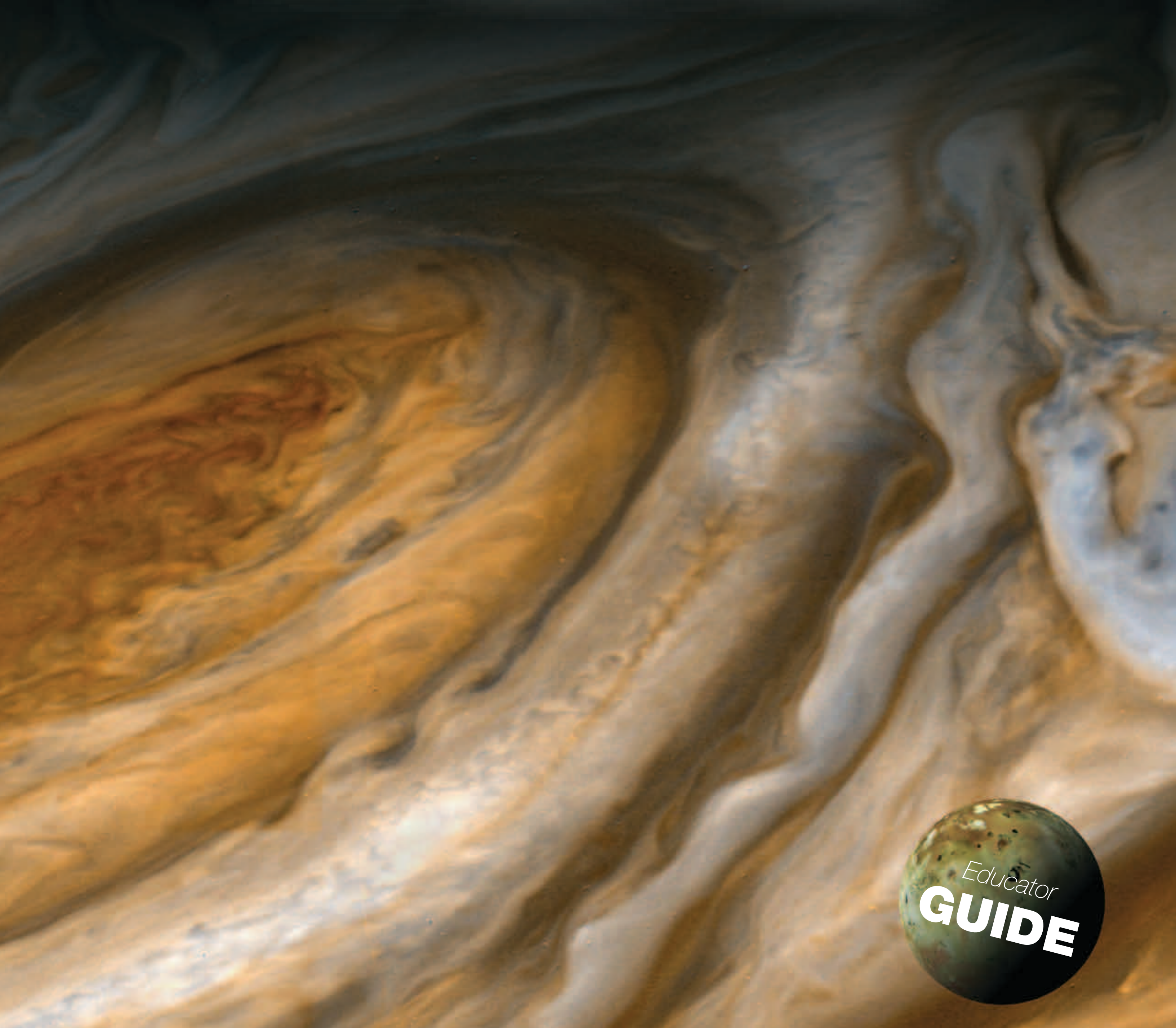
Kallisti Media

COSMIC JOURNEY

THROUGH HUBBLE AND CASSINI



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COSMIC J

Carina Nebula

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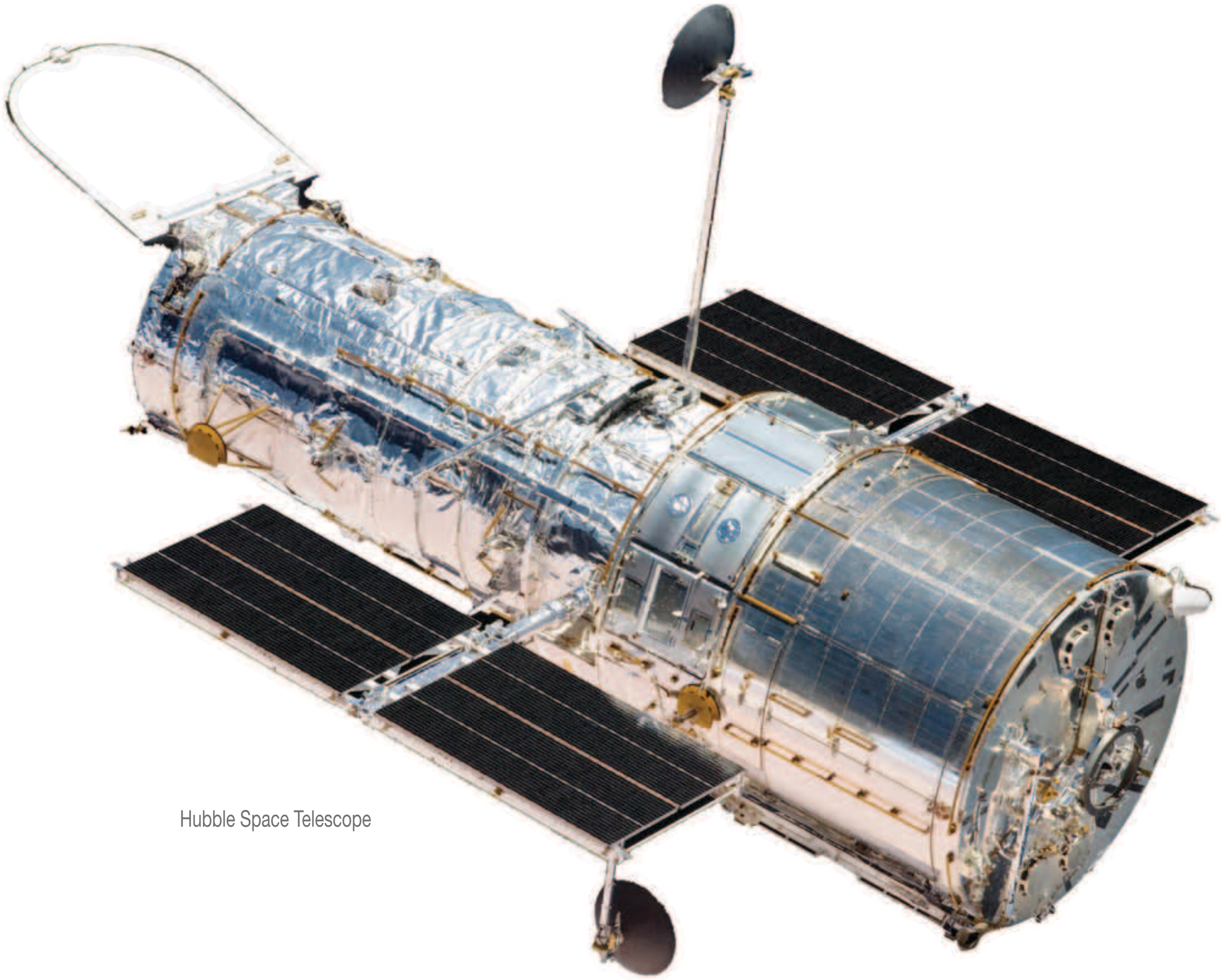

Hubble Space Telescope

INTRODUCTION

Cosmic Journey: Through Hubble and Cassini is a stunningly beautiful, totally immersive 3D journey from Shuttle launch to the far edge of the known Universe and back. Audiences will see the clouds of Jupiter, the rings of Saturn, gaseous nebulae and far away galaxies brought to life like never before. By combining images from the Hubble Space Telescope and the Cassini Orbiter with our very own custom technology we are able to deliver a riveting cinematic celebration of cosmology.

www.COSMICJOURNEYMOVIE.com

Film Information and Leasing:
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Acknowledgements:
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Special thanks to: Trey Swann; Cheryl Galloway, Science/Math/GATE Education Specialist; Kathy Burns, Language Arts/History/Social Science Education Specialist; Bonnie Swann, Executive Director of Curriculum NMUSD; Jim O'Leary; Raymond Shubinski.

USING THIS GUIDE

This guide was designed for teachers and students to accompany the film, *Cosmic Journey: Through Hubble and Cassini*. This guide is most powerful when used in concert with the film, but remains a valuable resource as a standalone guide for your classroom's comic journey. Teachers are strongly encouraged to adapt activities included in this guide to meet the specific content standards of the grade level that they teach.

There are ten activities that support the Common Core Standards for Visual and Performing Arts, Math, Science, Language Arts, and History/Social Science. In addition, this guide reinforces Digital Age readiness and 21st Century Skills.

The content covered in each activity is marked in the content column below. These activities were designed to comply with the content standards for K-12 education. Specific grade levels are listed under each activity.

	CONTENT AREA					
ACTIVITY	Visual and Performing Arts	Math	Science	Language Arts	History/Social Science	21st Century Skills
1. The Expanding Universe		•	•			•
2. Measure the Galaxy		•	•			•
3. Paint by Numbers	•	•	•			•
4. My, What Big Eyes You Have		•	•			•
5. How Far Away Is Saturn?		•	•	•		•
6. Traveling to Saturn		•	•	•		•
7. Personal Solar System	•	•	•			•
8. The Cassini Space-craft	•	•	•	•	•	•
9. Vision and Depth Perception	•	•	•			•
10. 3D Glasses	•	•	•			•

For more details on connections to Common Core Standards, please see Activity Connections to Common Core Standards on page 46.

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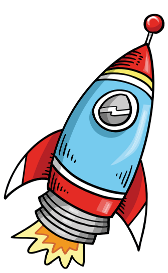
OUR COSMIC JOURNEY

Looking Back in Time

Since the earliest days of astronomy, since the time of Galileo, astronomers have shared a single goal -- to see more, see farther, see deeper. As we journey through space, from Earth outward our expanding frontiers have revealed the true geography of our Universe. As civilizations grew and technology progressed, we have become aware that our planet is just a dot in a vast Universe.

Space is truly gargantuan! By combining our understanding of the massive scale of the Universe and light's finite speed we are given a valuable view into the past. Literally, as we strain our gaze deeper into the Universe we look further back in time.

"Because light takes time to get here from there, the farther away 'there' is the further in the past light left there and so we see all objects at some time in the past," explains Floyd Stecker of NASA's Goddard Space Flight Center in Greenbelt, Maryland. So we can never see the Universe as it is, only as it was at various stages of its development.



In a vacuum, light travels at an impressive 186,282 miles per second. Even at that speed it takes light a long time to reach us here on Earth. The Moon is relatively close, and yet we see it as it was 1.2 seconds ago, and the more distant Sun as it was approximately 8 minutes ago. These measurements -- 1.2 light-seconds and 8 light-minutes -- can be thought to describe both time and distance.

The distance to more remote objects such as other stars is so great it is measured in light-years -- the distance light will travel in a year, or about 6 trillion miles (10 trillion kilometers). The closest star system to Earth is Proxima Centauri, and it still lies more than four light-years away. Meaning it appears to us on Earth as it was over four years ago when the light began its journey. In the case of distant galaxies, we see them as they were millions and even billions of years ago when the Universe was still relatively young.

Most of the scientific community now believes that the Universe has been expanding ever since the Big Bang 13.7 billion years ago. Again, due to the time it takes light to travel, the farther away in space we focus our attention, the further back in history we can see. The Hubble Space Telescope has witnessed galaxies forming barely half a billion years after the Big Bang -- capturing light generated 13 billion years ago. By examining Hubble's extraordinary images, astronomers can trace the origin and development of planets, stars, galaxies and even the Universe itself.

Early Astronomers

The history of astronomy is the study of humankind's early attempts to understand the skies. All people have looked up and wondered about the Sun, Moon, planets, stars, and their complex ballet of motion. The ancients studied the Moon and Sun to learn when to sow their crops and when to harvest. They also held the belief that the Moon and Sun orbited the Earth.

It was Ptolemy in 120 AD who is credited with systematizing the geocentric system of planets. In 1510 Nicolaus Copernicus proposed the heliocentric system whereby the Sun was the center of our Solar System and not the Earth. Early in the 17th century Kepler came up with detailed laws for planetary motion, and Galileo Galilei first used a telescope from lenses he made himself. Again, he stated that the Sun was the center of the Universe.

In the late 1600s Newton discovered the basic laws of Physics that allow us to understand the cosmos. But, it was Edwin Hubble who pushed the boundaries of the known Universe farther than all who came before him; Hubble discovered that our Milky Way was not the center of the Universe, but rather only one galaxy in among billions. In 1923 Hubble finds Cepheid variable star in Andromeda Galaxy (M31). Then in 1925 Edwin Hubble published a historic paper that showed the distance to M31, proving that our Milky Way is only one of many galaxies. Finally in 1929 Hubble correlates the distance to other galaxies with their recessional velocity, confirming the expansion of the Universe.

The history of astronomy is a very long one and astronomy has been pursued by all cultures, so there is a wide range of tools. Before the discovery of the telescope, the only observing device that people could use was the human eye, perhaps aided by a variety of sighting devices. The Chinese used armillary spheres, Tycho Brahe used long sighting tubes in the late 1500s, and some believe neolithic farmers made Stonehenge to point to the summer solstice Sunrise, and Newgrange to align with the winter solstice Sunrise.

After the invention of the telescope, there was a steady push for bigger, better, and more sensitive devices. Starting around the 1800s, various instruments, like micrometers and spectrometers, were constructed to give very detailed measures of the light coming from stars. Starting around 1900, the photographic plate and then

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the CCD camera revolutionized astronomy due to their great sensitivity.

Hubble

The Hubble Space Telescope's launch in 1990 sped humanity forward on our cosmic journey. Hubble is a telescope that orbits Earth. Its position above the atmosphere, which distorts and blocks the light that reaches our planet, gives it a view of the Universe that typically far surpasses that of ground-based telescopes.

Every 97 minutes, Hubble completes a spin around Earth, moving at the speed of about five miles per second (8 km per second) -- fast enough to travel across the United States in about 10 minutes. As it travels, Hubble's mirror captures light and directs it into several science instruments.

People often mistakenly believe that a telescope's power lies in its ability to magnify objects. Telescopes actually work by collecting more light than the human eye can capture on its own. The larger a telescope's mirror, the more light it can collect, and the better its vision. Hubble's primary mirror is 94.5 inches (2.4 m) in diameter. This mirror is small compared with those of current ground-based telescopes, which can be 400 inches (1,000 cm) and up, but Hubble's location beyond the atmosphere gives it remarkable clarity.

The Hubble Space Telescope is the direct solution to a problem that telescopes have faced since the very earliest days of their invention: the atmosphere. The quandary is twofold: Shifting air pockets in Earth's atmosphere distort the view of telescopes on the ground, no matter how large or scientifically advanced those telescopes are. This "atmospheric distortion" is the reason that the stars seem to twinkle when you look up at the sky.

Hubble is one of NASA's most successful and long-lasting science missions. It has beamed hundreds of thousands of images back to Earth, shedding light on many of the great mysteries of astronomy. Its gaze has helped determine the age of the Universe, the identity of quasars, and the existence of dark energy.

Cassini

NASA's Cassini spacecraft launched in October 1997 with the European Space Agency's Huygens probe. Two elements comprise the spacecraft: The Cassini orbiter and the Huygens probe. In 2004, Cassini-Huygens reached Saturn and its moons. There the spacecraft began orbiting the system in July 2004, beaming home valuable data that will help us understand the vast Saturnian region. Huygens entered the murky atmosphere of Titan, Saturn's biggest moon, and descended via parachute onto its surface.

Cassini-Huygens is one of the most ambitious missions ever launched into space. Loaded with an array of powerful instruments and cameras, the spacecraft is capable of taking accurate measurements and detailed images in a variety of atmospheric conditions and light spectra.

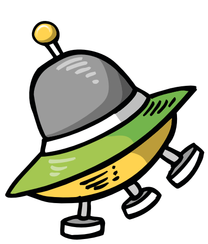
In some ways, the Cassini spacecraft has senses better than our own. For example, Cassini can "see" in wavelengths of light and energy that the human eye cannot. The instruments on the spacecraft can "feel" things about magnetic fields and tiny dust particles that no human hand could detect.

3D

Most human beings use what is known as binocular vision to perceive depth and see the world in 3D. The binocular vision system relies on the fact that we have two eyes, which are approximately 3 inches apart. This separation causes each eye to see the world from a slightly different perspective. The brain fuses these two views together. It understands the differences and uses them to calculate distance creating our sense of depth and ability to gauge distance.

A simple way to understand this principle is to hold your thumb up at arms length and close one eye. Then try closing the other eye. As you switch between open eyes you should see your thumb "jumping" back and forth against the background. To see how much of a difference the binocular vision system makes, have a friend throw you a ball and try to catch it while keeping one eye closed.

As you embark on your cosmic journey you will be aided by one of the finest 3D experiences available. Our 3D technology delivers amazing clarity and depth creating a stunningly beautiful, totally immersive 3D journey.



ACTIVITY 1
THE EXPANDING UNIVERSE

Grade Level:
6-12 (adapted)

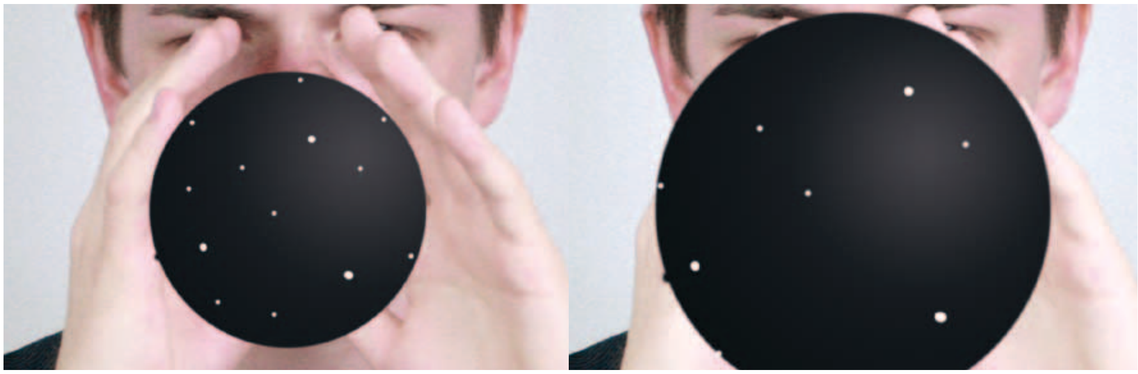
Content Area:
Math, Science, 21st Century Skills

Objective:
Students will observe a model of the expanding Universe, and learn that the farther away a galaxy is from us, the faster it is receding from us. Students will develop authentic models, and ultimately gather evidence supporting the Big Bang theory.

Materials:
- 1 large balloon for every 2 students
- 4 strips of paper cut 2 cm x 30 cm
- Metric rulers
- 1 marker for every 2 students
- Scissors
- Pen/pencil
- Large paper clips
- One copy of this student handout

Background:
In 1929, Edwin Hubble confirmed that the Universe is expanding. If the Universe is expanding, then one can assume that the galaxies that compose our Universe were once much closer together than they are now. If we run the expansion process backward, we get two results. The first is that it probably took approximately 13.7 billion years for the Universe to grow to its present size. Second, the Universe must have begun its expansion in an awesome event that astronomers call the Big Bang.

In this analogy the Universe is the balloon, and the dots are galaxies. As the Universe expands, the dots get farther and farther apart. No one dot is at the center but rather space expands away from all of them.



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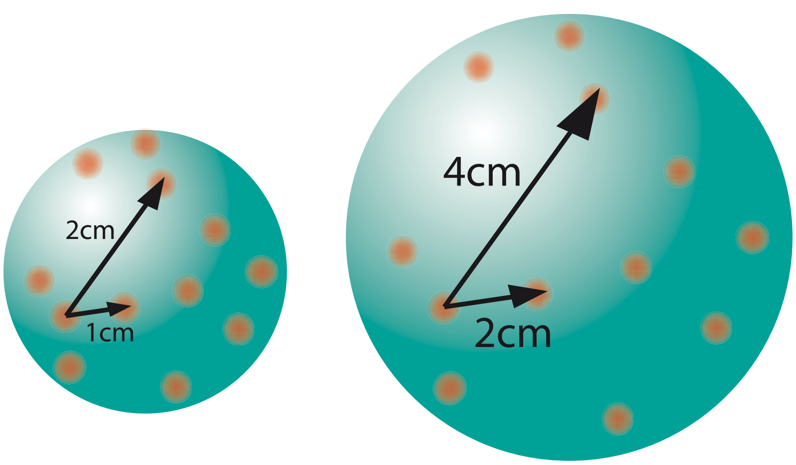
Procedure:

1. In this activity, you are going to create a model of the expanding Universe. Materials needed include a balloon, ruler, paper strip, a copy of this page, and a marker.
2. Use the markers to make 10-15 dots on the balloon and number 10 of them after the balloon is partially inflated.
3. Inflate balloon with 4 medium breaths to about the size of your fist; do not over inflate the balloon!
4. Bend the end of the balloon down and paper clip it so that no air escapes.
5. Record what happens to the dots in the space provided below. Be very specific; use complete sentences.
6. Measure and record the distance between dot number one (your "home" dot) and the next 10 other dots with the METRIC RULERS. Be careful not to indent the balloon by pressing on it.
7. Now measure and record the distance between dot number one (your "home" dot) and 10 other dots with the paper strip.
8. Double the size of the balloon by inflating it slowly; do not over inflate the balloon! Measure and record the data from the enlarged balloon using both tools.
9. Answer the summary questions below.



PARTIALLY EXPANDED			
Dot	Initial Distance from Dot #1 using the ruler	Initial Distance from Dot #1 using the paper strip	Difference
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

FULLY EXPANDED				
Dot	Final Distance from Dot #1 using the ruler	Final Distance from Dot #1 using the paper strip	Difference	Change from Before to After
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

Questions:

1. As the balloon (i.e. the Universe) expands what happens to the dots (i.e the galaxies)?

2. If you started with a fully expanded balloon (i.e. the Universe), and ran this experiment in reverse what would happen to the dots (i.e. the galaxies)?

3. Which measuring tool was more accurate? Why?

4. In this experiment your breath caused the balloon (i.e the Universe) to expand, what caused the actual Universe to expand?

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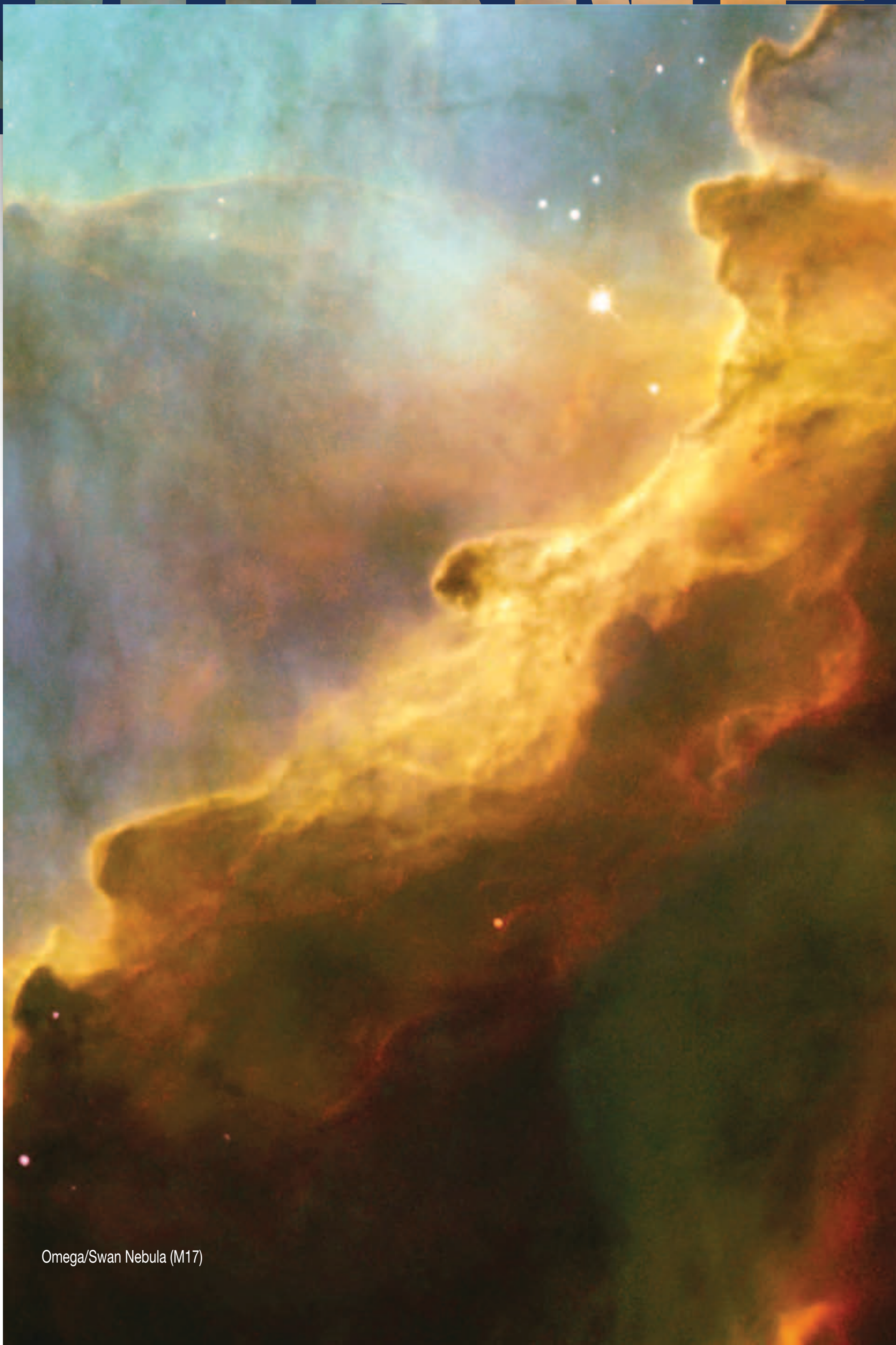

Omega/Swan Nebula (M17)

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ACTIVITY 2
MEASURE THE GALAXY

Grade Level:
3-12

Content Area:
Math, Science, 21st Century Skills

Objective:
Students will learn to convert distances between celestial objects into the scale of rice grains representing the size of Earth. Students will learn to convert the scale size of an object using ratio manipulation. Students will also calculate distances using large numbers.

Materials:
- About one tablespoon of uncooked rice (Rice grains about 1 mm in diameter the short way. If this size is unavailable, tapioca could be substituted)
- Ruler or meterstick with millimeter markings
- Calculators
- String, 15 meters long. The string is to show the distance from Earth to the Sun using the scale of one Earth = one grain of rice.
- Glue stick (optional)
- Hand lenses or forceps may be useful but are not obligatory.

Notes on the Activity:
Teams of three are suggested. Distances in space are very hard to imagine. We suggest reading the student sheet aloud, stopping to complete activities and calculations as they occur. Time should also be allowed for group discussion to create their "mathematical plans." Alter the plan if it leads to incorrect solutions and/or analyze results of the computation.

Notes on the Mathematical Plans:
Depending on age appropriateness, it is hoped that students will be able to think about the challenge of converting distances between celestial objects into the scale of rice grains representing the size of Earth.

1. The mathematical plan to convert the distance from Earth to the Moon should include finding the distance to the Moon in kilometers (km) and dividing by the diameter of Earth in km: 384,000 km /13,000 km per Earth diameter = 29.5 Earth diameters (rice grains).
2. After the students draw the line, it may help to have them go over the line with a glue stick. This will keep the rice grains from moving around during placement.
3. The mathematical plan for calculating the number of rice grains (mini-Earths) to show the distance to Mars is the same as for the Earth-to-Moon problem. This may be a time to introduce scientific notation: 78,000,000 km / 13,000 km = 6,000 rice grains. A discussion about the time needed to lay out 6,000 rice grains might lead to seeing the need for an easier method of measuring scale distances.
4. This activity begins to make the connection between the size of rice grains and millimeters.
5. The mathematical plan for changing the Earth-to-Mars distance from rice grains into millimeters (mm) of length is: one rice grain = 1 mm of length. Therefore, 6,000 rice grains x 1 mm per rice grain = 6,000 mm. If students are proficient in conversion in the metric system, have them change the 6,000 mm into either

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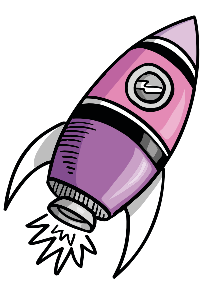
centimeters or meters. Then have them measure a length of string this long and lay it out in the classroom, perhaps crossing their rice grains of the Earth-to-Moon distance. A discussion of relative distances in the Solar System may lead to interest in computing distances to other planets, the Sun, or nearby stars.

TEACHER DATA TABLE

Distance from Earth to:	In Reality (km)	In Rice Grains	Length Rice Grains Occupy
Moon	384,000	29.5	2.95 cm
Mars	78,000,000	6,000	6 m
Sun	150,000,000	11,500	11.5 m
Pluto	5,900,000,000	454,000	454 m
Sirius	81,000,000,000,000	6,200,000,000	6,200 km



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STUDENT**OBSERVATION**SHEET
SUMMARY**QUESTIONS**

Overview:

Distances in space are very hard to imagine. Since few people walk between cities, it is even hard to imagine the distance between two widely separated places. Try to imagine a trip from your house to the next town. Can you imagine walking to the next town with a meterstick, stopping to measure every meter of your journey? __________________ (yes or no)

Now try to imagine the distance to the Moon, to another planet, or to a star. Science fiction movies make it seem easy to travel in space. But what would it be like to actually try to travel to another star?

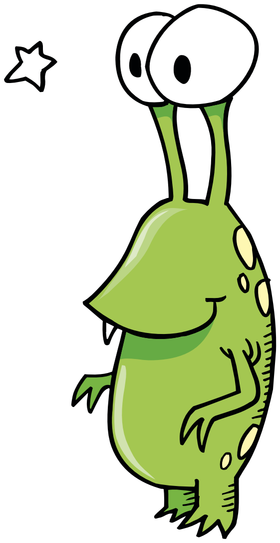
Procedure / Directions for measuring the Galaxy:

1. Imagine that Earth is only as big as a grain of rice. Mathematicians call this technique "changing the scale." Using the Student Data Table, compute the number of rice grains ("mini- Earths"), if placed beside each other in a row, needed to go from here to the Moon. Hint: To do this, you need to know that Earth is about 13,000 km in diameter.

   Consult the Student Data Table to find the distance from Earth to the Moon. Using this information, discuss and design a mathematical plan to change the distance from Earth to the Moon into rice grains laid in a row. Write down your plan. Check your plan with your teacher. Compute the number of rice grains in this scale that show the distance from Earth to the Moon. Write this number in your table.
2. Draw a line and try to lay this many grains of rice on it, side by side so that each rice grain touches its neighbor. All the rest of the computations will use the scale of one rice grain = one mini-Earth.
3. Using your mathematical plan, compute the number of rice grains needed to measure the distance to the other planet. Try laying out the rice grains (mini-Earths) to represent the distance from Earth to Mars. Check this with your teacher. Write this number in the Student Data Table. Would you like to count this many rice grains? __________________ (yes/no)

   Would you like to lay out that many rice grains in a row? __________________ (yes/no)
4. Measuring length instead of counting: Try changing rows of rice grains into measures of length. (An average coarse rice grain is 1 millimeter in diameter.) Look at the ruler or meterstick, and find the length called millimeters. Draw two dots that are 1 millimeter apart. Show your teacher. This is the size of a rice grain (mini-Earth). Draw four more dots along a line, each dot 1 millimeter farther away from the last. Using your ruler, draw a straight line through all five dots. Show your teacher. This represents five rice grains lined up.
5. We need to make a new mathematical plan to change a certain number of rice grains in a row into millimeters of length. Write down your plan and show it to your teacher. How many millimeters of rice grains are needed to measure the distance from Earth to Mars in rice grain (mini-Earth) units? Write this answer in the Student Data Table and check it with your teacher. Measure a length of string this long and stretch it out. This is how many rice grains are needed, lined up, to measure the distance from Earth to Mars. On this scale (one rice grain = one mini-Earth), Pluto is over 400 meters (4 soccer fields) away. On this scale, the distance to Sirius — a nearby bright star — is a line of rice grains stretching from here to New York City! You can see that distances in the universe are very hard to imagine.

STUDENT DATA TABLE			
Distance from Earth to:	In Reality (km)	In Rice Grains	Length Rice Grains Occupy
Moon	384,000		
Mars	78,000,000		
Sun	150,000,000		
Pluto	5,900,000,000		
Sirius	81,000,000,000,000		



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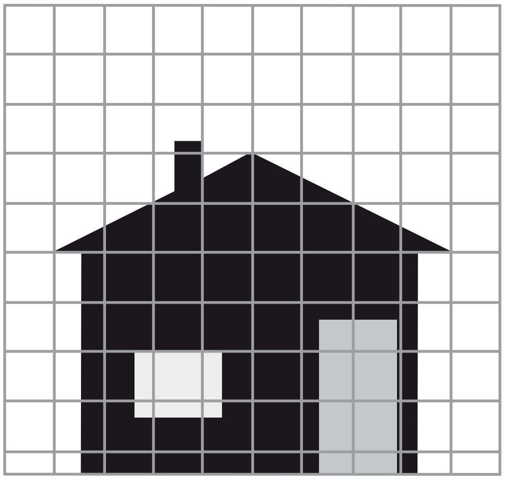
ACTIVITY 3
PAINT BY NUMBERS

Grade Level:
5-8

Content Area:
Visual and Performing Arts, Math, Science, 21st Century Skills

Objective: Students will learn how light collected from a space object converts into binary data and reconverts into an image of the object. The lesson demonstrates the imaging process of astronomical satellites such as the Hubble Space Telescope. The aim is to familiarize students with the process of data transmission to Earth and its re-assembly into images.

Materials (per group of 2 students):
- Transparent grid
- Paper grid
- Picture of house
- Pencil



Procedure:
1. Divide students into pairs.

2. Give one student (A) in each pair the paper copy of the blank grid on the next page. Give the other student (B) in each pair the picture of the house on the next page. Instruct student B not to reveal the picture to student A. Also give student B a copy of the transparent grid. (See notes about making student copies of the picture and grids on the next page.)

3. Explain that the picture is an object being observed at a great distance. It will be scanned by an optical device like those found on some astronomical satellites and an image will be created on the paper.

4. Have student B place the grid over the picture. Student B should look at the brightness of each square defined by the grid lines and assign it a number according to the chart above the picture. Student B will then call out the number to student A. If a particular square covers an area of the picture that is both light and dark, student B should estimate its average brightness and assign an intermediate value to the square such as a 1 or a 2. Note: The letters and numbers on two sides of the grid can assist the receiving student in finding the location of each square to be shaded.

5. After receiving a number from student B, student A will shade the corresponding square on the grid. If the number is 0, the square should be shaded black. If it is 3, the square should be left as it is.

6. Compare the original picture with the image sketched on the paper.

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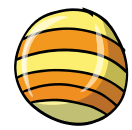


Background:

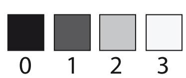
This activity simulates the process by which an astronomy spacecraft such as the Hubble Space Telescope collects light from an astronomical object and converts the light into a digital form that can be displayed on Earth as an image of the object. The student with the transparent grid represents the spacecraft. The picture is the object the spacecraft is trying to collect from. The student with the paper grid represents the radio receiver on the ground and the image-processing computer that will assemble the image of the object.

The image created with this activity is a crude representation of the original picture. The reason for this is that the initial grid contains only 64 squares (8 x 8). If there were many more squares, each square would be smaller and the image would show finer detail. You may wish to repeat this activity with a grid consisting of 256 squares (16 x 16). However, increasing the number of squares will require more class time. If you wish to do so, you can select a single student to represent the spacecraft and transmit the data to the rest of the class.

With the Hubble Space Telescope, the grid consists of more than 2.5 million pixels and they are shaded in 256 steps from black to white instead of just the 4 shades used here. Color images of an object are created by the Hubble Space Telescope with color filters. The spacecraft observes the object through a red filter, a blue filter, and then a green one. Each filter creates a separate image, containing different information. These images are then colored and combined in a process similar to color separations used for printing colored magazine pictures.

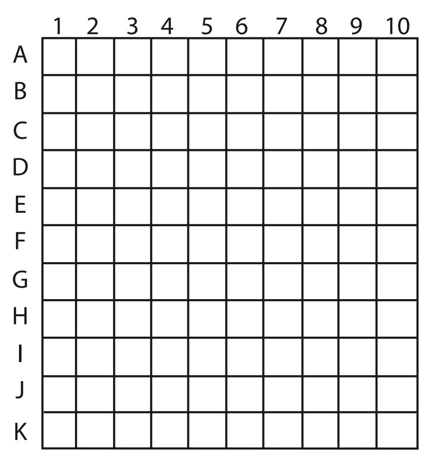
Management and Tips:

Students can provide their own pictures for this activity. It is important for the pictures to show strong contrast. The smaller the grid squares, the more detail that will appear in the image. However, simply going from a grid of 10 x 10 to a grid of 20 x 20 will quadruple the length of time it takes to complete the image.



Shading Values

Sample Picture



100 Pixel Grid

COSMIC

ACTIVITY 4
MY, WHAT BIG EYES YOU HAVE

Grade Level:
3-8

Content Area:
Math, Science, 21st Century Skills

Objective:
Students will learn that a telescope can gather more light and become more powerful when you increase the surface area of the lens or mirror. Students will discover the connection between what their eyes can see and what astronomers can see with telescopes.

Materials:
- CD (about 4-5/8 inches in diameter)
- Paper plate (9 inches in diameter)
- 12-inch disposable pizza pie pan
- 9x12-inch or larger sheet of paper
- Counter disks or coins, no more than 3/4 of an inch in diameter (about 400 will complete all 3 objects)
- Plastic bags or containers, paper plates, or pie plates to hold the counters
- Simple chart to record the diameters of the three "telescope mirrors," the estimate of how many "eyes" are needed to cover the surface area, and how many "eyes" were actually needed to cover the surface area of each

Background:
We all know that a telescope enables us to see objects that are much fainter than the human eye can see by itself. But, people often mistakenly believe that a telescope's power lies in its ability to magnify objects. Telescopes actually work by collecting more light than the human eye can capture on its own.

A telescope's sensitivity, or how much detail it can see, is directly related to the size of the mirror area that collects light from the objects being observed. A larger area collects more light, just like a larger bucket collects more water in a rain shower than a small one. The amount of light collected does not depend simply on the width (diameter) of the lens or mirror, but instead on the entire surface area of the lens or mirror. For a circular shape, the area is determined by the diameter times the diameter, or diameter-squared.

In this activity, we use a 3/4-inch plastic counting disk (or small coin) to represent the area of the human eye. A 4-5/8-inch CD, a 9-inch paper plate, and a 12-inch pizza pan represent small, medium, and large telescope mirrors.

The diameter of the paper plate outline is nearly twice the diameter of the CD. However, the area of the paper plate outline is nearly 4 times the area of the CD. The diameter of the pizza pan is 2.6 times that of the CD, but the area of the pizza pan is almost 7 times greater than the area of the CD. Counting the number of disks needed to cover the surface areas allows us to see how quickly the light-gathering area increases.

The pupil of the human eye can be anywhere from 2 mm to 8 mm in diameter. If we assume a typical size to be 5 mm, we can compare the pupil of an eye to the mirror of the Hubble Space Telescope, which is 2.4 m in diameter. This means that Hubble is 480 times the diameter of the pupil, and so its area is 230,400 times the area of the pupil of a human eye. If you think of the area of the pupil or the area of the Hubble mirror as a bucket that can capture light, Hubble can "capture" 230,400 times more light than the human eye!

The following activity will give you an idea of why astronomers build bigger telescopes in order to see fainter objects in the Universe.

OURNEY

Procedure:

- Trace an outline of the paper plate on the sheet of paper. (Do not work directly on the paper plate. The disks will slide off the raised plate edges.)
- Put the counters into plastic bags or containers, or onto paper plates or pie pans.
- Set up one or more stations with plastic counters, a CD, the paper plate outline, and a pizza pan. Each student or each group can have a chart for recording measurements.
- Explain that one disk represents the human eye. Have the students brainstorm how much their eyes can see (small objects, large objects, distant objects, etc.).
- Explain that telescopes can help our eyes to see faint objects at very great distances. The size of the telescope mirror helps to determine how much we can see.
- Place a line of disks across the diameter of the CD. Count the disks and record this number (see Fig. 1).
- The CD represents a small telescope mirror. Each disk represents one "eye." Have the students estimate how many disks will cover the CD (see Fig. 2). Record this number.
- Use the disks to cover the surface of the CD. How many "eyes" does it take to cover the CD? Record this number. How accurate were the estimates? This small "telescope mirror" would gather enough light to help us see fainter objects in the sky.
- Use the paper plate outline to represent a medium-sized telescope mirror. Place a line of disks across the diameter of the plate outline. Count the disks and record this number.
- Discuss the concept of area. The area of the paper plate outline is greater than that of the CD. Have the students estimate how many disks will cover the paper plate outline. Record this number.
- Use the disks to cover the surface of the paper plate outline. How many "eyes" does it take to cover the paper plate outline? Record this number. How accurate were the estimates? Compared to the small "mirror," the number of disks needed to cover the area increased far more than the number of disks needed to go across the diameter.
- Use the pizza pan to represent a large telescope mirror. Follow the same procedure as above. Count how many disks fit across the diameter and record the answer. Estimate how many "eyes" it will take to cover the surface of the pizza pan, record the number, then use the disks to cover the pan, record the number, and discuss how accurate the estimates were.
- Discuss why larger telescope mirrors gather more light and help us see much fainter objects than we can see with our eyes. Emphasize the larger area of the pizza pan relative to the areas of the CD and the paper plate outline.

Hubble primary mirror

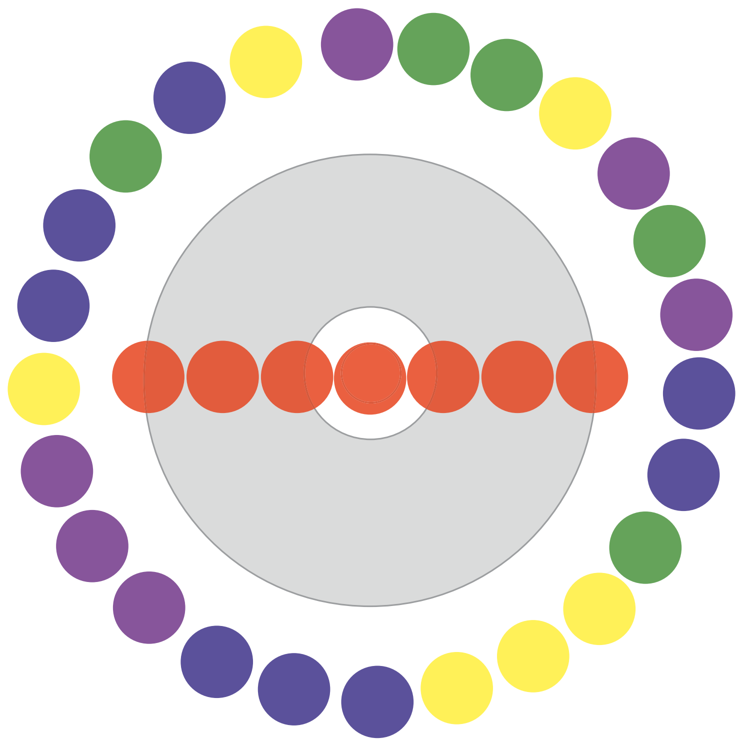


Figure 1: The disks (not quite 7) across the diameter of the CD

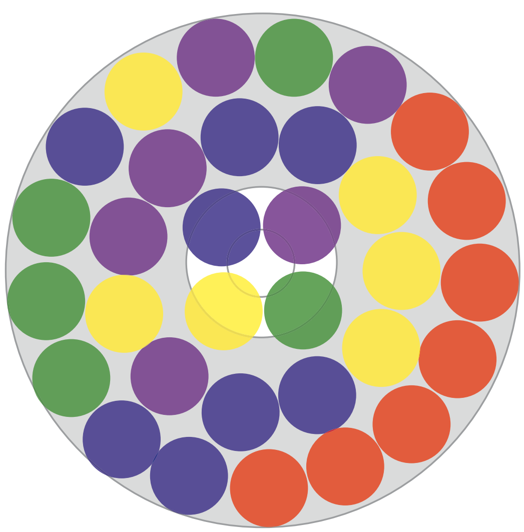
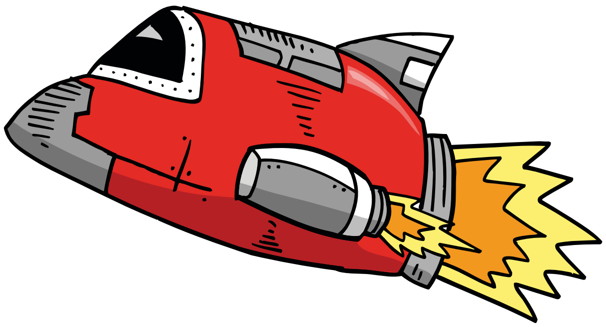


Figure 2: The disks (32) covering the entire area of the CD

RECORDING MEASUREMENTS				
	Diameter (number of disks across)	Estimated Surface Area (how many disks will cover)	Actual Surface Area (how many disks will cover)	Difference
CD				
Paper Plate				
Pizza Pan				



COSMIC

ACTIVITY 5
HOW FAR AWAY IS SATURN?

Grade Level:

K-6

Content Area:

Math, Science, Language Arts, 21st Century Skills

Objective:

Students will "take a walk" to Saturn, and in the process learn to understand the vastness of the Solar System and the size differences between our home — Earth — and our destination, Saturn. Students will practice descriptive writing and compare/contrast writing. Students will build an operational understanding of scale, both size and distance, in comparing the Sun, Earth, and Saturn. Lastly, Students will practice the scientific thinking skills of predicting, comparing, and relating.

Materials:

- Tongue depressors or popsicle sticks
- Glue
- Three stick models (per group of 3 students) – Sun on a stick, Earth on a stick, and Saturn on a stick
- Tape
- Large marker
- Large piece of chart paper
- Yard stick
- Highlighter or yellow marker

Before You Begin:

1. Print out copies of teacher reference 4: Sun, Earth, and Saturn image page for the "Sun on a stick," "Earth on a stick," and "Saturn on a stick." Cut out the images and glue (or laminate) them to tagboard. Then tape each object to a large tongue depressor or popsicle stick, so that students can easily hold them. Make enough so that you have enough for students to work in groups of three; make one extra set for the Chart of the Size Models for the Walk to Saturn.

2. Create a Chart of the Size Models for the Walk to Saturn

- On a large piece of chart paper, write the title:
  "A Chart of the Size Models We Use for Our Walk to Saturn"
- You will be using one set of the "Sun on a stick," "Earth on a stick," and "Saturn on a stick."
- Tape a "Sun on stick" on the left margin.
- Write: Our model Sun has a diameter of 8 inches.
  The real Sun has a diameter of about 800,000 miles.
- Tape an "Earth on a stick" below the Sun.
- Write: Our model Earth has a diameter of 8/100 of an inch (0.08).
  The real Earth has a diameter of about 8,000 miles.
- Tape a "Saturn on a stick" below the "Earth."
- Write: Our model Saturn has a diameter of 75/100 of an inch (3/4 inch or 0.75 inch).
  The real Saturn has a diameter of about 75,000 miles.
- Write: One inch in our model represents 100,000 miles (1:100,000).
- Draw a little rectangle, or fat line, that is exactly one inch long, and label it.

• Trace a yard stick, color in with a yellow marker or highlighter, and label it "36 inches or 1 yard."

• Write: One yard, or 36 inches in our model represents 3,600,000 miles.

So, with each giant-step pace, we will travel 3,600,000 miles!

3. Create a special Saturn envelope that you open upon arrival at Saturn as your class paces the Solar System. There could be photos or facts about Saturn written on strips of paper that students could take turns reading aloud.

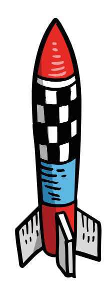
Procedure:

Understanding Size and Distance

1. Tell students that "we are going to begin our journey to Saturn with a scientific model that will help us understand both size and distance." Explain to the students that the Sun is the largest object in the Solar System — it would take 109 Earths to span the Sun's diameter. Remind students that the Sun is in the center of the Solar System and the planets orbit the Sun.
2. Show the students the "Sun on a stick" that is approximately 8 inches in diameter. This is our model Sun. Have students predict: If this is our Sun, how big do you think Earth should be? How big do you think Saturn should be? Have students draw their ideas.
3. Show the students the "Earth on a stick" and "Saturn on a stick" models. Earth and Saturn will be exaggerated in scale (compared with the 8-inch-diameter Sun) so that they can be seen by everyone in the classroom.
4. Students can make changes to their drawings, and label "first ideas" and "actual model size."
5. Display the Chart of the Size Models for the Walk of Wild Size you have made and have the students read it with you.
6. Ask the students, "Now that we have established the size scale for the Sun, Earth, and Saturn, how much space do you think we need for a scale model of distance between the Sun, Earth and Saturn?" Record predictions on the board.
7. Tell students: The distance between Earth and the Sun is 93 million miles. In the model, this will be 26 yards. Have a student volunteer take 26 paces in the classroom. (Students will see that it will be necessary to go outside to complete the model.)
8. Take the class outside.
9. Take a few minutes to demonstrate, and have students practice, pacing as close to a yard in length as possible. This is another good place to talk about the difference between a model and "real life," and that our giant-step paces will be almost, but not exactly, the same.
10. Distribute sets of Saturn on a stick, Sun on a stick, and Earth on a stick to student groups of three. Have the oldest student be the Sun, the second oldest be Earth, and the third oldest be Saturn.
11. Ask the students, "How far apart do you think you need to stand in order to model the distance that the Sun, Earth, and Saturn are from one another?" (Give students a few minutes to discuss.)
12. Have the groups model what they think are the scaled distances between the Sun, Earth, and Saturn.
13. Bring students back together and have a brief discussion about what they noticed.

Taking a Walk to Saturn

1. Collect the Sun, Earth, and Saturn stick models.
2. Have a volunteer Hold ONE Sun stick model. Have the students line up. Begin pacing together (teacher reads directions). Note: the pacing directions tell where the other planets are located. You can call these out as you pass each one. Also, you can continue past Saturn all the way to Pluto, if desired.



3. Stop at Saturn and discuss the model with your students. Prompt them with the questions on the "Taking a Walk of Wild Size: Directions for Pacing the Solar System" sheet. You may want to have students record their responses, especially if they are fourth graders. If you have created a special Saturn envelope, it can be opened upon arrival at Saturn. There could be photos of Saturn, or facts about Saturn written on strips of paper that students could take turns reading aloud. *Optional: This would be a good time to do the "Traveling to Saturn" activity (extension activity 2).*
4. Return to the classroom and have the students complete their Saturn Discovery Log entries.

Taking a Walk to Saturn

Directions for Pacing the Solar System

1. Start at the Sun.
2. Take 10 paces. (Remind student that these are "giant steps" and should be as close to a yard in length as possible.) Call out "Mercury."
3. Take 9 more paces. Call out "Venus."
4. Take 7 paces. Call out "Earth." (At this point, have the students look back at the Sun. Ask, "What do you notice?" "How big does the Sun look from Earth?")
5. Take 14 paces. Call out "Mars."

   (Ask students if they know which planet they will pass next on their journey to Saturn.)
6. Take 95 paces. Call out "Jupiter."

   (Ask students which planet is next. Have them predict how many more paces it will be to Saturn.)
7. Take 112 paces. Call out "Saturn."

   WOW! Saturn is 247 paces from the Sun, and 221 paces from Earth!

To The Outer Planets

If you have time, you can continue to Pluto!

It is 249 paces from Saturn to Uranus.

It is 281 paces from Uranus to Neptune.

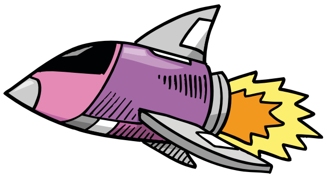
It is 242 paces from Neptune to Pluto.

Discussion

Talk about the model with your students, using the following questions to guide the discussion. Students can also write notes in their logs.

- How do you feel?
- What do you notice?
- Can you see the Sun? Can you see Earth?
- What do you notice about how the Sun looks from Saturn compared to how it looked from Earth? (size, brightness)
- Do you think it is colder on Saturn than Earth? Why?
- What problems or challenges do you think a spacecraft will have to overcome in order to travel from Earth to Saturn?
- What kinds of information about Saturn and Titan do you think a spacecraft could gather that we are unable to gather from Earth?

- How did the trip feel?
- What was most surprising?
- What questions do you have? ("I wonder...?" "What if...?")



Writing About Saturn

Options:

- A compare and contrast paragraph about the activity: "My ideas about the distance from Earth to Saturn before and after the activity."
- A descriptive paragraph about the activity.

1. Have students talk with a partner before beginning to write. They can share notes from their logs, or discuss one or both of the suggested writing activities.
2. Talking before writing gives students a chance to rehearse their ideas, to clarify ideas, and to learn from one another. A suggested format is to have students sit facing their partners "knee-to-knee and eye-to-eye." Give one partner 2 or 3 minutes to talk. The listener can then ask clarifying questions. Have students reverse roles.

Solar System Background Information

Information on Size

Diameter is the length of a straight line through the center of an object — so, the diameter gives us the measurement of how far it is across a planet, moon, or the Sun.

- The Sun's diameter is about 863,890 miles.
- Earth's diameter is about 7,928 miles.
- Saturn's diameter is about 74,913 miles.
- It would take about 109 Earths to span the diameter of the Sun.
- It would take about 11-1/2 Saturns to span the diameter of the Sun.
- It would take about 9-1/2 Earths to span the diameter of Saturn.

Information on Distance

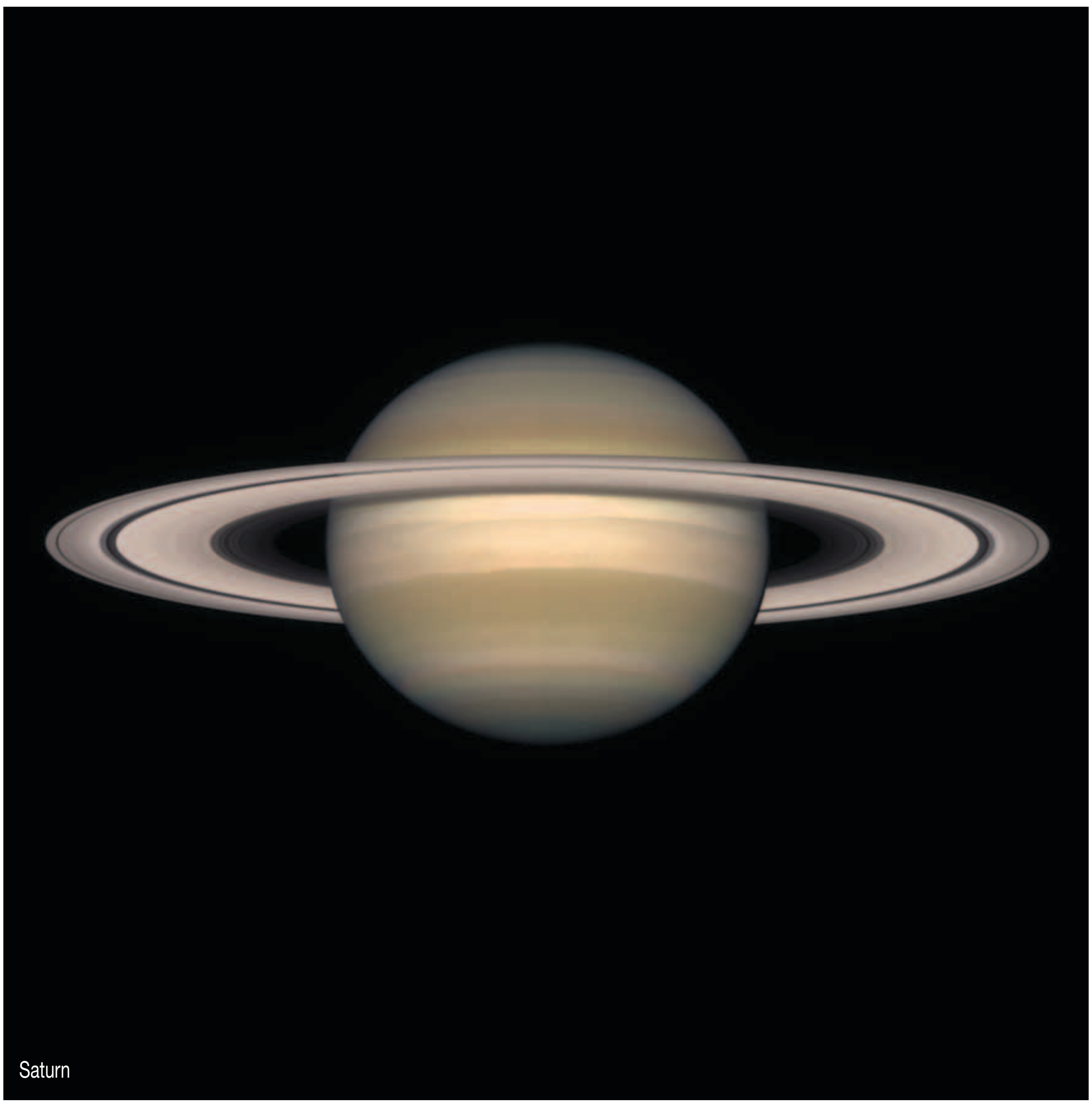
- The Earth is 93,000,000 (93 million) miles from the Sun.
- Astronomers give this distance a special name: an astronomical unit, abbreviated AU.
- Saturn is 890 million miles from the Sun, or 9.5 astronomical units
- So....Saturn is about 800 million miles from Earth.
- Walking at 3 miles per hour, it would take 30,441 years to get to Saturn. (yikes!)
- Driving a race car at 100 miles per hour, it would take 913 years to get from Earth to Saturn. (WOW!)
- Flying to Saturn in a jet plane, traveling at 600 miles per hour, would take 152 years (too long!).
- Flying in a rocket at a constant speed of 17,500 miles per hour, it would take 5 years! (Cassini will spend 7 years on its journey. This is because the spacecraft is too heavy to travel directly to Saturn. It must fly by several other planets to give it the "energy boost" needed to get to Saturn. Cassini's journey covers nearly 3 billion miles).

Information on Converting Miles to Kilometers, or Kilometers to Miles

The metric system is often used in science. As you learn more about astronomy, read different books, and visit different Web sites, you may find information presented in miles, kilometers, or both. Here is an easy was to convert from miles to kilometers, and kilometers to miles —

1 mile = 1.609 kilometers

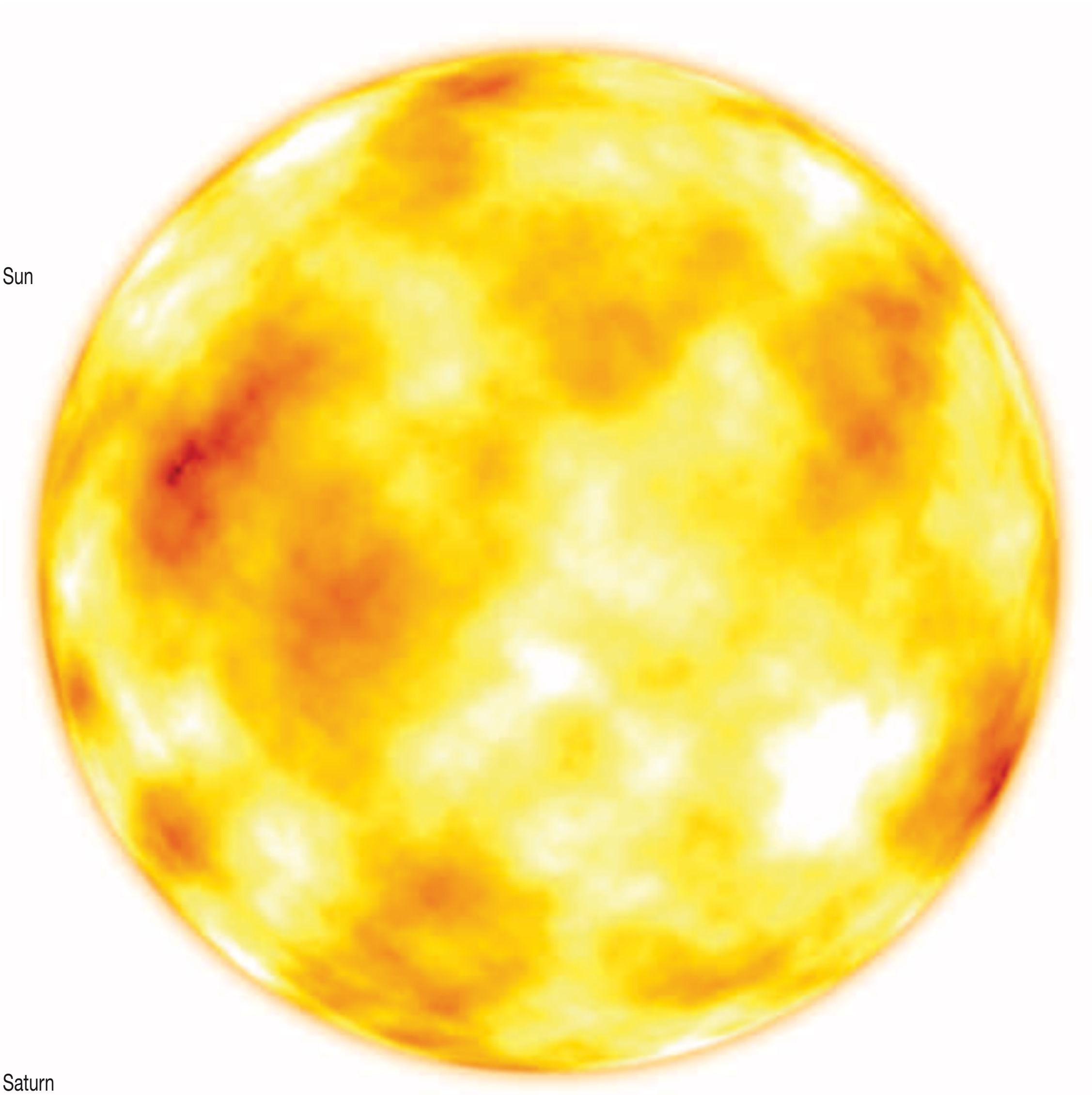
- To convert from miles to kilometers (km), multiply by 1.609. For example, if the diameter of Saturn is 74,913 miles, multiply 74,913 miles by 1.609 km per mile = 120,535 km.
- To convert from kilometers to miles, divide by 1.609. For example, if the diameter of Saturn is 120, 535 km, to find out miles, divide 120,535 km / 1.609 km per mile = 74,913 miles.



Saturn

OURNEY

Sun



Saturn

Earth

COSMIC

ACTIVITY 6
TRAVELING TO SATURN

Grade Level:

K-4

Content Area:

Math, Science, Language Arts, 21st Century Skills

Objective:

Students will build upon their understanding of scale in regards to distance, and gain a new appreciation for how much time it takes to travel to Saturn and other celestial bodies. Students will also practice the scientific thinking skills of predicting, comparing, and relating.

Procedure:

Have students complete the "Traveling to Saturn: My Predictions and Some Cool Facts" worksheet (suggested time 15–20 minutes).

- Display teacher's copy of "Traveling to Saturn: My Predictions and Some Cool Facts" worksheet on an overhead projector.
- Tell the students: "Most objects in our Solar System are really, really big; and really, really far apart. We're going to focus our attention on getting to Saturn."
- Ask students: How long do you think it will take to get from Earth to Saturn? Walking? In a racecar? In a jet? In a spacecraft? Students can record their responses on their personal copies of the "Traveling to Saturn" worksheet.
- Share the information from the "Traveling to Saturn Fact Sheet" with the students as they respond to each of the questions on their copies of the worksheet.
- Discuss why it took Cassini seven years to get to Saturn.

Traveling to Saturn Fact Sheet:

- Earth is 93 million miles from the Sun.
- Astronomers give the distance from Earth to the Sun a special name — an astronomical unit.
- Saturn is 890 million miles from the Sun, or 9.5 astronomical units.
- So — Saturn is about 800 million miles from Earth.
- Walking at 3 miles per hour, it would take you 30,441 years to get from Earth to Saturn.
- Driving a race car at 100 miles per hour, it would take you 913 years to get from Earth to Saturn.
- Flying to Saturn in a jet plane, traveling at 600 miles per hour, it would take you 152 years to get to Saturn.
- Flying in a rocket, traveling at 17,500 miles per hour, it would take you 5 years to get to Saturn. (It took the Cassini–Huygens spacecraft nearly 7 years to get to Saturn, because it was not traveling at a constant speed.)

OURNEY

My Predictions and Some Cool Facts:

How Long Would It Take to Travel To Saturn?

1. Walking at 3 miles per hour?

I predict it would take ______________________________

Actual time ______________________________

My response:

____

2. Driving a racecar at 100 miles per hour?

I predict it would take ______________________________

Actual time ______________________________

My response:

____

3. Flying a jet airplane at 600 miles per hour?

I predict it would take ______________________________

Actual time ______________________________

My response:

____

4. Flying a rocket at a constant speed of 17,500 miles per hour?

I predict it would take ______________________________

Actual time ______________________________

My response:

____

ACTIVITY 7
PERSONAL SOLAR SYSTEM

Grade Level:

6-10

Content Area:

Visual and Performing Arts, Math, Science, 21st Century Skills

Objective:

Students will develop a conceptual understanding of the size of objects in the Solar System and the immense distances between them. Students will make a scale model of the Solar System with the planets at their correct relative distances from each other and the Sun. Students will measure Solar System distances using the term Astronomical Unit – or AU – the average distance from the Earth to the Sun, 93 million miles (150,000,000 km).

Materials:

- Register tape (at least a meter long for each student)
- Scissors
- Markers

Background:

Our Solar System is a staggering 7 billion miles (11.2 billion km) across. This number is so large that is actually makes the 93 million miles (150 million km) from the Earth to the Sun seem small. In comparison, the 245,000 miles (400,000 km) to the Moon, which takes several days of rocket travel to cover, is barely anything at all.

Distances in the Solar System are commonly measured in Astronomical Units (AU). An AU is simply the average distance between the Earth and the Sun. Because the Earth's orbit around the Sun is an ellipse, the Earth is not always the same distance from the Sun. An AU is equal to approximately 93 million miles (150 million km). It takes 8 minutes for light to travel from the Sun to the Earth, traveling at the speed of light, of course.

The Moon, the closest Solar System body to us, is about 245,000 miles (400,000 km) away from the Earth. The most distant planet from the Earth isn't Pluto anymore. Pluto was reclassified as a "dwarf planet"; a dwarf planet is not just a small planet - it belongs to a separate class of objects. Neptune is now the outermost planet in our Solar System. Its orbit places it at approximately 2,794,000,000 miles (4,500,000,000 km) or 30 AU from the Sun.

Pluto is still an interesting member of the Solar System, however - its orbit is actually very eccentric and takes Pluto 2,734,000,000 – 4,598,000,000 miles (4,400,000,000 - 7,400,000,000 km) or 30 - 50 AU from the Sun. Pluto's orbit is also inclined with respect to the planets and doesn't fall within the same plane. As a result of its eccentricity, Pluto occasionally comes closer to the Sun than the planet Neptune does!

Modeling the Solar System at different scales helps students develop a conceptual understanding of the size of objects in the Solar System and the immense distances between them. The sky looks crowded from our vantage point on Earth, but models demonstrate the vast emptiness between each point of light.

Procedure:

- Tear a strip of register tape at least a meter long or arm's length
- Cut or fold over the ends so they are straight
- Label one end Sun and the other end **Pluto (30-50 AU)**
- Fold the tape in half and, at the crease, mark it **Uranus (19.2 AU)**

OURNEY

- Now fold the tape back in half, then in half again
- Label **Saturn (9.5 AU)** at the quarter mark (closer to the Sun)
- Label **Neptune (30 AU)** at 3/4 mark (closer to Pluto)
- The 3 most distant planets and Pluto have filled 3/4 of your tape
  - You still have 5 planets and the asteroid belt to fit into the remaining quarter between the Sun and Saturn
- Fold the Sun up to Saturn, crease it and label it **Jupiter (5.2 AU)**
  - For the remaining bodies in the Solar System, you'll only need 1/2 of the remaining 1/8th – or the inner 1/16th of your tape
- Fold the Sun out to meet Jupiter to mark the 1/16th spot. A planet does not go here, but the **Asteroid Belt (2.6 AU)** does
  - At this point, things start getting crowded and folding is tough to get precise distances
- Fold the Sun to the Asteroid Belt mark, mark it **Mars (1.5 AU)**
- Fold the Sun up to meet the line for Mars, leave it folded and fold that section in half. That leaves you with three creases. Mark them **Earth (1 AU)** , **Venus (.72 AU)** and **Mercury (.39 AU)**
- Look how empty the outer Solar System is – that's why they call it space!

Pluto is not where the Solar System ends – there's more!

The **Kuiper Belt** is a disk of dwarf planets, comets and other icy objects starting at the orbit of Neptune **(30 AU)** and extending out to about **50 AU**

The **Oort Cloud** is a sphere of icy objects where comets originate and extends from **20,000 AU to 100,000 AU.**

- On our Solar System scale, it would start at 1/3 mile and extend almost a mile – or from 5.5 to 16.5 football fields

Proxima Centauri is our next nearest star at **270,000 AU** (4.3 light years) from the Sun

- On our Solar System scale, this nearest star would be 4.2 miles away

Questions:

1. How big would the Sun be if your model were one meter long?

---

2. How big would the planets be if your model were one meter long?

Answer 1: Sun would be smaller than a grain of sand.
Answer 2: You couldn't see any of the planets without a magnifying glass

ACTIVITY **8**
THE CASSINI **SPACECRAFT**

Grade Level:

1-2

Content Area:

Visual and Performing Arts, Math, Science, Language Arts, History/Social Science, 21st Century Skills

Objective:

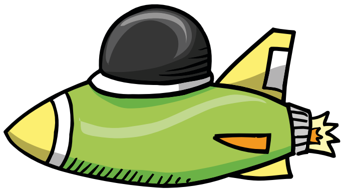
Students will learn about the Cassini spacecraft by designing and building their own spacecraft out of marshmallows and toothpicks. Students will engage in basic problem-solving as they design and construct their own small model of a spacecraft. Through writing and illustration, students will document their work and will complete a Design Review Summary. Like scientists and engineers, students will make presentations to show and explain their models and design summaries to their peers.

Materials:

- Miniature marshmallows, 30 per student
- Round toothpicks, 30 per student
- Sandwich bags, 1 per student
- Copies of "Cassini Spacecraft Design" and "Cassini Spacecraft Design Review Summary" worksheets

Background:

Cassini is a spacecraft equipped with 12 science instruments designed to learn about Saturn. Cassini has "almost human" features:



- Arm: holding a device to measure the magnetic field
- Hand: to sift through comic dust particles
- Eyes: cameras to take pictures of Saturn
- Food: power supply
- "Walking" Legs: main engine
- "Dancing" Legs: orientation thrusters
- Baby: Huygens probe
- Phone: antenna to send images home to Earth
- Skeleton: core structure
- Brain: computers

Scientists and engineers developing and designing the Cassini spacecraft faced a number of complex and challenging issues. The spacecraft has many unique requirements. Cassini has to:

- Hold all the fuel and equipment required for extended space travel
- Be durable for long-term space travel
- Be small enough to maintain the speed needed to travel a long distance quickly
- Have enough power to run all the equipment for at least 10 years

NASA's Cassini spacecraft launched in October 1997 with the European Space Agency's Huygens probe. Two elements comprise the spacecraft: The Cassini orbiter and the Huygens probe. Cassini-Huygens reached Saturn and its moons in 2004.

Flying in a rocket, traveling at 17,500 miles per hour, it would take you 5 years to get to Saturn. It took the Cassini–Huygens spacecraft nearly 7 years to get to Saturn, because it was not traveling at a constant speed.

Show students a diagram of the Cassini Spacecraft

http://saturn.jpl.nasa.gov/spacecraft/overview/

Procedure:

Introduction to Saturn and the Cassini–Huygens mission

1. Background knowledge about Saturn and the Cassini–Huygens mission is needed so that students understand the problems of size, distance, and durability that need to be overcome so the spacecraft can complete its voyage to Saturn.

Planning and Starting the Model

1. Explain to students that they will be designing and building a spacecraft model.
2. Tell students that they will each receive 30 marshmallows and 30 toothpicks for model building.
3. Explain that they will need to do some planning before starting to build the model.
4. Remind students that their spacecraft should be:
   - Lightweight and small
   - Able to carry enough fuel for the mission as well as equipment for collecting new information
5. Explain that students will make three "planning" designs, but will have to decide on one final design.
6. Explain that they will receive a spacecraft design worksheet that contains space for drawing and labelling their designs. Model how to draw a simple design.
7. Explain to students that the drawings will help them construct the model. Model putting together some of the basic parts of your spacecraft. Be sure to remind students not to use your design, but to create a design of their very own!
8. Distribute a "Cassini Spacecraft Design" worksheet to each student.

Completing and Documenting the Final Design

1. Have students gather their worksheets and models together.
2. Distribute the "Cassini Spacecraft Design Review Summary" worksheet.
3. Explain to students that they will draw and label their finished spacecraft.
4. Have students complete their drawings and answer the questions on the bottom of the worksheet.

Peer Reporting

1. Each student will make an oral presentation to show and explain his/her final drawings.
2. Begin the presentations by asking each student to explain how their model works and what they like best about their model.
3. Encourage students to ask questions of the presenters. To prompt student generated questions, you may begin the discussion with some of the following questions:
   a. What was the hardest part of designing your model?
   b. What was the hardest part of building your model?
   c. What are the parts of your model called? What do they do?
   d. Why did you choose this version of your design to be your final model?
   e. Would you change anything?
   f. Does your model have a name?
4. When finished, students can display their models in the classroom and add their worksheets to their portfolios.

COSMIC J

CASSINI SPACECRAFT DESIGN WORKSHEET

Name ______________________________

First Idea	*Second Idea*
Third Idea	*Final Plan*

CASSINI SPACECRAFT DESIGN REVIEW SUMMARY

Name ______________________________

Draw your finished spacecraft

1. What is the name of your spacecraft?

2. What was the easiest part of building your spacecraft?

3. What was the hardest part of building your spacecraft?

4. What changes did you make?

ACTIVITY 9

VISION AND DEPTH PERCEPTION

Grade Level:

5-8

Content Area:

Visual and Performing Arts, Math, Science, 21st Century Skills

Objective:

Students will learn the function of depth perception, and the definition of binocular vision. Students will test their depth perception using one eye and then two, and calculate the class average. Students will also identify monocular cues for depth.

Materials:

For the Introductory Activity

- Two pencils or pens for each student

For the Class Experiment (for each group)

- Measuring tools (tape measure or meter sticks)
- Plastic or paper cups, beakers or other sturdy containers
- Small items for dropping (paper clips, pennies)

Background:

Of all the senses, we rely most on our sense of sight. With it, we recognize shape, movement, distance and perspective, and color in our environment. Seeing with two eyes rather than one is called binocular vision, and it gives us both a sensation of depth and the impression that objects are three-dimensional.

One can determine how far away an object is located by using monocular and binocular cues.

Monocular Cues require only 1 eye to perceive depth (e.g. Cyclops). Binocular cues require 2 eyes to perceive depth.

Monocular cues include:

- Interposition (Overlap) – An object that is partially covered by another object is farther away.
- Familiar Size – Previous knowledge of object sizes aid in judging distance.
- Linear Perspective – The farther away an object is the smaller it appears to be.
- Atmospheric Perspective – Objects farther off in the distance appear less saturated and less sharp (fuzzier) than those nearby.
- Motion Parallax – Stationary objects that are physically closer to a moving viewer appear to shift faster than those farther away.
- Shading – Uses light falling on an object from a certain angle to give form and depth to an object. Cast shadows aid in locating an object.
- Patterns – Use contour lines to infer depth.

Binocular cues include:

- Convergence – The angle between the line of sight of each eye is larger as an object moves closer.
- Retinal Disparity – Each eye receives a slightly different view of a scene. The two views are used to determine the ratio of distances between nearby objects (e.g. Threading a needle utilizes retinal disparity).

OURNEY

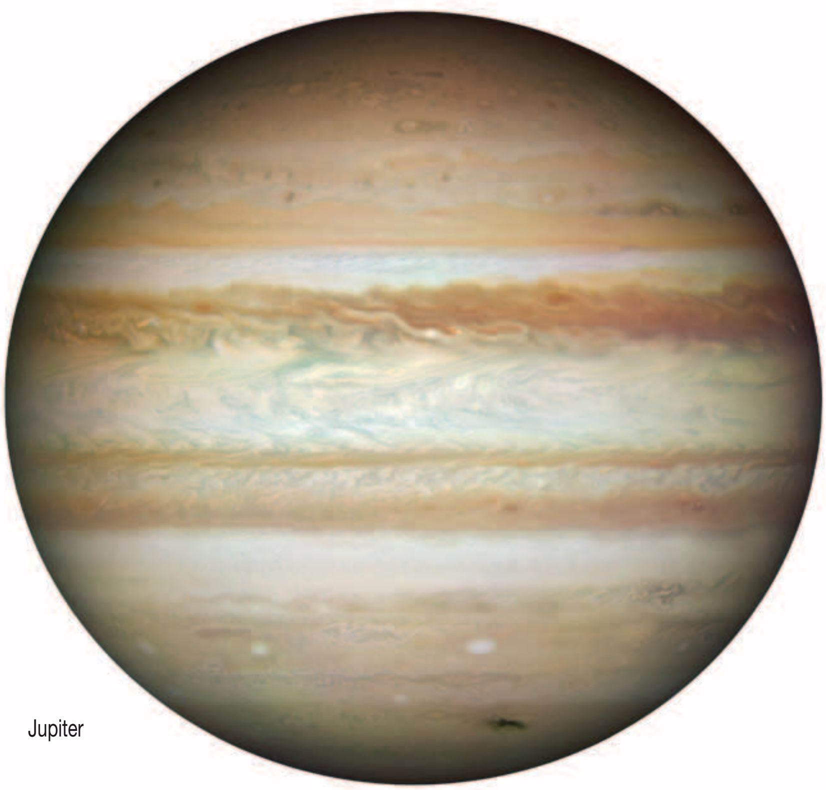
Spiral Galaxy NGC 1309

Demonstration:

When students enter the classroom on lab day, introduce the activities with an "eyecatching" short activity: Have each student hold a pencil or pen in each hand at arms length in front of the face. Ask everyone to touch the tips (e.g., erasers of pencils) together while closing one eye (pencils can be held horizontally – end to end, or vertically – one above the other.) Next have them open both eyes and repeat the activity.
Use the activity to open a short discussion of the importance of binocular vision and depth perception.

Procedure:

1. The Subject sits in a chair with a cup or container about two feet away, and covers one eye with a hand.
2. The Tester stands near the cup, holding a paper clip or other small object and moving it slowly over and around the cup, about two feet above the cup.
3. The Subject says "Drop it." when the object appears to be directly over the cup. Repeat the procedure three times.
4. The Recorder writes down the number of times the object went into the cup out of the three trials.
5. Repeat the trial with both eyes open and record the results.
6. Move the cup eight to ten feet away (ask your teacher exactly how far, and measure it, so that all groups do the same thing) from the Subject and repeat the one and two eye.
7. Repeat the procedures with another Subject.
8. The teacher will ask someone in your group to write your results in a class chart.
9. When all results are written, calculate the class average for the number of successful drops with one eye and then with two eyes, for each of the distances tested.



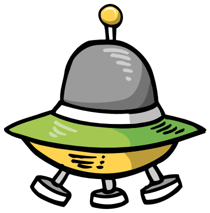
Jupiter

Questions:

1. How do your results compare with those of other groups?

2. Did anyone have very different scores from most of the class? What could be reasons for this?

3. How does having two eyes on the front of our heads give us depth perception? What is the relationship between binocular vision and depth perception?



4. Do some animals lack depth perception? If so, why?

5. Among mammals, do predators or prey animals most often have binocular vision and therefore depth perception?

6. What are some advantages that depth perception gives us?

7. People who have sight in only one eye can get along quite well. What clues from the environment do they use to help judge distances and depth?

COSMIC

ACTIVITY 10
3D GLASSES

Grade Level:
2-6

Content Area:
Visual and Performing Arts, Math, Science, 21st Century Skills

Objective:
Students will build their very own pair of color filter 3D glasses, and in so doing learn that there are many ways to view 3D images.

Materials:
- Oaktag (sturdy poster board)
- Scissors
- Clear tape
- Basic pattern for glasses (pattern included)
- Sheets of red and blue acetate (available at art supply stores)

Background:
Most human beings use what is known as binocular vision to perceive depth and see the world in 3D. The binocular vision system relies on the fact that we have two eyes, which are approximately 3 inches apart. This separation causes each eye to see the world from a slightly different perspective. The brain fuses these two views together. It understands the differences and uses them to calculate distance creating our sense of depth and ability to gauge distance.

3D Viewing
If you've ever used a View-Master or a stereoscopic viewer, you have seen your binocular vision system in action. In a View-Master, each eye is presented with an image. Two cameras photograph the same image from slightly different positions to create these images. Your eyes can then correlate these images automatically because each eye sees only one of the images.

There are many ways to view 3D images:
- Stereo Pairs (stereoscope: separate display for each eye)
- Shutter glasses (most common method)
- Color filter glasses (used in some old 3D movies)
- Polarizing glasses (used in some modern 3D movies)

Stereo pairs
Typical stereo pair images are two separate images of the same object taken a few inches apart. In this method, the two images are not interlaced but rather presented side by side (left eye image on left and right eye image on right). The images are directly viewable using parallel "free-viewing" glasses which allow each eye to only see its corresponding image.

LCD shutter glass method

In the LCD shutter glass 3D display, the left and right images are alternated rapidly on the monitor screen. When the viewer looks at the screen through shuttering eyewear, each shutter is synchronized to occlude the unwanted image and transmit the wanted image. Thus each eye sees only its appropriate perspective view. The left eye sees only the left view, and the right eye only the right view.

Color filter glasses

Color filter glasses are one of the oldest methods of viewing 3D images or movies. The system works by feeding different images into your eyes. The different color filters allow only one of the images to enter each eye, and your brain does the rest. There are two color filter systems: Red/Blue and Red/Green.

Polarizing glasses

This method is more commonly used in today's 3D movie projections. The audience must wear special glasses which have two polarizing lenses which have their polarization directions adjusted to be 90 degrees different. This makes is possible that left eye sees its picture without problems but everything meant to right eye (sent out at different polarization) seems to be black. Same applies also to right eye.

Procedure:

1. Cut out the sample pattern (including eyeholes) for your 3D glasses and tape the sides to the center section. You now have your stencil for the actual glasses.
2. Trace the stencil on the oaktag or sturdy poster board. Cut the glasses out making sure to also cut out the eyeholes.
3. Tape the red (left) and blue (right) acetate pieces to cover the eyeholes. Make sure to cut the acetate pieces a little larger than the opening for the eyes. DO NOT get tape on parts of the acetate visible through the eyehole.
4. View 3D images from NASA's Solar TErrestrial RElations Observatory (STEREO). The STEREO mission uses two nearly identical spacecraft to image the Sun and track its activity in high definition 3-D.

http://stereo.gsfc.nasa.gov/gallery/3dimages.shtml

Hints

1. You can decorate the glasses using any materials on hand. Encourage students to be as creative as possible!
2. The pattern provided is just one possible style. Vary the outer shape of the glasses to make them unique.
3. Take a picture of the whole class wearing their glasses. Or, even better, use the class wearing their glasses as the subject of your 3D photo!

Extension:

Create your own 3D images

Grade Level:

6-12

Materials:

- 1 Digital camera
- Photo editing software (Such as Adobe Photoshop)
- Red/blue 3D glasses (You already have them!)

Background:

You can create your own red/blue 3D images to print, or look at on a computer screen, using a normal digital camera and some image processing software. For this activity we explain how to use Adobe Photoshop, but you should be able to get the same results using similar programs by playing around with the tools and settings.

To recreate this 3D effect in print or on a computer screen, we need to simulate binocular vision. In short, we need to take two photos of our subject, separated by a short distance (the distance between your eyes: about 3 inches), then make it so your left eye only sees the left image and your right eye only sees the right. To do this we will use red/blue 3D glasses and when viewed through the glasses, our photo will appear three-dimensional!

Procedure:

http://stereo.gsfc.nasa.gov/img/3d_images.pdf

STEREO EYE: A 3D anaglyph maker
http://www.stereoeye.jp/software/index_e.html

Information on creating anaglyph images in color
http://en.wikipedia.org/wiki/Anaglyph_image#Anaglyphs_containing_color_information

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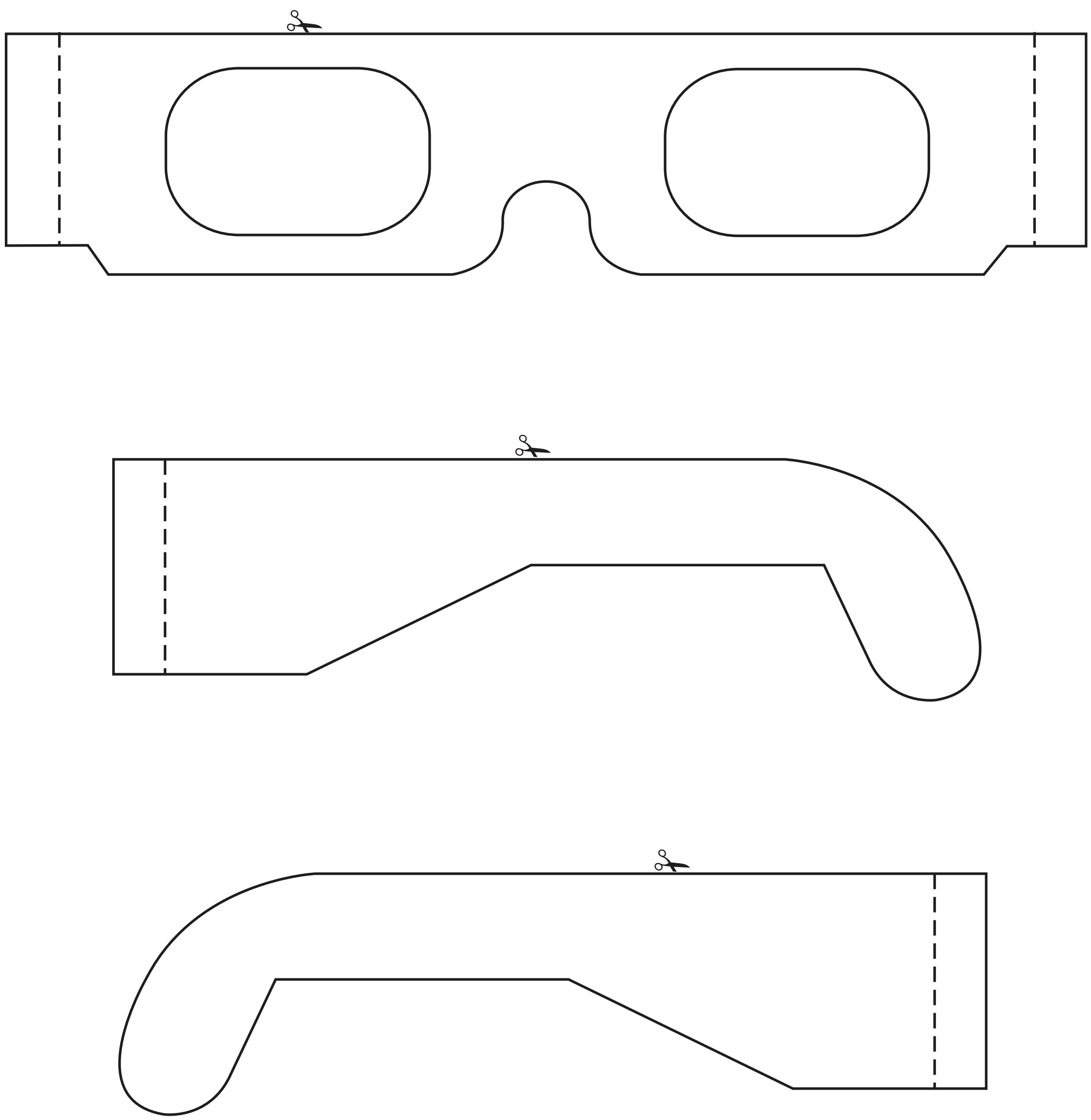


COSMIC JOURNEYS

ACTIVITY CONNECTIONS TO COMMON CORE STANDARDS

Activity 1: The Expanding Universe

Grade Level: 6-12 (adapted)

Math

- Measurement and Data
- Reason Abstractly and Quantitatively

Science

- Earth Sciences – Earth's Place in the Universe
- Investigation and Experimentation

21st Century Skills

- High Productivity
- Inventive Thinking
- Sound Reasoning

Activity 2: Measure the Galaxy

Grade Level: 3-12

Math

- Measurement and Data
- Reason Abstractly and Quantitatively
- Construct Viable Arguments
- Model with Mathematics
- Use appropriate tools strategically
- Ratio concepts and proportional relationships

Science

- Earth Sciences – Earth's Place in the Universe
- Investigation and Experimentation

21st Century Skills

- Visual and Information Literacy
- Teaming, Collaboration, and Interpersonal Skills

Activity 3: Paint by Numbers

Grade Level: 5-8

Visual and Performing Arts

- Analyze Art Elements and Principles of Design
- Artistic Perception – Processing, analyzing, and responding to sensory information

Math

- Attend to Precision
- Geometry
- Analyze, compare, create, and compose

Science

- Measurement
- Investigation and Experimentation

21st Century Skills

- Interactive Communication
- Effective use of real-world tools
- Curiosity and Creativity

Activity 4: My, What Big Eyes You Have

Grade Level: 3-8

Math

- Reason Abstractly and Quantitatively
- Construct Viable Arguments
- Geometry
- Measurement – Diameter, Ratio

Science

- Investigation and Experimentation
- Data collection and measurement

21st Century Skills

- Using Basic Scientific Literacy
- Understanding Basic Tools

OURNEY

Activity 5: How Far Away Is Saturn?

Grade Level: K-6

Math

- Ratio concepts and proportional relationships
- Geometry – Solve real world problems
- Graphing points on a plane

Science

- Physical Sciences
- Investigation and Experimentation
- Measurement
- Earth Sciences – Earth's place in the Universe

Language Arts

- Integration of Knowledge and Ideas
- Expository Reading

21st Century Skills

- Digital-Age Literacy
- Prioritizing Planning and Managing Results

Activity 6: Traveling to Saturn

Grade Level: K-4

Math

- Make sense of problems/persevere in solving them
- Reason Abstractly and Quantitatively
- Estimation and Prediction
- Reason with scale and distance

Science

- Investigation and Experimentation
- Predictions and Hypothesis

Language Arts

- Integration of Knowledge and Ideas
- Expository text
- Writing in response to text

21st Century Skills

- Inventive Thinking
- Effective Communication

Activity 7: Personal Solar System

Grade Level: 3-8

Visual and Performing Arts

- Perceive and respond to visual images

Math

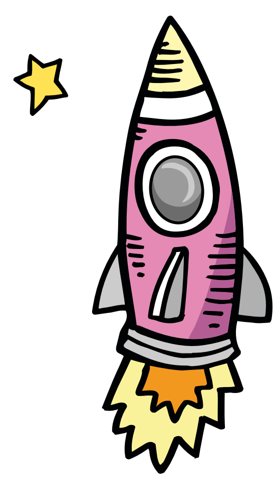
- Reason Abstractly and Quantitatively
- Construct viable arguments based on observation

Science

- Investigation and Experimentation
- Earth Sciences – The Solar System

21st Century Skills

- Digital-Age Literacy
- Inventive Thinking



ACTIVITY **CONNECTIONS** TO **COMMON** CORE **STANDARDS**

Activity 8: The Cassini Spacecraft

Grade Level: 1-2

Visual and Performing Arts

- Use visual analysis to design a 3 dimensional object
- Respond to a design rubric and visual arts review

Math

- Problem solving
- Reasoning Abstractly
- Create models with mathematics

Science

- Investigation and Experimentation
- Develop design summary
- Articulate the properties of their design

Language Arts

- Writing – Write informative/explanatory expository text to explain models and ideas

History/Social Science

- People who make a difference (Giovanni Domenico Cassini)
- The importance of individual action

21st Century Skills

- Effective Communication
- Inventive Thinking

Activity 9: Vision and Depth Perception

Grade Level: 5-8

Visual and Performing Arts

- Perceive and respond to images
- Analyze and compare images
- Present a reasonable argument in response to a visual image

Math

- Reason Abstractly and Quantitatively
- Attend to precision
- Describe and compare measurable attributes

Science

- Measurement using observational data
- Experimentation and Investigation

21st Century Skills

- Effective Communication
- Team Collaboration
- Ability to produce relevant products
- Inventive Thinking

Activity 10: 3D Glasses

Grade Level: 2-6, 6-12

Visual and Performing Arts

- Process, analyze, and respond to sensory information

Math

- Reason Abstractly and Quantitatively
- Construct viable arguments for observation

Science

- Investigation and Experimentation
- Compare and contrast observational data

21st Century Skills

- Inventive Thinking
- Digital-Age Literacy
- High Productivity

OURNEY

Sombrero Galaxy M104

COSMIC JO

3D: Three-dimensional, a three-dimensional form or appearance.

A

Astronomy: The science that deals with the material Universe beyond the Earth's atmosphere.

Asteroids: Small bodies composed of rock and metal in orbit about the Sun.

AU (Astronomical Unit): The distance from the Earth to the Sun, based on the mean Earth-to-Sun distance, 149,597,870 km.

B

Big Bang: The huge "explosion" 13.7 billion years ago in which the Universe (including all space, time and energy) is thought to have been created. According to this theory, the Universe began in a super-dense, super-hot state and has been expanding and cooling ever since. The phrase was coined by Fred Hoyle during a 1949 radio broadcast.

Binocular: The simultaneous use of both eyes, two-eyed or two-sights.

Black Hole: A region of space around a very small and extremely massive object within which the gravitational field is so strong that not even light can escape.

C

Cassini Spacecraft: NASA's Cassini spacecraft, launched in October 1997, reached Saturn along with the Huygens probe in 2004. The Cassini orbiter beams home valuable data that will help us understand the vast Saturnian region.

Cassini, Giovanni Domenico: An Italian/French astronomer. Cassini was the first to observe four of Saturn's moons, and he discovered the Cassini Division in the rings of Saturn (1675).

Celestial Body: Natural objects visible in the sky.

Comets: Small bodies composed of ice and rock in various orbits about the Sun.

Cosmology: The study of the Universe.

D

Dark Energy: A theoretical repulsive force that counteracts gravity and causes the Universe to expand at an accelerating rate.

Dwarf Planet: More developed than asteroids, but different than the known planets. Pluto, Eris and the asteroid Ceres became the first dwarf planets. Unlike planets, dwarf planets lack the gravitational muscle to sweep up or scatter objects near their orbits. They end up orbiting the Sun in zones of similar objects such as the asteroid and Kuiper belts.

E

Earth: Third planet from the Sun, a terrestrial planet.

Ellipse: A closed plane curve generated in such a way that the sums of its distances from the two fixed points (the foci) is constant.

Expanding Universe: A Universe which is constantly growing in size and in which the constituent parts (galaxies, clusters, etc) are flying ever further away from each other. It also suggests that, in the distant past, the Universe was much smaller and ultimately had its beginning in a Big Bang type event.

G

Galaxy: One of the basic building blocks of the Universe, a galaxy is a massive system composed of numerous stars, nebulae, stellar remnants, gas, and dust, bound together by gravity. There are many different kinds of galaxy including spiral (like our own Milky Way galaxy), elliptical, ring, dwarf, lenticular and irregular.

Gravity (or Gravitational Force): The force of attraction that exists between any two masses. It is by far the weakest of the four fundamental forces.

H

Heliocentric: Sun-centered.

Hubble, Edwin Powell: An American astronomer who confirmed the existence of galaxies other than our own, the Milky Way. He also helped establish that the Universe is expanding.

Hubble Space Telescope: A telescope that orbits Earth, launched in 1990. Its position above the atmosphere, which distorts and blocks the light that reaches our planet, gives it a view of the Universe that typically far surpasses that of ground-based telescopes.

Hubble Constant: The relationship between the distance of an object and the speed at which it is traveling away from us. The further away an object is the faster away from us it is traveling.

Huygens, Christiaan: A prominent Dutch astronomer. His work included early telescopic studies elucidating the nature of the rings of Saturn and the discovery of its moon Titan.

Huygens Probe: The European Space Agency's Huygens probe, launched in October 1997, reached Saturn along with the Cassini orbiter in 2004. Huygens entered the murky atmosphere of Titan, Saturn's biggest moon, and descended via parachute onto its surface.

J

JPL: Jet Propulsion Laboratory, operating division of the California Institute of Technology, and a NASA laboratory.

Jupiter: Fifth planet from the Sun, a gas giant or Jovian planet.

L

Lenticular: Of or pertaining to a lens; resembling the seed of a lentil in form; lentil-shaped.

Light: Electromagnetic radiation in the neighborhood of 1 nanometer wavelength.

Light speed: 186,282 miles (300,000 km) per second, the constant c.

Light time: The amount of time it takes light or radio signals to travel a certain distance at light speed.

Light Year: A measure of distance, the distance light travels in one year. A light year is 5,865,696,000,000 miles (9,460,800,000,000 km), or 63,197 AU.

M

Magnifier: An instrument that magnifies an image.

Mars: Fourth planet from the Sun, a terrestrial planet.

Matter: Anything that has both mass and volume (i.e. takes up space).
Mercury: First planet from the Sun, a terrestrial planet.

Meteor: A meteoroid which is in the process of entering Earth's atmosphere. It is called a meteorite after landing.

Meteorite: Rocky or metallic material which has fallen to Earth or to another planet.

Meteoroid: Small bodies in orbit about the Sun which are candidates for falling to Earth or to another planet.

Milky Way: Our galaxy. The galaxy which includes the Sun and Earth (The word "Galaxy" actually means milky way in Greek).

Monocular: of, involving, or affecting a single eye.

Moon: A small natural body which orbits a larger one. A natural satellite. Capitalized, the Earth's natural satellite.

N

NASA: National Aeronautics and Space Administration.

Nebula: A nebula is a cloud of gas and dust in space. Some nebulas are regions where new stars are being formed, while others are the remains of dead or dying stars. The word nebula comes from the Latin word for cloud.

Neptune: Eighth planet from the Sun, a gas giant or Jovian planet.

O

Orbit: The path one object takes around another.

Orbiter: Something that orbits, especially a spacecraft that orbits a planet or moon without landing on it.

P

Parsec: 3.26 light years

Planet: An object moving around a star.

Pluto: Formerly the ninth planet from the Sun, Pluto was reclassified as a "dwarf planet"; a dwarf planet is not just a small planet - it belongs to a separate class of objects.

Proxima Centauri: It is the closest known star to our own Sun (distance 4.22 light years).

Q

Quasar: Quasi-stellar object observed mainly in radio waves. Quasars are extragalactic objects believed to be the very distant centers of active galaxies.

R

Recessional Velocity: The velocity at which an object moves away from an observer. The recessional velocity of a distant galaxy is proportional to its distance from Earth. Therefore, the greater the recessional velocity, the more distant the object.

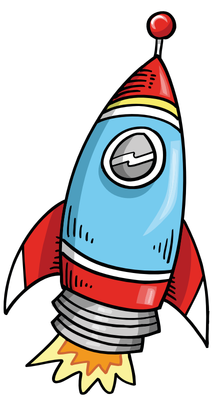
Red Shift: When an object is traveling away from the Earth, the light from this object is stretched out, making it look redder.

Revolve: When something is moving in a circle around another object, such as the way the Moon circles the Earth, it is said to revolve around that object.

Rotate: When an object spins it is said to be rotating.

S

Satellite: A small body which orbits a larger one. A natural or an artificial moon. Earth-orbiting spacecraft are called satellites. While deep-space vehicles are technically satellites of the Sun or of another planet, they are generally called spacecraft instead of satellites.



Saturn: Sixth planet from the Sun, a gas giant or Jovian planet.

Sirius: The brightest star in the night sky. Sirius is over 20 times brighter than our Sun and over twice as massive. Sirius is 8.7 light years away.

Singularity: A region of space where the density of matter, or the curvature of space-time, becomes infinite and the concepts of space and time cease to have any meaning. According to general relativity, the Big Bang started with a singularity, and there is a singularity at the centre of a black hole.

Solar System: A Solar System consists of a star and all the objects orbiting it as well as all the material in that system. Our Solar System includes the Sun together with the eight planets and their moons as well as all other celestial bodies that orbit the Sun.

Solstice: Either of the two times a year when the Sun is at its greatest distance from the celestial equator: about June 21, when the Sun reaches its northernmost point on the celestial sphere, or about December 22, when it reaches its southernmost point.

Speed of Light: In a vacuum, light travels at 186,282 miles (300,000 km) per second, a speed which remains constant irrespective of the speed of the source of the light or of the observer. It is the term c in Einstein's famous equation $E = mc^2$.

Star: A massive, luminous ball of gas or plasma, held together by its own gravity. There are many different types of stars including binary stars, proto-stars, dwarf stars, supergiants, supernovas, neutron stars, pulsars, quasars, etc.

Stereoscopic: Stereoscopic imaging or 3-D (three-dimensional) imaging is any technique capable of recording three-dimensional visual information or creating the illusion of depth in an image.

Sun: The star that is the central body of our Solar System, around which the planets revolve and from which they receive light and heat.

Supernova: A cataclysmic explosion caused by the collapse of an old massive star which has used up all its fuel. It leaves behind a cloud of brightly coloured gas called a nebula, and sometimes a highly compressed neutron star or even a black hole.

T

Telescope: An arrangement of lenses or mirrors or both that gathers visible light, permitting direct observation or photographic recording of distant objects.

U

Universe: The huge space which contains all of the matter and energy in existence. The Universe (or cosmos) is usually considered to have begun about 13.7 billion years ago in a singularity commonly known as the Big Bang, and has been expanding ever since.

Uranus: Seventh planet from the Sun, a gas giant or Jovian planet.

V

Venus: Second planet from the Sun, a terrestrial planet.

OURNEY

Spiral Galaxy M81

RESOURCES

NASA Education
http://www.nasa.gov/audience/foreducators/hubble-index.html

NASA Hubble
http://www.nasa.gov/externalflash/hubble_servicing/

Amazing Space
http://amazing-space.stsci.edu/

Top Stars
http://topstars.strategies.org/

STEREO Mission
http://stereo.gsfc.nasa.gov/

All About 3D
http://www.vision3d.com/stereo.html

Hubble Site
http://hubblesite.org/

The Best of the Hubble Space Telescope
http://archive.seds.org/hst/hst.html

Main Hubble Page
http://hubble.nasa.gov/

Hubble Mission
www.nasa.gov/hubble/

Cassini Mission
http://saturn.jpl.nasa.gov/index.cfm

Space Science Curriculum Standards Quilt
http://quilt.jpl.nasa.gov/

Basics of Space Flight
http://www2.jpl.nasa.gov/basics/index.php

Space Science Education Resource Directory
http://teachspacescience.org/cgi-bin/ssrtop.plex

Space Place
http://spaceplace.nasa.gov/

NASA Core
http://www.nasa.gov/offices/education/programs/national/core/home/index.html

NASA Education Program
http://www.nasa.gov/offices/education/about/index.html

JPL Education Gateway
http://www.jpl.nasa.gov/education/

Quest
http://quest.arc.nasa.gov/

Goldstone Apple Valley Radio Telescope Program
http://www.lewiscenter.org/gavrt/

JPL Solar System Ambassadors Program
http://www2.jpl.nasa.gov/ambassador/index.html

National Science Education Standards
http://www.nap.edu/openbook.php?record_id=4962

OURNEY

Crab Nebula

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