans

The NASA Wavelength website allows you to search their lesson plan collection by grade and topic.
http://nasawavelength.org/

Sq' Baa Hane'/Story of the Stars: Educational Activities Weaving NASA Science and Navajo Knowledge offers several lesson plans integrating NASA and Navajo perspectives of the sky.
https://astrobiology.nasa.gov/uploads/filer_public/d7/fd/d7fdeb5d-549c-4248-b219-02e3e125b56e/storystars-2.pdf

Videos

NASA posts lots of educational videos on their YouTube channel.
https://www.youtube.com/channel/UC9SM7V7J1pAhPabOUST01fw

Musician and educator Coma Niddy raps about space and science.
https://www.youtube.com/channel/UCxZpM39a6aPP62h95rdEo7A

The BBC produced an excellent show about science and Islam including how Golden Age Islamic scientists contributed to astronomical research.
https://www.youtube.com/watch?v=FLay7RD3kEw

E-Newsletters

Sign up for NASA Education EXPRESS to get the most up-to-date information on workshops, resources, and opportunities for educators sent to your email.
https://www.nasa.gov/audience/foreducators/Express_Landing.html

Contact OMSI's Planetarium Director Jim Todd to sign up for OMSI's Space Science email updates.
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Books

*Dot to Dot in the Sky: Stories of the Moo*n by Joan Marie Galat

The Earth Under Sky Bear's Feet: Native American Poems of the Land by Joseph Bruchac

Faces of the Moon by Bob Crenlin

Follow the Drinking Gourd by Jeanette Winter

Galileo for Kids: His life and ideas by Richard Panchyk

Greet the Dawn the Lakota Way by S.D Nelson

The Moon Over Stars by Dianna Hutts Aston

The Night the Moon Fell/La noche que se cayó la luna by Pat Mora

Sky Sisters by Jan Bourdeau Waboose

The Star People: A Lakota Story by S.D Nelson

The Stars: A new way to see them by H.A. Rey

The Story of the Milky Way: A Cherokee tale by Joseph Bruchac and Gayle Ross

Thirteen Moons on Turtle's Back: A Native American year of moons by Joseph Bruchac and Jonathan London

Why the Moon Paints her Face Black: A southern Paiute sky story told by Eleanor Tom

Why the Sky is Far Away retold by Mary-Joan Gerson

You are Stardust by Elin Kelsey

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