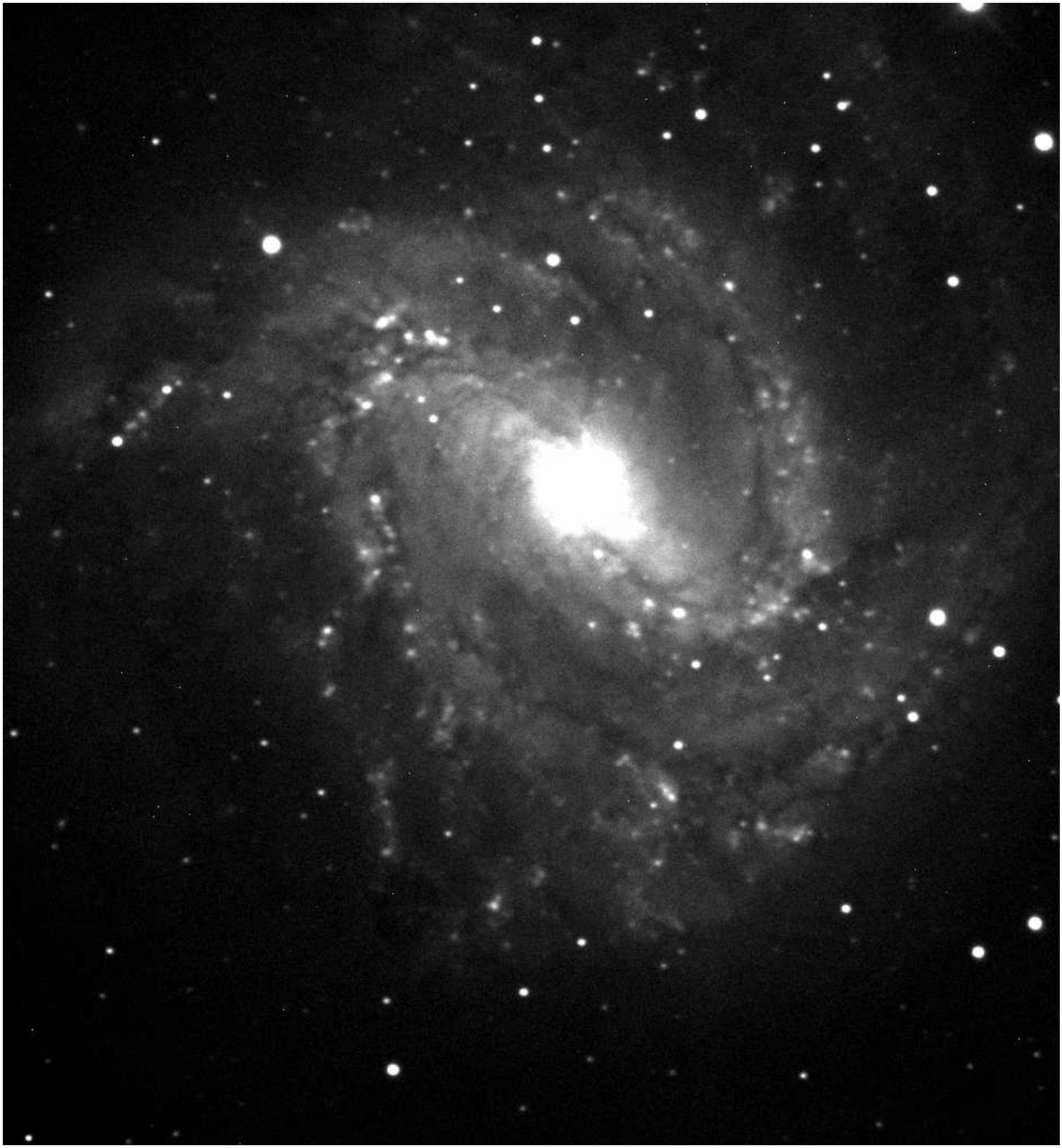
National Park Service
U.S. Department of the Interior

Theodore Roosevelt National Park

Explore the Universe:

Travelling the solar system via modeling



Southern Pinwheel Galaxy Photo Credit: Jennifer C. Frost, Skynet Robotic Telescope Network 2013

Explore the Universe:
Travelling the solar system via modeling

Theodore Roosevelt National Park
Medora, ND

U.S. Department of the Interior
Washington, DC

Introduction

It is 1,000 years into the future and something doesn't seem quite right. Scientists, who have been carefully studying the motion of the planets from Earth, are reporting that one of the planets appears to be moving backward. Is it yours?

Solving this space mystery will help students understand the fundamentals of the scientific method by having them do background research, formulate a rudimentary hypothesis, test the hypothesis using a physical model the class constructs, evaluate and report the results of that test, and apply their findings to other objects to test their hypothesis' ability to predict outcomes.

The activities in this manual will incorporate cross-cutting concepts from language arts, mathematics, visual arts, social studies, and history, as well as cover its primary focus in science. There will be a table at the beginning of each project detailing applicable Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS). The projects are divided into three sections:

Section 1: Pre-flight Preparation
Section 2: In-flight Testing
Section 3: Post-flight Debrief

While we recommend completing the entire series, activities in Section 2—which focuses on planetary motion and the apparent seasonality of some constellations—include modifications to allow classes, who were unable to complete the previous section, to still participate in the live workshop with the ranger on September 26, 2013. To obtain information and sign up for this event, please contact Park Ranger Jennifer Frost at Jennifer_Frost@nps.gov.

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Section 1: Pre-flight Preparations

It is 1,000 years into the future and something doesn't seem quite right. Scientists, who have been carefully studying the motion of the planets from each planet in our solar system, are reporting that one of the planets appears to be moving backward compared to its normal direction. Is it yours?

Since there is concern that this phenomenon could spread to other planets and cause wide-spread chaos affecting life on Earth, the Global Space Agency wants you to record your findings each day, so they can understand what's happening. Are observers on your **planet** seeing the same phenomenon?

The chart below provides an overview of curriculum standards met in this section.

Using the information you've gathered, the Global Space Agency would like to brainstorm with you, as an emerging expert on your planet, about possible causes for this phenomenon. So, it is important to do some research before settling on a hypothesis. The activities in this section will help you prepare for this meeting.

In this distance learning event, we will explore our solar system to answer this question and others. It will be good to periodically reflect on what you have learned and record your observations and questions. You will need to keep a lab notebook for this purpose.

North Dakota Curriculum and Next Generation Science Standards
By Grade

Fourth Grade

Science Content and Achievement Standards Addressed
4.2.2: Conduct simple investigations to answer questions based on observations
4.5.5: Identify components of our solar system

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.1: Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text
RI.2: Determine the main idea of a text and explain how it is supported by key details; summarize the text
RI.3: Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text
RI.4: Determine the meaning of general academic and domain-specific words or phrases in a text relevant to a grade 4 topic or subject area
RI.7: Interpret information presented visually, orally, or quantitatively and explain how the information contributes to an understanding of the text in which it appears
RI.8: Explain how an author uses reasons and evidence to support particular points in a text
RI.9: Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably

Social Studies Content and Achievement Standards Addressed
4.1.4: Interpret current events using print and electronic media (newspaper, children's news magazines, television, Internet)

Fifth Grade

Science Content and Achievement Standards Addressed
5.5.4: Identify the characteristics of the Earth (spherical in shape, orbits the Sun, rotates on a tilted axis, etc.)
5.5.5: Identify the objects in the sky that have predictable patterns of movement (Sun, planets, Moon, and stars)

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.2: Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text
RI.4: Determine the meaning of general academic and domain-specific words or phrases in a text relevant to a grade 5 topic or subject area
RI.7: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently

Social Studies Content and Achievement Standards Addressed
5.1.2: Identify differences between primary and secondary resources (maps, charts, line and bar graphs, Internet, atlases, journals, photographs, interviews, periodicals, etc.)
5.1.3: Evaluate current events using print and electronic media (newspaper, children's news magazines, television, Internet)
5.2.4: Explain the significance of scientists, inventors, and historical figures

Sixth Grade

Science Content and Achievement Standards Addressed
6.1.1: Construct a model to represent concepts, features, or phenomena in the real world (solar system, etc.)
6.5.4: Identify the basic characteristics (composition, rings) of objects (planets, Sun, small bodies) in the solar system

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.2: Determine a central idea of a text and how it is conveyed through particular details; provide a summary of the text distinct from personal opinions or judgments
RI.4: Determine the meaning of words or phrases as they are used in a text, including figurative, connotative, and technical meanings

Social Studies Content and Achievement Standards Addressed
6.1.1: Use a variety of primary and secondary resources (magazines, journals, artifacts, interviews) to gather and interpret information

The consistency of the papier mâché paste (above).

A balloon with hanging loop in place (below).

Activity 1-Constructing the Planets

What is unique about your planet? How does it compare to other planets in the solar system? This activity will help you prepare a three dimensional representation of your planet, which you can then use later to help you understand the type of eclipse effects it might experience from its satellites.

Materials

Papier Mâché Paste

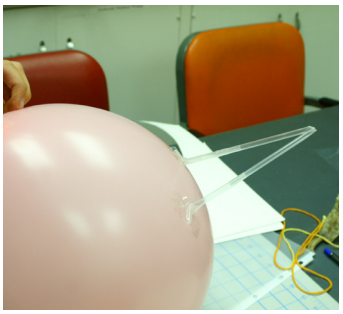
1.5 cups Bleached all-purpose flour
6 Tbsps. Salt (will slow mold growth, usually for several days)
12 cups Water
Large Saucepan
Hot plate/stove
These materials will be used to make the papier mâché paste. Add 6 cups tap water to ½ cup flour. Pour this mixture into 6 cups of boiling water and bring back up to a boil. Remove from heat. Stir in 6 tablespoons of salt, cover, and let cool. Paste will thicken and be ready for use once it cools. If prepared the night before, you may need to add 2-3 cups more water prior to use to offset overnight evaporation and absorption.

Old newspapers cut or torn into strips
White paper towels or white paper
Balloons (ideally, 5 different sizes)
Paints
Card stock or poster board
Pipe cleaners, wire, or drinking straws
Paper Clips
Fishing line, string, or yarn

Instructions

To build the planets, you will need to inflate the balloons. Try to make Jupiter quite large, with Saturn a little smaller. The next smaller planets, Uranus and Neptune, are close in size. Next in the size continuum are Venus and Earth with Mars and Mercury being the smallest. This can be achieved by different-sized balloons (preferred) or under-inflating to different sizes. The planets most likely will not be proportional since Jupiter would have to be quite large to create a decent-sized Mercury. General size can help you differentiate the **gas giants** (Jupiter, Saturn, Uranus, and Neptune) from the smaller, **terrestrial planets** (Earth, Venus, Mars, and Mercury), so even having just two substantially different sizes for planets will help. If you'd like to break into smaller groups, consider including the **dwarf planets** Eris, Pluto, Makemake, and Haumea (listed in order of size). For this event, any reference to "planets" should be understood to include any dwarf planets you've decided to incorporate. Because these dwarf planets can have irregular and far-reaching orbits (believed to be influenced by Neptune's gravitational pull), you may want to generically include them in the **Kuiper Belt** location.

In this image, each support for Saturn's rings was made with two straws, one inserted inside the other at one end. The support was then creased in three places with the two end creases being taped to the balloon.



Each group should have one planet they are working on, so that all planets are covered by the entire class. Each group will also need papier mâché paste, newspaper strips, and a balloon corresponding in size to their planet. Tie string or fishing line to the paperclip and tape that to each balloon leaving a loop of string or fishing line sticking out above the tied-off balloon end to be used for hanging the planet after it is fully dried (about 48 hours) and decorated. Using the newspaper strips dipped in the papier mâché paste, run the strip between the thumb and forefinger to "squeegee" the excess paste off the strip. Coat the balloon with 2-3 papier mâché layers leaving the loop for hanging sticking out. The last layer should be paper towel strips or white printer paper strips to make painting easier, as newspaper ink tends to bleed through paint.

For ringed planets (the gas giants), tape pipe cleaner or wire with an "L-shaped" bend to opposite sides of the balloon. (Remember: Uranus is tipped over, so its ring holders should be positioned near the hanging loop and opposite the loop.) To help hold it in place, be sure to papier mâché a little around the pipe cleaner, straws, or wire being used to support the planet's rings. Rings can be cut out of the cardstock or poster board (or even more pipe cleaners for fainter rings) and painted but should not be affixed to the planet until the papier mâché dries fully.

Bonus: Left over papier mâché paste and newspaper strips can be used to create Kuiper Belt Objects. Wad full sheets of newspaper into different shapes and sizes and tape a paper clip with fishing line or string tied in a loop to it. Cover with strips of newspaper dipped in papier mâché paste.

While the papier mâché planets are drying, groups can research their respective planets and write a report discussing the planet's special features, such as rings, **satellites** (moons), **atmospheres**, temperatures, etc. They should also try to include what makes their planet a planet instead of a dwarf planet (or a dwarf planet versus an asteroid). You should be prepared to present your research to your classmates after the last activity has been completed.

When the planets are dry, paint them according to the pictures found during your research. Be creative! Consider using cotton for clouds, glitter, etc.

Additional Cross-cutting Concepts

* To incorporate math standards: Calculate the size a planet would have to be in order for its orbit to fit in the classroom (combine with Activity 3).

* To incorporate art curriculum: Mix white, black, and/or primary colors (blue, red, and yellow) to create the colors needed for your planet. Creating a simple color wheel can help with visualizing this process.

* To incorporate social science curriculum: Research the source of your planet's name and the planet's satellites' names. [Note: Since some Greek and Roman mythology stories may be considered risqué, you may want to direct them to age-appropriate resources. Internet searches using terms like "Greek and Roman mythology for kids" will usually yield a number of appropriate results.]

Photograph of Saturn taken August 22, 2013

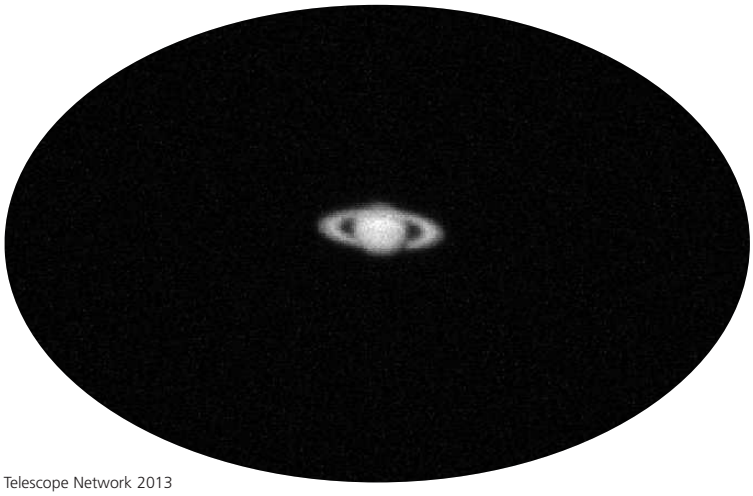


Photo Credit: Jennifer C. Frost, Skynet Robotic Telescope Network 2013

A sample constellation from the PowerPoint download.

Activity 2-Making Zodiacal Constellations

This activity will prepare the observation field. Planetary motion is often plotted against the stars to determine rate and direction of motion. Since the stars are so far away, their apparent motion is negligible when compared to the motion of objects considerably closer.

Materials

Large sheets of Kraft or butcher paper
Aluminum foil
Marker/Sharpie
Crayons (light colors recommended for dark-colored paper, dark colors recommended for light-colored paper)
Glue
Scissors
Diagrams of constellations
Star pattern
Paint or markers (optional)
Pictures of the zodiacal constellations

A PowerPoint presentation (already scaled to standard letter size) download of the zodiacal constellations—which can be printed and used as a visual guide or projected onto hanging, blank sheets of paper to mark star placement—is found on the Curriculum Materials page at http://www.nps.gov/thro/forteachers/trnp-curriculum.htm.

Instructions

Work individually or in groups to carefully cut **star** shapes out of the foil using the supplied pattern. Arrange the stars on large sheets of Kraft paper according to the diagram for your constellation and glue the stars in place. Then, connect the stars to replicate the **constellation** picture. Write the name of the constellation. Hang the constellations on the walls (three per wall) in the appropriate, counterclockwise order. You may want to have any constellations that will be in front of whiteboards or bulletin boards on cardboard or poster board, so they can be easily moved and replaced.

Option: Though we are focusing on the twelve zodiacal constellations for this event, it is appropriate to include other constellations found above and below the zodiac, as these will also be seasonal constellations and will allow for smaller groups to be made. Just remember that the closer the constellation is to the poles, the less-likely it is that the constellation will be seasonal. In fact, true **circumpolar** constellations never appear to set. However, this could present a great opportunity for further discussion of planetary **rotation** and **revolution**.

Additional Cross-cutting Concepts

* To incorporate language arts and social studies curricula: Research stories about the constellation and give a short presentation about it. [Note: Sometimes the Greek and Roman mythologies can be considered risqué, so it might be prudent to find age-appropriate resources. An internet search for "Greek and Roman mythology for kids" brought up a number of appropriate resources. Groups may also be directed toward the stories from other cultures, like the American Indian, according to the cultures being studied for the respective grade.]

Activity 3-Plotting Proportional Orbits

Note: This activity was modified from the "Pocket Solar System" and is included here with permission from the Astronomical Society of the Pacific.

Materials

Roll of cash register tape
Yellow construction paper or Kraft paper (or other material)
Chalk
Masking/painter's tape
Markers
Pencil
Push pins/tape/s-hooks
Large painter's drop cloth (Optional for orbits that need to be packed up or moved to other locations. Proportions should be measured from the center of the drop cloth to one of the sides. Permanent marker may be used to mark orbits in this case.)
Lab notebook

An Excel spreadsheet download to assist with verifying orbit calculations (and obtaining an approximation of how much tape will be needed for the orbits) can be found on the Curriculum Materials page at http://www.nps.gov/thro/forteachers/trnp-curriculum.htm.

Instructions

Using the "Sun Edge" crease as the Sun marker for the room-sized solar system.

The segment from the Sun's center to its edge is ignored in the folding process but will be used when marking the orbits. This ensures Mercury's orbit clears the Sun while still providing a pivot point at the Sun's center. The pocket solar systems do not have this extra bit of tape.

Clear the floor space. With the yellow construction or Kraft paper, create a large Sun. Trace its outline in the exact center of the room with chalk before hanging the paper Sun in the middle of the classroom/meeting space ceiling. One student should stand in the center of the Sun outline while another student unrolls the register tape to the closest wall and tears or cuts it where it touches the wall. The student standing on the Sun should write "Sun" on the register tape where it crosses the edge of the chalk line and crease it. From here on, the term "Sun" will refer to the crease where the word "Sun" is written.

The student at the wall should write "Kuiper Belt" on his/her end. Fold the Kuiper Belt to the Sun and crease it (others from the class may need to help). Unfold it and write "Uranus" on the crease. Refold the paper and bring the crease to the Sun. Make a new crease. Unfold the strip. On the fold closest to Pluto, write "Neptune". On the fold closest to the Sun, write "Saturn".

Now, fold the Sun up to Saturn's **orbit** (crease) and crease the fold. Unfold it and write "Jupiter" on the crease. Fold the Sun up to Jupiter's orbit and crease it. Unfold it and write "**Asteroid belt**" on the crease. Now, fold the Sun up to the asteroid belt and crease it. Unfold it and write "Mars". Fold the Sun up to the orbit of Mars and crease it, but this time fold the crease up to the orbit of Mars and crease that before unfolding. Write "Earth" on the crease closest to Mars, "Venus" on the next crease, and "Mercury" on the crease closest to the Sun crease.

Stand in the center of the Sun outline and hold the end of the solar system "tape measure" on the center of the Sun, so the crease marked "Sun" is again at the edge. No use this as a type of compass to make big circles for each orbit. Use white chalk to create the orbit lines. Hold the chalk at each orbit mark (crease) and walk in a circle using the chalk to mark the arc on the floor. Go over all the chalk lines with painter's tape to create longer-lasting Sun and orbit markings. Use markers to write the name of each object on its respective tape line from the Sun outward. (If there are still blank spaces on the tape, feel free to write the planets' names again in

a different colored marker.) Keep the "tape measure" to use as a guide for hanging the planets from the ceiling above their appropriate orbit once the planets are painted. To make that process easier, you may want to just tack the "tape measure" to the ceiling and hang the planets all to one side of the ceiling Sun on their designated spot. However, for the event, you will want the full orbits on the ground.

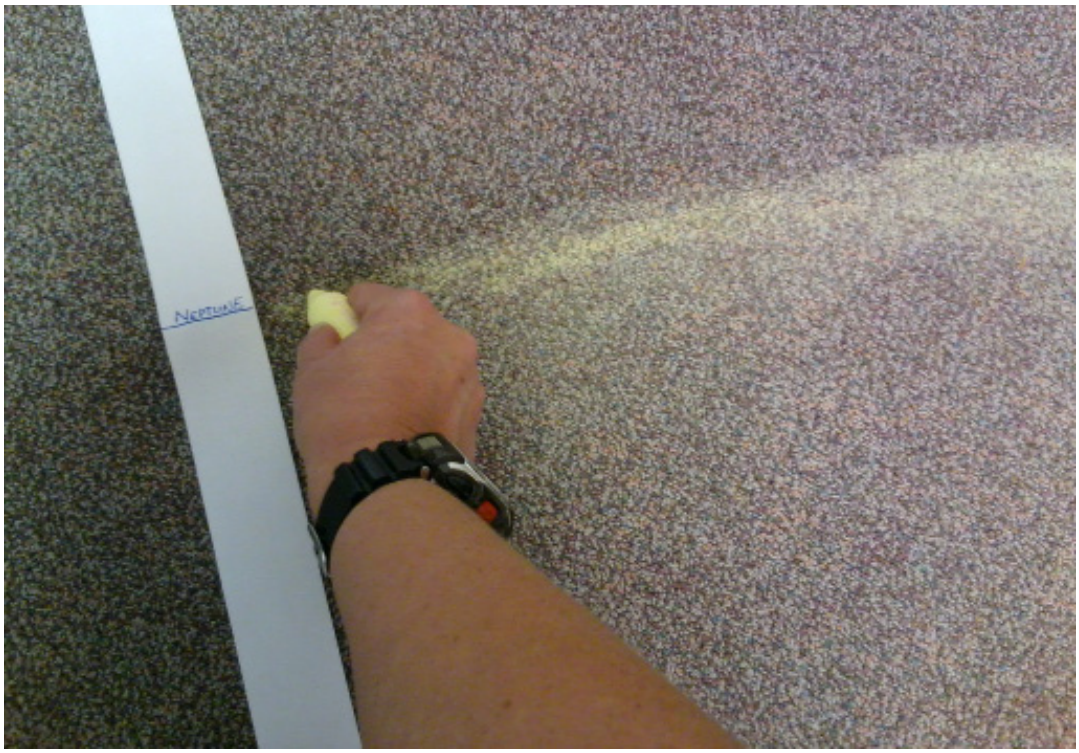
If there are time and materials, make a solar system that is as long as you are tall (the distance from fingertip to fingertip is roughly equal to a person's height). Go back through the steps of folding and marking. However, this time, the Sun will be at one end since there will be no need to incorporate the size of the Sun in the pocket solar systems. When finished, roll the solar system up and carry it in your pocket! These pocket solar systems can be used to help show others in class where your planet is in relation to the other planets when you give your planet presentation.

Take some time now to write observations made about your planet in your lab notebook.

Additional Cross-cutting Concepts

* To meet math curriculum standards: Use the solar system "measuring tapes" to discuss proportions and fractions. Make all the folds as described, but instead of writing the names of the landmarks as you are making creases, wait until the end and provide instructions such as "Write 'Sun' at the end with the creases closest together and 'Kuiper Belt' at the opposite end. On the crease that is 1/2 the way from the Sun to the Kuiper Belt, write 'Uranus'…" The group can work together to decipher for the classroom-sized "tape measure" and/or individually with the pocket version. You may also choose to calculate proportional distances to each planet.

* To meet additional science curriculum standards: Research the types and sizes of stars in each constellation and use that information when making the constellation. For example, color red giants appropriately and make them larger than a main sequence white star. Use the red-colored star to represent red giants, like the star Antares in Scorpio.



Marking out an orbit for Neptune using chalk and the solar system "tape measure".

One person is holding the "Sun's Center" end of the tape in place while another person is holding the "Kuiper Belt" end of the tape and walking around that pivot point. One or more people are drawing the orbits with chalk. These lines will be marked with painter's tape later.

Activity 4-Building a Hypothesis

Now that we have asked a question (Are your planet's observers also seeing planets change direction in their orbit?) and performed some research, we can explore a hypothesis. What do you think the answer to the question might be? How might you use the model to prove your hypothesis?

Materials

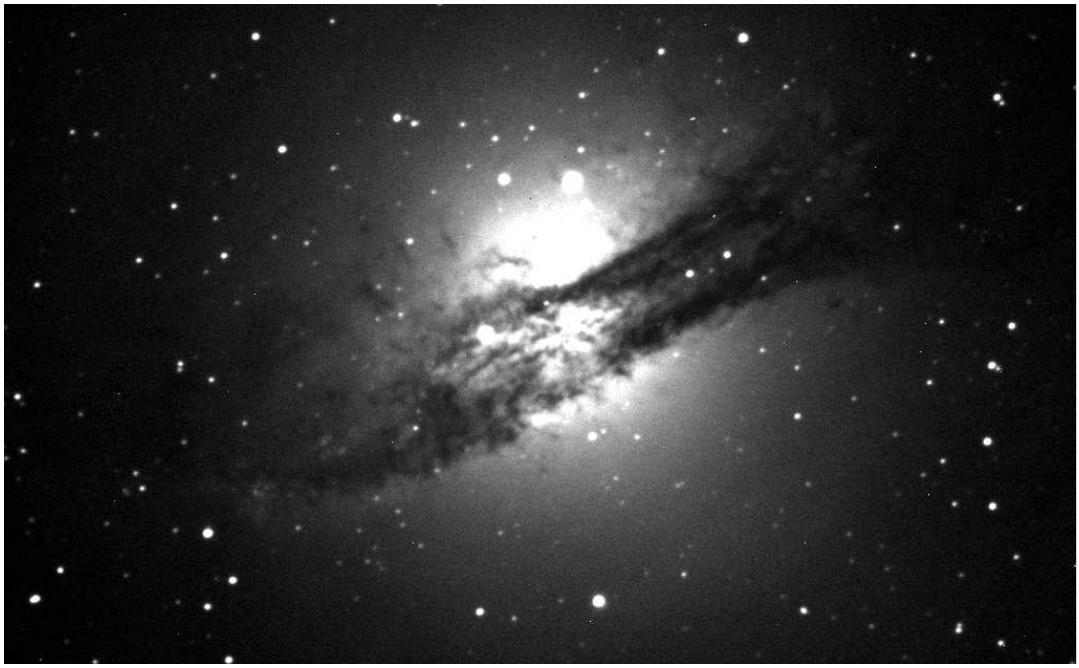
Lab notebook
Planet research
Pen

Instructions

Write at least a couple of pages about what you expect to see, how you think the solar system functions (planetary movement, what holds them together, etc.), and anything else you think should be noted about your planet. Be sure to include what you think is happening based on this information and methods you might use to test your **hypothesis**. This information should be written into your lab notebook where you will keep all your observations on this journey. Be sure to date the pages, so you know when each entry was written. This will help you find information and see how your knowledge and understanding of things and events changes. You will be asked to revisit this data after the distance learning event. Include in your notebook any jargon or unfamiliar words and their definitions. Your group will help you test your hypothesis.

Additional Cross-cutting Concepts

* To incorporate language arts curricula: Research scientific articles about the solar system and how it functions. Identify possible vocabulary words (new words or jargon) from the article(s) and look them up. Use these words in sentences where the context provides a definition of the word(s), write them in your lab notebook, and incorporate them into your reports. You will learn how to use the model to understand how the solar system functions and to prove or disprove your hypothesis in the next section.



Centaurus A is a "peculiar galaxy" because it shows signs of being both an elliptical and a spiral galaxy. See that band of dust crossing it diagonally? That's associated with spiral galaxies. There is also a group of young, hot, blue stars (if this were color, it would be more noticeable) near the upper right part of the band. This is also associated with spiral galaxies. However, the overall aspect of this galaxy clearly matches that of the elliptical galaxy. That dust band is pretty heavily warped, which indicates that something major must have happened. In conjunction with all the other things discussed, scientists hypothesize that "something" was the collision of two galaxies: one spiral and one elliptical.

Photo Credit: Jennifer C. Frost, Skynet Robotic Telescope Network 2013

Section 2: In-flight Testing

Now that your classroom is a 3D model of our solar system, you are ready to move like a planet. It is highly recommended that the classroom model created in Section 1 be used for this event.

If your class was unable to do the set-up or will be teleconferencing from a different location, quick modifications to the Section 1 model can be made as follows: 8 sheets of typing paper, each with a different planet's name in large print on it to replace the papier mâché planets; 12 large sheets of paper or cardboard, each with the name of a zodiacal constellation on it, posted three per wall; two orbits chalked or taped off on the floor (these will represent any given inner and outer planet orbits).

The chart below provides an overview of curriculum standards met in this section.

Please note that most of the education standards identified as being met with these exercises will not be covered unless all the activities are implemented.

North Dakota Curriculum and Next Generation Science Standards By Grade

Fourth Grade

Science Content and Achievement Standards Addressed
4.2.2: Conduct simple investigations to answer questions based on observations
4.5.5: Identify components of our solar system
4.5.6: Identify tools that are used to study the universe (telescopes, space probes, satellites, space craft)
4.6.2: Explain how an invention may lead to other inventions
4.8.2: Identify scientific advances that changed popular beliefs (Earth was center of universe, world was flat, etc.)

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.1: Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text
RI.2: Determine the main idea of a text and explain how it is supported by key details; summarize the text
RI.3: Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text
RI.4: Determine the meaning of general academic and domain-specific words or phrases in a text relevant to a grade 4 topic or subject area
RI.7: Interpret information presented visually, orally, or quantitatively and explain how the information contributes to an understanding of the text in which it appears

Fifth Grade

Science Content and Achievement Standards Addressed
5.5.5: Identify the objects in the sky that have predictable patterns of movement (Sun, planets, Moon, and stars)

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.4: Determine the meaning of general academic and domain-specific words or phrases in a text relevant to a grade 5 topic or subject area
RI.7: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently
RI.8: Explain how an author uses reasons or evidence to support particular points in a text, identifying which reasons and evidence support which points

Social Studies Content and Achievement Standards Addressed
5.1.2: Identify differences between primary and secondary resources (maps, charts, line and bar graphs, Internet, atlases, journals, photographs, interviews, periodicals, etc.)
5.2.4: Explain the significance of scientists, inventors, and historical figures

Sixth Grade

Science Content and Achievement Standards Addressed
6.2.1: Explain the components of a scientific investigation (hypothesis, observation, data collection, data interpretation, communication of results, replicable)
6.5.4: Identify the basic characteristics (composition, rings) of objects (planets, Sun, small bodies) in the solar system
6.8.2: Identify scientific advances that have resulted in new ideas and further advances

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.4: Determine the meaning of words or phrases as they are used in a text, including figurative, connotative, and technical meanings
RI.7: Integrate information presented in different media or formats as well as in words to develop a coherent understanding of a topic

Activity 1-Flight Instructions

This activity will be covered live in the September 26, 2013, distance learning event. Be prepared to wander like a planet through our solar system with the help of our astronomer park ranger!

Materials

Planets (Make sure they are easily accessible or else have note cards with the planets' names on them)
Distance learning equipment (Details provided at sign-up)
Swivel desk chair
Different colored sticky notes
Light bulb in a lamp without the shade (and extension cord to help it reach the "Sun" on the floor).
Markers
Orbits are marked and constellations are up and desks are moved to the sides of the classroom, so the orbits are easily accessible.

Instructions

At the event, we will cover planetary motion discussing the orbits of the planets and the difference between a **revolution** around the Sun along an **orbit** and the **rotation** of the planet on its axis. We will use the constellations on the walls and the lamp "Sun" to understand day-night cycles and why certain constellations are visible only certain times of the year. We will also discuss/demonstrate the **retrograde motion** of Mars by plotting its apparent motion from "Earth" using sticky notes, which are labeled with the planet's name and the number of the note posted (so, first note posted would be "1", etc). Taping string or yarn to each sticky note in order may help with visualizing the predominate direction of planet travel and where direction changes occur.

If time permits, we will conclude by addressing Moon phases. However, Section 3 will also have an activity to help explain Moon phases and eclipses.

The Moon is at its first quarter phase and is waxing, or growing, when its face appears lighted on the right side. The Moon is at its third quarter phase and is waning, or getting thinner, when only the left half of its face appears lighted from our angle. These are the best times for observing and photographing the Moon because the angle of the Sun emphasizes the shadows of the craters and maria making them easier to see. The line of the shadow is called the "Terminator Line" or just the "Terminator".

Why is the Moon not really only a quarter lighted when it is at first quarter and third quarter?

(The term "quarter" is a reference to the Moon only being a quarter of the way through the cycle of its phases.)

Photo Credit: Jennifer C. Frost/Robert Fergson Observatory 2013

Section 3: Post-flight Debrief

In this section, you will put it all together. You will cover the Moon's revolution around Earth and how this affects the phases. Testing of hypotheses will take place and test results will be reported to the other researchers in your class.

This is your chance to shine! After learning about the Moon's phases, think about how this information might apply to your planet. What were the results of your hypothesis testing? What did you learn about your planet and the solar system? How are your test results different or the same as other results from your class?

The chart below provides an overview of curriculum standards met in this section.

You are well on your way to being a planetary expert!

North Dakota Curriculum and Next Generation Science Standards By Grade

Fourth Grade

Science Content and Achievement Standards Addressed
4.1.1: Explain changes in the real world using a model
4.1.2: Identify changes that can be steady or irregular
4.2.2: Conduct simple investigations to answer questions based on observations
4.5.5: Identify components of our solar system

Crosscutting Statements
Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena
Patterns of change can be used to make predictions
Patterns can be used as evidence to support an explanation

Fifth Grade

Science Content and Achievement Standards Addressed
5.1.1: Use an appropriate model to convey scientific information
5.2.2: Formulate an explanation supported by data
5.5.4: Identify the characteristics of the Earth (spherical in shape, orbits the Sun, rotates on a tilted axis)
5.5.5: Identify the objects in the sky that have predictable patterns of movement (Sun, planets, Moon, stars)

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.3: Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a scientific or technical text based on specific information in the text
RI.8: Explain how an author uses reasons or evidence to support particular points in a text, identifying which reasons and evidence support which points

Crosscutting Statements
Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena
Patterns of change can be used to make predictions
Patterns can be used as evidence to support an explanation

Sixth Grade

Science Content and Achievement Standards Addressed
6.1.3: Explain the connection between cause and effect in a system
6.2.1: Explain the components of a scientific investigation (hypothesis, observation, data collection, data interpretation, communication of results, replicable)
6.8.2: Identify scientific advances that have resulted in new ideas and further advances

English Language Arts and Literacy Content and Achievement Standards Addressed
RI.7: Integrate information presented in different media or formats as well as in words to develop a coherent understanding of a topic

Social Studies Content and Achievement Standards Addressed
6.2.9: Identify the features and accomplishments of classical Greek civilization (contributions to art, literature, science, and philosophy)

Crosscutting Statements
Patterns in rates of change can provide information about natural and human designed systems
Patterns can be used to identify cause and effect relationships
Graphs, charts, images, etc., can be used to identify patterns in data

Activity 1-The Moon in Motion

Is the dark side of the Moon always dark? How can an eclipse tell us about our planet? What causes the different phases of the Moon? You can answer these questions and more when you understand the Moon's motions.

Materials

Styrofoam balls (at least four)
Lamp without a lamp shade
Skewers and lumps of clay or foam (or string and push pins)
Softball
Solid cube (a wood block will work here)
Lab notebook

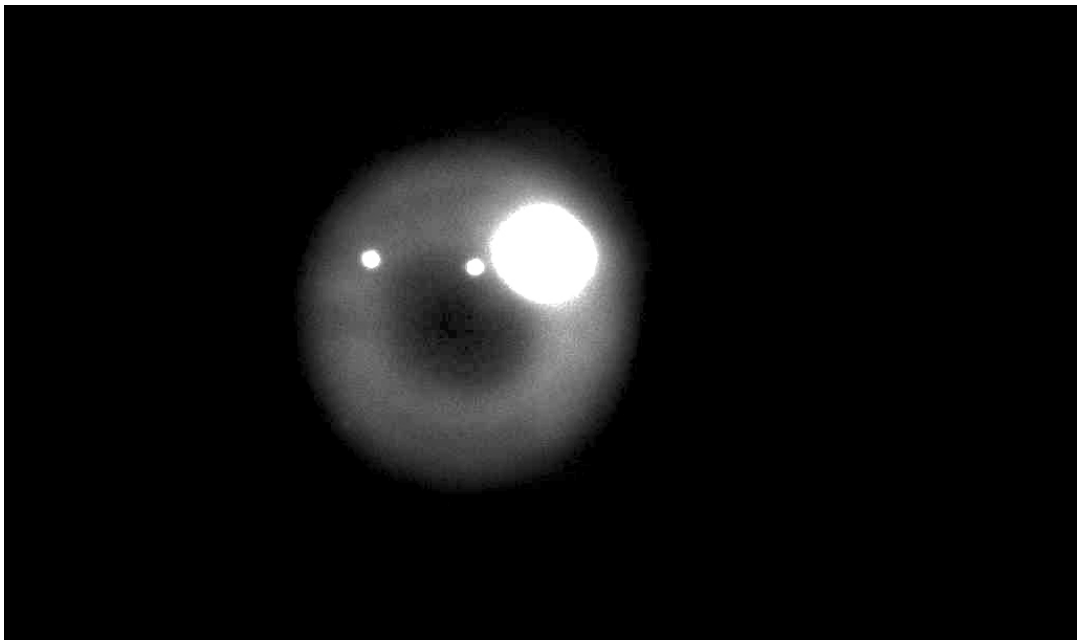
Instructions

Hang the Styrofoam balls from the ceiling on very long strings or impale the balls on skewers and support the skewers with foam blocks or lumps of clay. The Styrofoam balls should be suspended to one side of the lamp (Sun) at the twelve o'clock, three o'clock, six o'clock, and nine o'clock positions. Situate the lamp and balls in such a fashion as to ensure the student observing from Earth's position (in the middle of the Styrofoam balls) doesn't cause an "**eclipse**", turn off the other lights, and close any curtains or blinds. Take turns standing in the middle of the balls and turning to look at each one. What "phase" of the Moon do you see? Why would the new Moon (closest to the Sun) appear during the daytime? Now, hold a softball in the Earth's position and on the same plane as the Sun and Moons. Where is the shadow cast? Is it possible to have a lunar eclipse at the first quarter Moon? Full Moon? At what phase can a solar eclipse occur? The length of time it takes for the Moon to rotate one time on its **axis** is roughly equal to the length of time it takes for it to revolve around Earth. This can be modeled by holding a "Moon" at arm's length and turning around. Is the backside of the Moon always dark?

Create an eclipse by passing a Styrofoam ball through the softball's shadow. Does the shape of the eclipse's starting and ending lines change when the softball is replaced by the solid cube and the experiment is run again? Observations like this one helped Aristotle determine that the Earth must be round. Take some time to note your observations in your lab notebook. How can this information apply to your planet and its satellites?

Shadowy image of Jupiter with three of its satellites (moons) creating eclipses.

Photo Credit: Jennifer C. Frost, Skynet Robotic Telescope Network 2013



Activity 2-Putting It All Together

Now, it's your turn to present to the Global Space Agency your hypothesis and whether or not your research proved it was correct. If it wasn't correct, what is an alternate explanation? Try testing it!

Instructions

To help the agency (your class) eliminate other possible explanations, they will need the full details of what you learned about your planet. The report you share with the agency should include what order the planet is in, why it's a planet, proportionally where the planet is in the solar system, where its name originated, information about its satellites, and the other cool things you've discovered. What information surprised you? Was your planet the one in retrograde motion? What did you all discover about motion in the solar system?

During the course of this event, you were asked a question (was the planet in retrograde motion yours?), you performed research, you developed a hypothesis, you tested that hypothesis, and you evaluated your results to determine if your hypothesis was true or false. In doing these activities, you completed the steps of the scientific method. Congratulations! You are a scientist!

In fact, the problem you just solved was one that plagued early astronomers. They noted that some planets appeared to move backward in relation to the background constellations before moving forward again. This was very difficult to explain with the **geocentric** model of the universe in use at that time. Aristotle's observations established that the Earth must be round. He argued that Earth's shadow, as cast on the Moon during a lunar eclipse, proved that the Earth was round and not square as many thought based on the apparent shape of the horizon. (Note: Earth's shadow only falls across the Moon during a lunar eclipse. The Moon's phases are the result of its own shadow.) Aristotle's other observation demonstrating the Earth was round, which was the fact that everything falls toward Earth's center, also seemed to support that it must be the center of the universe.

Congratulations! You are a scientist!

Ptolemy attempted to explain the retrograde motion of some planets using the geocentric system. This required a complex series of **epicycles**, which explained most of the observed motions and differences in planet brightness over time, though some observations still defied explanation. Additional epicycles were added until the model became extraordinarily complex and required a lot of assumptions be made.

Aristarchus of Samos proposed a **heliocentric** model of the universe based on his measurements of eclipse durations and **parallax**. He stated that the sun was larger than Earth and the Moon, and that the Moon could cover the Sun because it was proportionally closer than the Sun. Unfortunately, his model was disregarded in favor of the already long-standing Ptolemaic model.

Copernicus, however, would be influenced by Aristarchus's ideas many centuries later. He created models, most likely very similar to what we used to solve our scenario, to demonstrate how simple the explanation was if we moved the sun to the center of the system and had Earth join the other planets in revolving around it. Copernicus's model was also in line with **Occam's Razor**, which favors the hypothesis that requires the fewest assumptions.

The story continues through Keppler, Galileo, Hubble, Newton, Einstein…and, now, you! In a short time, you tested centuries of theory and research explaining just one of the mysteries of the heavens: Retrograde planetary motion. Each of the scientists mentioned and others would further refine the model of our solar system until it resembles the model we now understand with its elliptical orbits, dwarf planets, **centaurs**, asteroids, **comets**, **Oort Cloud**, et cetera. Shortly, Voyager 1—which exited the **heliosphere** around August 25, 2013—will begin providing us with additional information from **interstellar** space. It is now up to you to continue our journey of understanding.

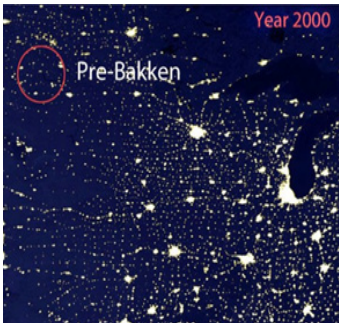


Photo Credit: Defense Meteorological Satellite Program, NOAA

Photo Credit: Suomi NPP, NASA

As posted on Astro Bob's site, http://astrobob.areavoices.com/2013/01/12/earth-at-night-glows-with-lovely-and-loathsome-lights/

Afterword

Identity is an assemblage of constellations. –Anna Deavere Smith

He insisted that stars were people so well loved, they were traced in constellations, to live forever. – Jodi Picoult, My Sister's Keeper

In 2001, the University of Padua in Italy teamed up with the National Oceanic and Atmospheric Administration (NOAA) to study our night skies. Their research was disheartening for an astronomer like me. It revealed that 99% of the population in the continental United States and Europe experience night skies that were severely impeded by stray light. This held true for about two-thirds of the world's population over all. A fifth of all humankind is unable to see our galactic home, the Milky Way (as cited in Mizon and Taylor's article, "The Fight for Darker Skies: Towards a 21st Century Solution to a 20th Century Problem?", Dark Skies, October 2008).

Theodore Roosevelt National Park in North Dakota offers the opportunity to explore the heavens with its Class I airshed and dark night skies. However, both of these resources are at risk due to expanding development around the park. The photos in the margin show how the night skies around our park have been affected by development in our region.

As an amateur astronomer studying the night skies for more than 30 years, I have witnessed similar changes to our night skies in other regions. Like many people, I grew up in a big city. I had to travel to dark night skies for my star viewing since my neighborhood's streets were brightly illuminated. Over the years, these journeys became longer and longer, as I tried to find skies dark enough to observe meteor showers and deep sky objects. When I got older, I had the privilege of being a park ranger giving weekly astronomy programs in the exact same location during the summer months for several years. Each year, I watched our dark night skies—and with it familiar asterisms, like the constellation Virgo and much of Leo—slowly fade away, engulfed by the lights of the growing surrounding cities. I was deeply saddened to say "good-bye" to these old, astronomical friends that had once been subjects of my "Starry, Starry Night: Our history is in the stars" talks but now were no longer visible to many of my park's visitors. Not only did I lose the opportunity to talk about those constellations, but people attending my talks could no longer hear the stories from other cultures that I shared about those objects. So, the visitors lost a part of our global heritage, as well. We all lost a part of our identity and history, and we lose a little more each year. Sadly, this is a story that is becoming all too familiar.

The good news is that this does not have to be a permanent change. We can choose fuel efficient cars and carpooling whenever possible to help reduce traffic congestion and airborne pollutants and to minimize the need for extra highway lighting. We can choose lighting that is sufficient for our needs and that only turns on when needed. We can choose light bulbs that supply enough lighting for security and avoid buying unnecessarily high wattages. We can choose to install or modify light fixtures to aim the light onto the ground where we need it rather allowing it to radiate to the sky above where it serves no purpose. We can choose to help others in our neighborhoods to make educated decisions that protect our night skies, too. The power to save our night skies is yours. Choose wisely!

Wishing you dark skies and excellent viewing,

Park Ranger Jennifer Frost
Education Technician
Theodore Roosevelt National Park

Word List

Many words used by astronomers have slightly different meanings than when used commonly. Here is a list of words with special meanings found in this guide. Can you determine the special meanings of these words?

Asteroid (Belt)
Atmosphere
Axis
Centaurs
Circumpolar
Comet
Dwarf Planets
Eclipse (Lunar and Solar)
Epicycles
Gas Giant
Geocentric
Heliocentric
Heliosphere
Hypothesis
Interstellar
Kuiper Belt
Occam's Razor
Oort Cloud
Orbit
Parallax
Planet
Retrograde Motion
Revolution
Revolution
Rotation
Satellite
Star
Terrestrial Planets
Zodiac

Photograph of light pollution from Bakken oil field flaring behind the silhouette of a butte in the North Unit of Theodore Roosevelt National Park on a cloudy night, August 10, 2013.

Photo Credit: Jennifer C. Frost 2013

Acknowledgements

There was a number of people, who willingly gave of their limited time and resources. The author begs the forgiveness of anyone she missed. The omission is not a reflection of your contribution but a reflection of poor memory.

Having said that, I would like to thank the following individuals and entities for their help with this project:

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...Thank you!

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www.nps.gov/thro/teachers/curriculummaterials.htm

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