YOUTH ASTRONOMY APPRENTICESHIP

Hands-On Activities

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Astronomy in the Marketplace

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Goals

- Learn about the distinctive names of objects in the universe
- Become aware of astronomy terms in daily life

Activity Overview

You will begin asking your group to brainstorm as many items as they can with brand names that are also astronomical terms (This is where you could show the examples such as the Milky Way bar or the Comet detergent package to give the participants a good idea of what you are talking about.)

After generating a good list, ask the group to spend the next few days looking around their homes, local stores, and in magazines and newspapers for as many products and business names they can find related to astronomy. Have them bring in any items they can and put them on display in the room.

Background

This activity was designed to be an introductory activity for anyone with little or no background in astronomy, to peak interest and to begin a discussion using some of the language of astronomy. A key concept is that astronomy has influence outside the field of science.

Astronomy actually plays a much larger role in our lives than many people think. We use words like month and disaster (literally "dis-aster," or "against the stars"), or refer to the days of the week (which are named after the Sun, Moon, and the five easily visible planets), without consciously making the connection to the Moon, the star, or the planets. (Note: In ancient times the passage of time was noted based on the revolutions of the Moon, and so there was a single word *menes* for both “moon” and “month”) Astronomical terms are also used around the world in advertising, probably in part because of their universal identification and mysterious, exotic, or exciting connotations. Some examples of astronomy terms in various mediums follow:

- ❑ Cars – Ford Taurus, Chevy Nova, Subaru, Mercury
- ❑ Cleaning Products – Comet
- ❑ Sports Teams – L.A. Galaxy, Houston Rockets, Houston Comets, Dallas Stars, Houston Astros
- ❑ Watches – Pulsar Watches
- ❑ Chewing gum – Eclipse, Orbit
- ❑ Health & Beauty Products – Venus Razors
- ❑ Candy – Milky Way Bars, Mars Bars, Starbursts
- ❑ Food & Drink – Sunny Delight, Sun Chips
- ❑ TV shows – Star Trek
- ❑ Movies – Star Wars, Pluto Nash, Meteor Man, Galaxy Quest

Preparation

Space Required: Large room/discussion space

Materials:

- ❑ Several examples of packages/labels/advertisements with references to astronomy (Milky Way bar, Comet dishwashing liquid)
- ❑ Chart paper

Preparation time: 🕐

Activity time: 20 – 30 minutes

Gathering of materials and final preparations:

Prior to leading this activity, you should have assembled all of the necessary materials, and you will want to have set up the chart paper in the front of the room for taking down the items as the group brainstorms. (If possible, the lists that the participants generate should be left up or should be recorded and given to the participants to keep as the course progresses.) And you should have your example items that have astronomical words in the name to start off the brainstorming.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms will come up during discussion.

Procedure

Discussion lead-in:

The allure of astronomy is so strong that many companies have named products after astronomical objects. Begin a discussion on the fascination of astronomy, asking participants to list some common consumer products that have been named after astronomical objects.

1. The facilitator and participants will come up with as many examples of astronomy in the as they can. Show the example items to get the brainstorm going.

2. Lead a debrief, discussing why astronomy terms and ideas are so prevalent in our marketplace and our media. In this discussion of why advertising executives and screenwriters would use astronomy terms as their product name or in their scripts, one can ask the youth, "Do you think that the astronomy topics presented in movies is always accurate to the real science?"

3. Ask the participants to spend the next few days looking around their homes, in local stores, and in magazines and newspapers for as many products and business names they can find related to astronomy. Have them bring in the labels of any item they can and post them on a big sheet of paper.

Follow up

Participants devise their own astronomically named product. Participants can write and illustrate advertisements for their products. Groups can produce packages or samples of their new products, extolling their virtues, with emphasis on the astronomical terms, images, and ideas they incorporated. Groups can share their products and creative advertising campaigns in a group presentation.

Watch out for…

- ❑ Keep in mind that young people will want to talk a lot about favorite movies, plots, characters, etc., and take the discussion away from Astronomy in the Marketplace into an "Our Favorite Show/Scene" discussion. In your discussion with the participants, make sure the conversation doesn't get too far off topic when talking about TV shows and movies that they know that have to do with astronomy.

- ❑ Talking about science through science fiction is not totally counterproductive in that some of the shows introduce legitimate words and ideas participants would not necessarily come across otherwise. But much of the 'science' may be false and misleading, so there is a danger of misconceptions being reinforced by being included in a science after-school program.

- Many lyrics in popular songs contain references to astronomy terms and concepts. You may want to open up the brainstorm to include terms in songs and song titles—especially if the youth are struggling to name products.

Vocabulary

astro: A prefix used in English that refers or attaches the meaning of a star or stars, a celestial body or outer space to the name. "Astro" is derived from the Greek word "astron" meaning star.

comet: Comets are loose collections of ice, dust, and small rocky particles in the Solar System that orbit the Sun and, when close enough to the Sun, exhibits a visible coma (or atmosphere) and/or a tail — both primarily from the effects of solar radiation upon the comet's nucleus. The nucleus itself measures a few kilometers or tens of kilometers across, and is composed mostly of rock, dust and ice. Comets are nicknamed 'dirty snowballs.

corona: The outer part of the Sun's atmosphere.

galaxy, galaxies: A giant collection of gas, dust, and millions or billions of stars

Mars: the fourth planet from the Sun in the solar system, named after the Roman god of war (the counterpart of the Greek Ares), on account of its blood red color as viewed in the night sky.

Mercury: The innermost and smallest planet in the solar system (since Pluto was re-labeled as a dwarf planet), orbiting the Sun once every 88 days.

meteor: The visible event that occurs when a meteoroid or asteroid enters Earth's atmosphere and becomes brightly visible.

Milky Way: The galaxy which is the home of our Solar System together with at least 200 billion other stars and their planets.

nova: A cataclysmic nuclear explosion caused by the accretion of hydrogen onto the surface of a white dwarf star.

Pluto: The second-largest known dwarf planet in the Solar System (after Eris) and the tenth-largest body observed directly orbiting the Sun. Originally classified as a planet, Pluto is now considered the largest member of a distinct region called the Kuiper belt

pulsar: Exceptionally small and very dense star (about double the sun's mass but only a few miles in radius) that is spinning at very high speed. This spinning star emits energy that is seen as pulses as the star rotates.

star: A ball of material, mostly hydrogen, in dynamic equilibrium between gravity tending to collapse it and fusion reactions in the core tending to expand it. Our Sun is a star.
starburst: A generic term to describe a region of space with an abnormally high rate of star formation.
Subaru: Japanese name for Pleiades, stars in the constellation Taurus.
The Sun: A star that is the basis of the solar system and that sustains life on Earth, being the source of heat and light.
Taurus (The Bull): This is one of the 13 constellations of the Zodiac.
Venus: The second-closest planet to the Sun, orbiting it every 224.7 Earth days.

Useful Websites

The Universe in the Classroom: This electronic educational newsletter is for teachers, youth group leaders, librarians, and anybody else who wants to help children of all ages learn more about the wonders of the universe:
http://www.astrosociety.org/education/publications/tnl/tnl.html

Youth Generate Rules to Govern Their Space

Goals

- ❑ Create a safe and comfortable space that nurtures open conversation, question asking, and feedback.

Activity Overview

This activity is meant to be an outline of discussion questions which pushes students to engage in conversation in order to initiate open communication, set expectations and lay down ground rules for acceptable feedback and tone within the learning environment.

Through discussion, students create a list of acceptable expectations that govern a "safe" space and decide what each of these expectations means to the group as a whole.

Background

Science based learning activities require participants to partake in critical thinking and comfortably ask questions pertaining to the relevant topics. Creating a safe and comfortable space allows participants to take advantage of opportunities and engage in conversation. Through this engagement, participants can then gain a better understanding of the subject matter being discussed.

Preparation

Space Required: A quiet, comfortable room

Materials:

- ❑ White board or chart paper
- ❑ Dry erase markers or colored markers

Preparation time: 🕐

Activity time: 20 minutes

Gathering of materials and final preparations:

Be ready to transfer the agreed upon rules from the white board to a large piece of paper so that they may be hung up somewhere in the room for the duration of the program.

Procedure

Discussion lead-in:

We are going to be working very closely in groups and as a result, we need to establish rules and expectations to create a safe space in which everyone in the group feels comfortable and free to ask questions and make appropriate comments.

Generate Rules:

1. Lead discussion with questions such as, "What are some rules that you feel are important for creating a safe space?" and "What rules would be helpful in order to create a space that is comfortable for you?" Also asking questions such as "What are some personal reactions that would make you second guess whether or not you should ask a question?" or "What does the word respect mean to you?"

2. Allow participants enough time to think in depth about what these questions mean to them. Make sure everyone in the activity has shared at least one idea. Record their answers on chart paper/white board and keep posted in a visible area for future reference.

Follow up

Many of the upcoming activities will require students to work in small groups in which they will be sharing ideas and working closely on projects. Hence, the expectations set by each group during this activity may potentially become a part of any activity done in the next several weeks of the program.

Watch out for…

- ❑ Sometimes youth may try to project their own negative self-image, or attitudes as suggestions for the group.

Modeling the Universe

Goals

- ❑ Create a model of the universe, reflecting on the relative sizes, distances and organization of the objects within

Activity Overview

Participants will think about where we fit in the universe, and create a physical model of their image of the Universe. The models will be shared within the group and decisions made regarding the size, shape, and relative position of objects within the tabletop universe will be discussed.

Background

Our galaxy, the Milky Way, is just one of countless galaxies in the universe. Our view of the universe is expanding. Less than a century ago, astronomers thought that our Milky Way Galaxy of stars might be the whole universe. Today, we can observe the splendor of galaxies far beyond our own. We can see the estimated 100 billion galaxies that make up our "observable universe." For more information on the "observable universe, refer to the **Vocabulary** section of this activity.

A model is a simplified imitation of something that can help us explain and understand it better. Models can take different forms, including physical devices or sculpture, drawings or plans, conceptual analogies, mathematical equations, and computer simulations.

In this activity, participants make a physical model to represent as much of the universe as they can. They will then analyze their own and other's models with regard to what they represent, what they misrepresent, what they leave out, and perhaps most importantly, **what questions they raise.**

While the idea of creating a physical model of the entire universe in one sitting can seem a bit daunting, this activity quickly elicits your group's ideas and preconceptions about the contents and organization of the cosmos. Most participants will be somewhat familiar with solar system objects, but may be confused about the relationship of stars to planets, and about the relative distances. The scientists' view of the hierarchical "nested" structure of the universe—planetary systems and stars as components of stellar neighborhoods, stellar neighborhoods as components of galaxies, galaxies as components of galaxy clusters —is not second nature to most people.

Preparation

Space Required: Large room with tables or floor space adequate for groups of participants to assemble sizeable models with arts and crafts supplies.

Materials:

- ❑ Chart paper
- ❑ Modeling clay
- ❑ Paper
- ❑ Balloons
- ❑ Different sized balls and marbles
- ❑ String
- ❑ Markers
- ❑ Scissors
- ❑ Straws
- ❑ Construction paper
- ❑ Other odds and ends that might be useful in creating models

Preparation time: 🕐 🕐 (Additionally several days to gather the above materials if they are not on hand).

Activity time: 1 hour

Gathering of materials and final preparations:

Prepare modeling materials (the arts and crafts materials listed at the beginning of this activity plan) for each group of 3-4 participants. Make sure each group also has piece of chart paper for the first brainstorming.

Procedure

Discussion lead-in

This activity begins with participants brainstorming about objects in the universe and the concept of models in small groups. Participants with less experience with these concepts will require more time and guidance during the discussion part of the activity.

1. Before breaking into smaller groups, tell them they will have 3 minutes to brainstorm objects in the universe and write them on the chart paper before they share with the large group.

2. Ask the participants to generate a list of objects in the universe on the chart paper. Tell them they will be sharing 1 or 2 objects with the larger group after 3 minutes.

3. Have groups share 1 or 2 objects. Encourage group crosstalk by asking questions as exotic or obscure objects are mentioned. Make sure to stress that NOT knowing what they are is OK! That's why they are all here!
   - ❑ Example: One person says, "Pulsars!" Ask the large group, "Does anyone know what a pulsar is?" This is not time to actually answer the questions, but more of an introduction to all the cool objects they will have the opportunity to explore during the program – a teaser of sorts.

4. After each group shares, give them time to continue making their own lists. Encourage them to use objects other groups mentioned if they didn't have it.

5. After a couple more minutes (2-4), have the small groups come back together for the discussion of models.

6. Facilitate a group discussion of what models are and what models are used for. Begin by asking participants to name some familiar models, such as a globe, or a dollhouse. Discuss how scientists use models to suggest how things work and to predict phenomena that might be observed. A model is not the real thing. It can always misrepresent certain features of the real thing. Different models may represent only part of what is being modeled.

Modeling

1. Divide participants into groups of 3-4. Each participant can have one or more of the following roles: model maker(s), recorder of model features, spokesperson.

2. Challenge participants to create a model of the universe in less than 30 minutes. Mention to the youth that creating a model of the entire universe is a tall order, but they should create **their model** from what they know or

how they think the universe may be arranged. Tell them to not stress about having the perfectly correct model at this stage in the program. You may wish to have some groups choose just a part of the universe to model (such as the solar system, or a galaxy, or perhaps just the earth-moon system). One person in the group should write down the features of the model as it is built, along with questions that arise.

2. While they are working, have them answer the following questions on chart paper:
   - ❑ What features of the universe does your model represent?
   - ❑ What things does your model misrepresent?
   - ❑ What things about the universe does your model omit, or not represent at all?
   - ❑ What questions came up as your group worked on your model?

Sharing models/Debrief

1. As each group presents their model, ask them to comment on the four questions above.

2. In addition use the following questions for the whole group to further probe the participants' understanding of their models.
   Are there any patterns that emerge in one model or among all models?

   What parts of the astronomical models do you think represented the "real thing" particularly well? Why?

   What parts of the astronomical models do you think misrepresented the "real thing?

   Why is representing the whole universe a difficult challenge?

   How can these models be used to make predictions regarding observations of the universe? For example: where is Earth in this model and what would an observer on Earth see if they lived in this universe?

   What are some things you need to find out to design a better model?

Follow up

This activity can be used as an introduction for further exploration about the universe and the role that models play in developing a scientific understanding of the world. A number of follow-up activities can be found at this website:
http://cfa-www.harvard.edu/seuforum/mtu/

Activities include explorations regarding the size and scale of the universe, the age of the universe, and a tour of objects in the universe. Additional material on this website include a mapping of national standards, a history of cosmological models, as well as links to a number of other materials that will help participants develop their models further.

Watch out for…

- ❑ As the participants are modeling the universe, make sure that their models accurately reflect their genuine perception of the structure of the universe, and the objects in the universe. Make sure participants have some explanation as to why they put an object where they did, regardless of the fact that they are not expected to have all scientifically correct answers! By asking the youth questions about what each piece of their model is going to represent as they construct it, you will get the youth to develop explanations for their choices.

- ❑ This is an introductory activity that can also be used as an assessment tool by repeating the activity at the end of the program. Be sure to take pictures of their models and record their descriptions to be able to compare to the models that the youth create at the end of the program.

Vocabulary

asteroid: A rocky space object that can be a few feet wide to several hundred miles wide. Most asteroids in our solar system orbit in a belt between Mars and Jupiter.

black hole: A region in space where gravity is so strong that not even light can escape from it. Black holes in our galaxy are thought to be formed when stars more than approximately ten times as massive as our Sun end their lives in a supernova explosion. There is also evidence indicating that supermassive black holes (more massive than ten billion Suns) exist in the centers of some galaxies.

comet: Comets are loose collections of ice, dust, and small rocky particles in the Solar System that orbit the Sun and, when close enough to the Sun, exhibits a visible coma (or atmosphere) and/or a tail — both primarily from the effects of solar radiation upon the comet's nucleus. The nucleus itself measures a few kilometers or tens of kilometers across, and is composed mostly of rock, dust and ice. Comets are nicknamed ‘dirty snowballs.

crater: A hole caused by an object hitting the surface of a planet or moon.

gravity: The force of attraction between all masses in the universe; for example the attraction of bodies near or on the earth’s surface to the Earth.

model: A model is a simplified imitation of something that can help us explain and understand it better. Models can take different forms, including physical devices or sculpture, drawings or plans, conceptual analogies, mathematical equations, and computer simulations.

neutron star: A compressed core of an exploded star made up almost entirely of neutrons. Neutron stars have a strong gravitational field and some emit pulses of energy along their axis. These pulsing neutron stars are known as pulsars.

observable universe: The region of space that it is theoretically possible for us to observe, small enough that light from the furthest regions has had sufficient time to reach us since the Big Bang. Both popular and professional research articles in cosmology often use the term "universe" to mean "observable universe". This can be justified on the grounds that we can never know anything by direct experimentation about any part of the universe that is causally disconnected from us, although many credible theories, such as cosmic inflation, require a universe much larger than the observable universe. No evidence exists to suggest that the boundary of the observable universe corresponds precisely to the physical boundary of the universe (if such a boundary exists); this is exceedingly unlikely in that it would imply that Earth is exactly at the center of the universe, in violation of the cosmological principle. It is likely that the galaxies within our visible universe represent only a minuscule fraction of the galaxies in the universe.

orbit: The path followed by an object in space as it goes around another object; to travel around another object in a single path.

planet: A spherical ball of rock and/or gas that orbits a star. The Earth is a planet. In 2006, the International Astronomical Union ruled that Pluto is no longer a planet but rather a dwarf planet.

satellite: An object that moves around a larger object. There are natural satellites such as moons and there are man-made satellites such as the Hubble Space Telescope.

solar system: The system of the Sun and the planets, their satellites, the minor planets, comets, meteoroids, and other objects revolving around the Sun. As of 2006 our solar system contains eight objects defined as planets.

star: a giant ball of hot gas that creates and emits its own radiation through nuclear fusion. Our sun is a star. Most of the objects you see in the night sky are stars, and they come in many different varieties. Even though you cannot see the stars during the daytime, they are still present. The intense light coming from the Sun simply overwhelms the dim light coming from the star.

supernova: A special event at the end of massive stars' lives in which the star explodes and shines millions of times brighter than it had during its lifetime. Only stars about 10 times the mass of our sun will die in this way.

telescope: A device which allows us to see far away objects even when we cannot see them with the naked eye.

Useful Websites

Frequently Asked Cosmic Questions: Does the universe have an edge, beyond which there is nothing? How do we know there really was a Big Bang? Find answers to frequently asked questions about the structure and evolution of the universe here. Recommended for teachers and students Grades 7-12, and general audiences: http://cfa-www.harvard.edu/seuforum/questions/

Universe Forum Learning Resources: Resources for investigating the structure and evolution of the universe – in the classroom and beyond: http://cfa-www.harvard.edu/seuforum/learningresources.htm

Cosmic Cast of Characters

Goals

- ❑ Become familiar with the types of objects in the universe
- ❑ Become familiar with the MicroObservatory Image Archive
- ❑ Learn how to make careful observations of images

Activity Overview

Participants are divided into groups of two or three, and are instructed to make as many observations of MicroObservatory images as they can generate. These are images of objects in one of the four "What's Out There?" sections listed in the Comic Cast of Characters table: the "bit players," the stars, nebulae, and galaxies.

Each group shares their observations and presents interesting information about the category of objects that was assigned to them to the larger group.

Background

The universe contains many different types of objects that the youth will be able to take images of using the MicroObservatory telescopes. These objects have been separated into four categories on the Cosmic Cast of Characters table. The "bit players" are all objects within our solar system, whereas the stars and nebulae are outside of our solar system, but still inside of our galaxy. The last category is galaxies, and these are of course separate galaxies outside of our galaxy. For information about what these objects are, how far away they are from us, and other interesting facts, review the Cosmic Cast of Characters table available in the appendix.

Preparation

Space Required: A large room, computers for at least each pair of participants.

Materials:

- ❑ Cosmic Cast of Characters Table worksheet copies
- ❑ Markers
- ❑ Chart paper

Preparation time: 🕐 🕐

Activity time: 30 minutes

Gathering of materials and final preparations:

Make copies of the Cosmic Cast of Characters table, one per participant. The youth will keep this table and return to it to gather additional information in later activities and projects.

Review table, ensure that you are comfortable presenting these categories of objects, review the vocabulary section for basic definitions, and the websites for additional background information.

Remember that the youth are bound to have questions that you will not have a clear-cut answer to right away. That's normal and you are not supposed to have all answers ready. Instead inform the youth that we will be keeping a running list of the questions that come up, and we will work together to explore these questions. There are plenty of resources to turn to as well that will provide up-to-date information regarding what astronomers are currently saying about these topics. See the "Useful Websites" section for a few potential resources.

Browse through the MicroObservatory Image Archive Directory so that you are familiar with its set-up and organization. This way you can easily navigate through it and answer any related questions from the participants.

Procedure

Discussion lead-in:

We are about to take our first images of astronomical objects by controlling MicroObservatory telescopes and scheduling them to take images overnight. But first, we want to take a moment to think about what type of object we may want to choose as our target, and find out some information about what it means to be that type of object. In this activity we will get into groups and sharpen our observing skills while finding out about some interesting facts about these distant objects.

Image Analysis

1. Randomly break the youth into groups of two or three, assigning each group a different category from the "Cosmic Cast of Characters" table

to closely examine. Pass out the table of the Cosmic Cast of Characters to every participant.

2. Instruct the groups to return to the MicroObservatory website, http://mo-www.harvard.edu/MicroObservatory/, and click on "Get Images" on the side frame on the left part of the window. From there, the youth will be on the Latest Image Directory page. Inform them that these are the most recent images taken by MicroObservatory users, and the location where their images will be posted after they take them later in the session.

3. Next, have the participants scroll back to the top of the page and click on the blue colored "Image Archive Directory" link. From here the groups should click on the name of the category of object given to them, for example "Galaxies."

4. Instruct each group to locate two images within their category that they would like to examine further.

5. Tell each group to come up with as many detailed observations as possible about each image in the next 10 minutes, and record them onto a piece of chart paper. Model making simple observations, for example, what seem to be stars in many of the images should be described as small round dots in the image. Some round dots appear to be slightly larger than others. Explain that youth should focus on describing, "What they see" in the image and not "What they think something they see in the image may be."

6. After the youth have made many observations tell them to read the information about their category of object in the "Notes, Description" column on the "Cosmic Cast of Characters" table. Tell them to have two interesting facts from the table to present to the larger group along with their observations.

7. Now give the groups five additional minutes to come up with any questions that have come up after making many detailed observations. Each group needs to formulate at least one question.

Debrief:

1. After the 15 minutes have passed come back together as a large group. Alternate between groups reporting their observations, and then the two interesting facts that they found out after looking over the table.

2. Finally, ask them to share at least one question, either about their group's category of objects, or their own. Record the questions on a piece of the large chart paper. Use this opportunity to highlight "good

questions” i.e. questions that do not ask for just a “yes/no” answer or for a number. Make sure to keep record of all questions anyway.

Follow up

Continue to keep track of the lists of questions generated during each activity, these questions may provide the youth with the topic they want to focus on for one of their projects.

Print the “Cosmic Cast of Characters” on 11x17 paper and post the four pages on the wall. Each week you can print some of the images the youth take and then pin them on the page that represent their group: Jupiter will go with the “Bits Players” and the Whirlpool Galaxy with the galaxy group, etc.

Watch out for…

- ❑ It is important that the youth gradually but steadily get used to making observations. It is not so critical that they come up with lots of details, it is much more important that they clearly describe only what they see in the images.

- ❑ Make sure that participants formulate complete sentences when they describe what they see. It may help to ask another person to repeat and rephrase the description that a youth just provided. If the second youth has a hard time repeating the information, that may be a sign that the original description was not a good one.

Vocabulary

asteroid: Asteroids, also called minor planets or planetoids, are a class of astronomical objects. The term asteroid is generally used to indicate a diverse group of small rocky celestial bodies in the solar system that orbit around the Sun.
billion: The cardinal number equal to 10^9, or a one with nine zeroes after it.
black hole: A region of space resulting from the collapse of a star with a gravitational pull so strong that from a certain distance, not even light can escape it.
comet: Comets are loose collections of ice, dust, and small rocky particles in the Solar System that orbit the Sun and, when close enough to the Sun, exhibits a visible coma (or atmosphere) and/or a tail — both primarily from the effects of solar radiation upon the comet's nucleus. The nucleus itself measures a few kilometers or tens of kilometers across, and

is composed mostly of rock, dust and ice. Comets are nicknamed 'dirty snowballs.

galaxy: Any of many very large groups of stars, gas, and dust that constitute the Universe, containing an average of 100 billion (10^{11}) stars and ranging in diameter from 1,500 to 300,000 light-years.

globular cluster: A system of stars, generally smaller in size than a galaxy, that is more or less globular (like a globe) in shape.

light-year: The distance that light travels in one year.

Milky Way: The galaxy which is the home of our Solar System together with at least 200 billion other stars and their planets.

million: The number equal to 10^6, or a one with six zeroes after it.

The Moon: The natural satellite of Earth.

nebula: A diffuse mass of interstellar dust or gas, or both. A nebula can be visible as luminous patches or areas of darkness depending on the way the dust and gas absorbs or reflects light given off either inside or outside the cloud.

The Sun: A star that is the basis of the solar system and that sustains life on Earth, being the source of heat and light.

supernova: A special event at the end of massive stars' lives in which the star explodes and shines millions of times brighter than it had during its lifetime. Only stars about 10 times the mass of our sun will die in this way.

universe: All matter and energy, including the earth, the galaxies, and the contents of intergalactic space, regarded as a whole.

Useful Websites

NASA Solar System Exploration: This is a great site to explore the newest discoveries pertaining to our solar system and its planets. It is also a great resource for learning about each planet in our solar system; their discovery and also some fun facts about other objects in our solar system: http://solarsystem.nasa.gov/planets/

Amazing Space: Astronomy information for educators: http://amazing-space.stsci.edu/eds/tools

From Starlight to Image

Goals

- ❑ Learn how starlight is converted into a digital image
- ❑ Become familiar with the specific vocabulary of digital imaging
- ❑ Discuss the strengths and weaknesses of models

Activity Overview

Participants will be given to an explanation of the function of the camera's, or "detectors," on the MicroObservatory telescopes. They will also observe a demonstration that illustrates how the light collecting elements on a MicroObservatory telescope's camera is related to the information they see on the screen.

Background

A CCD camera attached to a telescope "sees" differently from the human eye. A main difference is that the CCD is usually color-blind, i.e. it only records white, black and shades of gray depending of the intensity of the light that falls on the CCD.

A CCD (charge-coupled device) is an electronic instrument for detecting light. In the case of an astronomical CCD camera, this light is usually very dim. The heart of the CCD consists of a thin silicon wafer chip. The chip is divided into thousands or millions of tiny light sensitive squares called pixels.

Each pixel on the detector corresponds to an individual pixel in the final image. When a photon of light strikes the surface of certain materials (like the silicon in a CCD chip) the energy imparted by the photon can release an electron from the material. In a CCD, this electron is stored within the walls of a pixel. During a long exposure, photons rain down from the astronomical object being imaged and strike the CCD detector. The pixels in the detector act like wells and begin to fill up with electrons (generated by the photons impacting the chip). If an area of the CCD is imaging a bright object such as a star (which gives off lots of photons), the pixels in that area fill up with more electrons than those in an area imaging something dim like faint nebulosity or the black night sky. (Though even the pixels imaging black sky will end up containing some electrons for several reasons.) Once the exposure is finished (usually done by closing a shutter on the camera), the charge must be transferred out of the CCD and displayed on a computer monitor.

A numerical value is assigned to each pixel's charge, based on the number of electrons contained in the pixel. This value is sent to a computer and the process repeats until each pixel's electrons have been converted to a pixel value and are displayed as a raw image on the computer screen.
No matter how we change the way we display this raw image using our image processing software, the information contained in the image, namely the number of photons that originally were captured by each individual pixel in the CCD detector, remains the same.

Preparation

Space Required: A large room.

Materials:

- ❑ Multiple copies of the detector grid with the number of counts in each pixel
- ❑ One detector grid without the printed counts, this can either be on regular printer paper, printed onto a poster, or recreated on chart paper as neatly as possible.
- ❑ Large LEGO blocks are visually better for the demonstration when paired with a poster sized detector, but normal LEGO blocks may be used as well with the detector grid on printer paper.
- ❑ A copy of the happy face worksheet
- ❑ Magnifying glass

Preparation time: 🕐

Activity time: 15 minutes

Gathering of materials and final preparations:

Copy the Happy Face and two grid pages. You should notice that on the grid with the number counts, the high values such as the 6's and 8's correspond with the whiter regions of the Happy Face. Ready stacks of LEGO blocks to simulate the accumulation of light particles. Draw the happy face made of pixels on the board to represent the object in outer space and unroll the large detector poster on a nearby table. If some youth arrive early to this session, have them shade the grid with the number counts in a ‘color-by-number’ manner; where the low numbers are a dark gray or black, and the higher values are a light gray color or left white.

Procedure

Discussion lead-in:

Before conducting this activity, participants should be introduced to and understand how their work with the MicroObservatory telescopes relates to the activity they will do. Participants should know:

- ❑ The vast majority of telescopes that professional astronomers use (and also MicroObservatory) are equipped with digital cameras.

- ❑ Digital cameras create images from numerical data assigned to each pixel. The word pixel is a combination of the words “picture” and “element.” A pixel is the smallest discernible sample of visual information—the “little squares” that make up an overall picture.

Examining a Computer Display

Instruct the youth to use a simple magnifying glass to look at a computer screen: they will see the pixels that make up the computer display. Then ask participants to describe what they observe:

What colors are the dots or lines you see?

No matter what colors are in the image on screen, do the colors of the dots remain the same?

The image on the screen is composed of thousands of tiny red, green, and blue dots (or lines, in some screens). Each color in an image is a combination of the red, green, and blue dots, glowing at different brightnesses. For example, the color yellow is created from the red and green dots glowing together, with very little or no blue. White is created from the red, green, and blue dots all glowing together. Brown is a combination of dim red and dim green.

Demonstration:

1. Explain to the youth that having taken their first images using MicroObservatory, they should now reflect on how the whole process works as they follow along with the following model demonstration (the process proceeds from starlight, to the telescope’s detector, and finally to the pixels of an image).

2. Remind participants that they are not just telling a website to return an image; they are controlling robotic telescopes using computers. In fact, this is the same manner in which professional astronomers control

their telescopes. Additionally, the only way that the youth and astronomers can learn anything about astronomical objects is by studying the light coming from these objects. We cannot travel to most of these objects and take a scoop out of their surfaces to bring it back to study—we must use a telescope to collect light and learn about these objects in this manner.

3. Tell the youth to pretend that the happy face that has been drawn on the board is really a distant astronomical object emitting light, like a star cluster.

4. On a nearby table place the blank detector grid poster/paper. Explain to the youth all of the following: this ‘detector’ is actually a CCD, or charge-coupled device. A CCD is a light sensitive object that looks like a grid of boxes; each box is called a pixel. Each pixel records the number of light particles that hit its surface.

5. Explain to the youth that if they point the telescope at the happy face, the light from this object will enter the telescope and hit the detector on one of the pixels. Show the LEGO block traveling from the happy face to the detector grid and place the block on the box it would hit. Demonstrate this a few times, especially showing that the bright eyes of the happy face have more light particles originating from these areas, and so the stacks of blocks on the detector that correspond with these regions stack higher than other darker regions of the target object.

6. Further explain that the detector records the number of blocks, or particles of light, that hit each pixel on the detector. Then show the grid with the numbers written in.

7. Finally, explain that the information collected by the detector is sent to a computer, which can then interpret or “de-code” the original starlight and show it as an image with black, white, and shades of gray pixels.

Follow up

Computer Activity 3: Contrast

Vocabulary

CCD: CCD stands for charge-coupled device. A CCD is a detector made on a silicon wafer. Due to the physical nature of silicon, photons of light that hit it generate electrons in the silicon. The job of the CCD is to collect these electrons in its "light buckets" (called **pixels**) during the length of the exposure to light. The more light falling on a particular "light bucket" or pixel, the more electrons that pixel will contain. The buckets then transfer their electrons (think of a “water bucket brigade”) out to the CCD controller (which contains the electronics to control the CCD) and on to the computer. The computer then regenerates the image.

false color: Assigning colors to an image in order to bring out specific qualities or details of the image. False color can be applied to images taken in visible or invisible light.

photon: Colloquially, a photon is a "particle of light." Light can be created or absorbed only in discrete amounts of energy, known as photons. The energy of a photon is greater the shorter the wavelength--smallest for radio waves, increasingly larger for microwaves, infra-red radiation, visible light and ultra-violet light. It is largest for x-rays and gamma rays.

pixel: The smallest individual component of an image or picture—the greater the number of pixels per inch the greater the resolution.

digital: Of, pertaining to, or using data in the form of numerical digits. Available in electronic form; readable and able to be manipulated by a computer.

resolution: An optical system's resolution is a measure of the smallest detail it is able to resolve. An instrument through which one can see the stitches on a baseball from some distance away would be said to have greater resolution than another through which one can only see the shape of the baseball. Seeming counterintuitive, this attribute is independent of magnification! Two different telescopes may be pointed at the same object at the same magnification, however the one with greater resolution will present a "sharper" image than the "blurrier" picture offered by the other.

Useful Websites

Starizona: This website is designed to teach how to take CCD images and to process them to achieve impressive results. It is also intended to be a showcase of CCD imaging to inspire you to head out under the stars and capture beautiful pictures! Advanced:
http://www.starizona.com

Cosmic Survey

Reprinted and adapted with permission from Cosmic Questions Educator's Guide.

Goals

- ❑ Reflect on their understanding of relative size and distance pertaining to objects in the universe
- ❑ Be introduced to the concept that light travels at a finite speed

Activity Overview

In this activity, a three-part questionnaire launches participants into discussions about where objects in space are located, and when they formed. By physically manipulating images (on cards) of objects in space, participants represent their own mental models of space and time.

Background

Many people, adults and children alike, are familiar with the names of objects in space, but they have an incomplete mental model of where those objects are in space, their relative size and distance, and how they fit into the scheme of the universe. Understanding the sizes and distances of celestial objects can be tricky because in our everyday experience, the stars all seem the same distance away, and the moon can appear close (bigger) or far away (smaller) depending on whether you observe it near the horizon or higher in the sky. Most people's knowledge of dim and distant objects such as nebulae and galaxies comes mainly from images in books, where all the images are about the same size with no indication of scale.

Preparation

Space Required: A large room with table space enough for small groups of youth to work with cards and a piece of chart paper.

Materials:

- ❑ Enough sets of 7 different images cut from a copy of the Cosmic Survey Master for each participant or pair of participants. The images can be found on page 16 in the Cosmic Questions Educator's Guide: http://cfa-www.harvard.edu/seuforum/download/CQEdGuide.pdf

Preparation time: ⌚ ⌚ ⌚ (including reviewing background information and preparation of enough sets of images for your group)

Activity time: 45 minutes

Gathering of materials and final preparations:

Make enough copies of the Cosmic Survey Master images for each participant or pair to have a set of 7 images. Have chart paper for each group.

Procedure

Discussion lead-in:

This is an introductory activity that guides participants as they begin to think about where we fit in the universe. Participants should become familiar with the objects in the solar system and the terms for celestial (astronomy) objects beyond our solar system that they will have to work with later on.

- ❑ Ask participants to name some objects in the universe. Every time they name an object ask what else they know about it.

- ❑ What kind of information could we gather about objects in the universe? (i.e. brightness, color)

- ❑ What are some important characteristics or features of these objects? (i.e size, distance, age)

- ❑ Hand out the sets of seven images. Ask the participants to identify the objects on each card. If they are not familiar with the objects explain briefly what they are, but without giving away too many details.

- ❑ Referring to the images of the Hubble Space Telescope and of the Sun explain that they should compare the size of the **actual objects** and not the size of the image of the objects as reproduced on their cards.

Survey:

1. Hand out a set of images to each participant or pair of participants. Hand out one piece of chart paper to each group of two participants. Have each group set their chart paper up with three columns: How Big, How Far, and How Old. Instruct them to list the objects in the images from least to greatest, respectively, from top to bottom on the chart paper.

2. Ask participants to answer the survey questions in this order:
   - ❑ How Big?
   - ❑ How Far?
   - ❑ How Old?

   This order represents increasing levels of complexity for most people.

3. Organize the group into discussion groups of three. Give each group a piece of chart paper. Ask the team to name a recorder and a spoke person.

4. Explain that each team is to discuss the three survey questions and come to an agreement, if possible, on the best order of images of each question. One member of each team should record questions that arise as they order the images.

5. Circulate among the group, encouraging them to discuss any disagreements fully and to write down arguments in support of their answers.

Discussion:

1. Lead the group in a discussion about the 3 different survey questions. Play the role of moderator, requiring each group to explain why they chose that order (in the sequence: How Big?, How Far?, How Old?).
2. Keep in mind that ideas and insights about the three-dimensional organization of the universe develop gradually. Getting the "right answer" is not as important as the critical thinking skills participants develop as they confront the questions that arise as they struggle with their mental models of the universe.
3. Ensure that participants are also comfortable saying, "We don't really know about these objects." See the **Discussion notes** for "correct" answers and frequent participant ideas.
4. After discussing each question, poll the participants on the alternative orders of images suggested. Do not announce the correct order at this time; participants should be encouraged to think for themselves.
5. To facilitate the discussion you can ask some of the following questions:
   - ❑ What is a planet?
   - ❑ What is a star?
   - ❑ What is a galaxy? What does it consist of?
     (Stars, thus a galaxy is larger …..)
   - ❑ Which ones can you see with your naked eye?
     (Either objects very close of very big ….)
   - ❑ Why would you need a special tool (a binocular or a telescope) to see some of these objects?
     (Some may be too small, others too far away ….)

- ❑ How could we group the objects?

6. After getting a group consensus on all three questions, let participants know the correct answers and observations of astronomers. This information is found in the **Discussion notes**.
7. Be sure to collect the participants' chart paper: you will use these results for your evaluation.

Discussion notes

* This section is for facilitator use only, do not copy these charts for the youth, the numbers are not as important as the size, distance, and age of each of these objects relative to each other. Additionally, it is not necessary to read the entire table to the youth; these are to be used as a reference point when leading the discussion.

Question 1: How Big?

The correct order for the 7 images, from smallest to largest is:

Object	**Size (English Units)**	**Size (Metric Units)**	**Time to Travel W = walk D = drive**
Telescope	40 feet long	12 meters	W: 9.1 sec
Moon	2 thousand miles diameter	3,200 kilometers	W: 27.8 days
Saturn	75 thousand miles diameter	121,000 kilometers	W: 2.85 yrs
Sun	875 thousand miles diameter	1,408,000 kilometers	D: 1.66 yrs
Pleiades	60 trillion miles across the cluster	$1x10^{14}$ kilometers	D: 109 thousand yrs
Galaxy	600 thousand trillion miles across	1×10^{18} kilometers	D: 1 trillion yrs
Hubble Deep Field Galaxies	600 million trillion miles across the cluster	1×10^{21} kilometers	D: 1000 trillion yrs

Note the size in metric units is in scientific notation as well. For example, the number $\mathbf{1 \times 10^{14}}$ is the same as the number 1 with 14 zeros following it, or **100,000,000,000,000** and so on down the column (1×10^{18} is the number 1 with 18 zeros).

It's hard to tell the size of objects from many of the images we see, since they look about the same size in the pictures. But the Sun is much larger than Saturn or any of the planets. In fact, a million Earths would fit inside the Sun. Size counts in nature. Objects much larger than Saturn or Jupiter are fated to turn into stars such as our Sun.

Participants may also wonder if in the image of the Pleiades, we are talking about the sizes of the individual stars, or all the stars in the picture. For this picture and the Hubble galaxies, the challenge is to figure out the relative size of the "field of view" – all the stars or galaxies in the cluster.

Question 2: How Far?

The correct order for the 7 images, from closest to Earth to farthest, is:

Object	**Size (English Units)**	**Size (Metric Units)**	**Time to Travel W = walk D = drive F = fly**
Telescope	350 miles above surface of Earth	560 kilometers	W: 4.9 days
Moon	250 thousand miles	402,000 kilometers	W: 9.5 yrs
Sun	93 million miles	1.5×10^8 kilometers	D: 177 yrs
Saturn	120 million miles (at its closest)	1.3×10^9 kilometers	D: 4,500 yrs
Pleiades	2400 trillion miles	4×10^{15} kilometers	D: 4 billion yrs
Galaxy	200 million trillion miles	3×10^{20} kilometers	F: 50 trillion yrs
Hubble Deep Field Galaxies	30 billion trillion miles	5×10^{22} kilometers	F: 7500 trillion yrs

Figuring out the relative distances of the Sun and Saturn requires knowledge about the relative orbits of the planets. Depending on how much astronomy background participants have had, the Pleiades may be placed inside the solar system, or as the farthest objects in space. In general, most people (students and adults) have a hard time understanding the relative distances of the last 3 objects.

Participants often struggle with the distance of the Hubble Space telescope; after all, it takes images of very distant objects. How far away is the Hubble Space telescope? Many people believe that it is beyond the orbit of the Moon, but it's actually only 350 miles high. That's high enough for a clear view above the Earth's atmosphere, but low enough to enable it to be serviced by the astronauts aboard the space shuttle. (See “In this activity, what out for ….”)

Many people think the beautiful Pleiades cluster of stars must be further away than a cluster of galaxies, because they look smaller. But all the stars we see in the night sky are much closer than even the nearest galaxy. A galaxy is a "city" of many billions of stars. Galaxies are so far away that we can't make out the individual stars in them. In fact, the roughly 5000 stars we can see with the naked eye are just some of the closest of the billions of stars in our own galaxy, the Milky Way.

Question 3: How Old?

For this question, the correct order for the 7 images is actually somewhat ambiguous, and the subject of much current astronomical research! In confronting this seemingly simple survey question, participants are grappling with the big ideas of formation of the solar system, life cycles of stars, and evolution of the universe! A best response, one that most astronomers–but not all–might give, is:

Object	How Old?
Telescope	Launched in 1990
Pleiades	80 million years
Moon	4.5 billion years
Saturn	4.5 billion years
Sun	4.5 billion years
Galaxy	10 billion years
Hubble Deep Field Galaxies	10 billion years

We tend to think of stars as having been around for a very long time. In fact, our Sun is billions of years old. But new stars, like those in the Pleiades, are continually being born. The Pleiades stars are only about 80 million years old.

Which is older, the Sun or the Hubble galaxies? It depends on what you mean by "age." The Sun is about 4.5 billion years old. But the Hubble "deep-field" galaxies are among the most ancient and distant objects we can see in the sky. The light from them has taken about 10 billion years to reach us. So they were born long before our Sun. On the other hand, the Hubble deep field galaxies are young galaxies! Because of light’s travel time, we see these galaxies as they were when they formed, only a few billion years after the Big Bang. Many of the stars in the galaxies in this image may be younger than our Sun, so we are looking at the “baby pictures" of objects that are now old. (See Watch out for… the fourth bullet for more on this)

Follow up

For evaluation purposes, you will be asked to do this activity again at the end of the program. Your assessment will be based on the comparison of answers to the survey the participants gave today and the answers they will give then. This comparison will allow you to see whether their ideas and understanding have changed over the course of the program.

Watch out for…

- ❑ Participants often also have a misconception that "space" telescopes such as the Hubble or the Chandra X-ray Observatory gather data by actually going to the objects they observe and returning with images. Participants should be made aware that these telescopes actually orbit close to the Earth (like telecommunication satellites do) and gather light from distant objects. It is impossible to travel the immense distances to the objects in most of the pictures.

- ❑ Participants often mistake apparent brightness and apparent size (how large something appears in an image) for actual qualities. Participants should be made aware that distance has an effect on how large or bright something looks, whether it is a planet, a star, or a galaxy. The same can be said of a car: the car looks small when is approaching from a mile away, and its headlights look faint. When the car gets closer, we can appreciate its real size and the brightness of the headlights.

- ❑ It may be useful to introduce some scale factors when considering the relative size of objects. 100 Earths can fit in the Sun diameter. All the planets of the solar system could fit into the Sun. A galaxy is a "city" of many billions of stars.

- ❑ Lastly, this may be the place that you introduce the concept that light takes time to reach us from distant objects. If light took 4 years to come from a star that means that the image that we see shows the star as it was 4 years ago. In this way, you could talk about telescopes as "time machines," that allow us to look farther and farther into the past when we look at more and more distant the objects.

Vocabulary

It may be useful to review the vocabulary that accompanied the introductory activity, "Modeling the Universe". The following terms are specifically applicable to this activity:

billion: The number that is represented as a one followed by 9 zeros: 1,000,000,000
galaxy: A giant collection of gas, dust, and millions or billions of stars.
Hubble Space Telescope: The Hubble Space Telescope (HST) is a space-based telescope that was launched in 1990 by the space shuttle. From its position 350 miles above the Earth's surface, the HST has expanded our understanding of star birth, star death, and galaxy evolution, and has helped move the existence of black holes from theory to fact. It has recorded over 100,000 images in the past eight years.
Hubble Deep Field Galaxies: A remarkable image taken by the Hubble Space Telescope that covers a speck of the sky only about the width of a dime 75 feet away. Gazing into this small field, Hubble uncovered a bewildering assortment of at least 1,500 galaxies at various stages of evolution.
moon: A natural satellite revolving around a planet. The Moon is the natural satellite of the Earth.
Pleiades: A group of stars (technically called an open star cluster) in the constellation Taurus, consisting of several hundred stars, of which six are visible to the naked eye. The Pleiades are named for the seven daughters of the mythological god Atlas (Maia, Electra, Celaeno, Taygeta, Merope, Alcyone, and Sterope), who were thought to have metamorphosed into stars.
Saturn: The sixth planet from the sun and the second largest in the solar system. Saturn is a gas giant made primarily from hydrogen and helium, and has a beautiful system of rings.
The Sun: The star in our solar system. The Earth and the other planets of the solar system orbit around the Sun. The Sun sustains life on Earth, being the source of heat and light.
telescope: A device that allows us to see far away objects.
trillion: The number that is represented as a one followed by 12 zeros: 1,000,000,000,000

A complete list of all the terms used in this program can be found in the Vocabulary section of this notebook.

Useful Websites

How Big is Our Universe: For more information, take a look at this website to get more information about space science and the structure of the universe:
http://cfa-www.harvard.edu/seuforum/howfar

Planet Quest: Interstellar Trip Planner: Using this fun and interactive website, the youth can further explore how long it would take to reach certain astronomical objects by various modes of transportation. Note: Flash must be enabled in your web-browser for the trip planner to work, and pop-up blocking will have to be disabled for the PlanetQuest website:
http://planetquest.jpl.nasa.gov/gallery/gallery_index.cfm
From this first link, click on **interstellar trip planner**, or just follow the direct link below:
http://planetquest.jpl.nasa.gov/gallery/planetZone_tripPlanner.html

Comets and Asteroids

Goals

- ❑ Practice and improve communication skills
- ❑ Reflect on the effectiveness of different styles of communication

Activity Overview

This activity is used as an icebreaker to initiate dialog, which enhances communication and pushes students to possibly step out of their comfort zones in order to improve their ability to communicate.

Background

Communication skills can be the building block to a successful partnership. In order for students to vocalize their thoughts and ideas clearly to each other, it is important that they are able to learn to articulate their ideas and communicate in a direct and precise manor.

Throughout this activity, the students are expected to work in pairs and small groups. In order to do this successfully, good communication is essential among group members. It is also an important part of the groups final project presentation.

Preparation

Space Required: Large Room (approximately 20'X20')

Materials:

- ❑ Small and medium size soft balls
- ❑ Blindfolds
- ❑ Masking tape or four cones for marking boundaries

Preparation time: 🕐

Activity time: 25 minutes

Gathering of materials and final preparations:

Have enough blindfolds for every pair of student to have one. There should be approximately twice the amount of balls than participants involved in the activity. Depending on where the activity is being done, there may be a need for boundaries to be set up if the given space is too large.

Procedure

Discussion lead-in:

This activity will be done in two parts, in order to ensure there is time for reflection and discussion of relevant skills.

Activity:

1. **Round 1**: Begin by scattering balls randomly among activity space. Once this is done, ask one student from each pair to place a blindfold over their eyes and stand next to their partner anywhere inside the playing space. All groups should be somewhat equidistant away from one another and spread among the game space. At this point the player that is not blind folded will verbally lead their blindfolded partner around the playing space encouraging them to pick up as many balls as possible. The team with the most balls is the winning team.

2. Discuss what made this activity difficult.
   - ❑ How does communication play a role in the efficiency of gathering the comets and asteroids?
   - ❑ What were some examples of good directions, what were some examples of directions that were confusing for students to hear?

3. Repeat this activity with the opposite partner blindfolded. Give the teams a chance to practice communication skills they discussed.

4. **Round 2**: This round begins in the same way as Round 1. During this part of the activity, the non-blindfolded partners are using their communication skills to instruct their blindfolded partner to gather the comets and asteroids, and throw the objects at the other blindfolded players with the intention of hitting the opponents. If a blindfolded player is struck by a comet or asteroid, both the struck player and their partner are eliminated and must leave the activity area. (It is acceptable strategy for the non-blindfolded partner to block their blindfolded partner from being hit by an asteroid or comet). This makes clear communication from the non-blindfolded partner imperative in order for the partners to stay in the game.

5. Repeat this round at least once. Have partners take turns being blindfolded. Reduce the amount of balls to create more of a challenge.

6. Discuss what this activity was like for the partners.

Follow up

Context of other partnership activities and project coordination.

Watch out for...

- Players peering out from under blind folds.
- If the game is going on forever, you may want to disallow the command-giving partner from blocking incoming balls.

Toilet Paper Solar System

Adapted from "Toilet Paper Solar System"
Family ASTRO Activity from the Astronomical Society of the Pacific
http://www.astrosociety.org/education/activities/handson.html

Goals

- Gain an appreciation of the actual distances between the orbits of the planets
- Construct a model, which represents the span of relative distances between orbits of planets in the solar system
- Discuss the strengths and weaknesses of a model

Activity Overview

Participants work in teams. Each team is given a table of scaled-down measurements of the distances between the Sun and the planets' orbits in our Solar System. The teams will mark off these scaled-down relative distances on a piece of toilet paper. The incredible distances, even scaled down, generally surprises anyone who has never visually represented these distances before.

Background

Many people have never given much thought to the distance to objects in the night sky. While it is impossible to deal with actual distances because they are so huge, it is useful to employ a scale model to show the relative distances between objects in our Solar System.

This activity uses toilet paper as a measure, and each sheet represents a unit of measurement. In the football field version the participants will calculate the distance from the sun (located on the goal line of the diagram) and instead, find the number of yards from the goal line instead of the number of squares of toilet paper.

In this activity the participants should also make observations in reference to how our solar system appears. Encourage them to think what the reason may be behind this. The following is background information on some questions that may arise through out the activity:

Preparation

Space Required:

A large room for group discussion, and a long clear hallway, at least 42 feet long. If this space is not available, photocopy the illustration of a football field and model the scale of the solar system (taken from Life in the Universe). See appendix.

Materials:

- ❑ One table of distances per group
- ❑ One roll of toilet paper, 101 sheets or more, per group.
- ❑ Felt-tip marker(s) or gel pen, preferably 10 colors, per group; but one pen per group will do
- ❑ Clear tape for repairs

Preparation time: (assembling materials, reviewing Solar System Live website)

Activity time: 30 minutes

Gathering of materials and final preparations:

- ❑ Photocopy the handout with the distances to the planets' orbits (found at the end of the activity).
- ❑ Get ready to pass out pens, table of distances, tape dispenser and roll of toilet paper to each group
- ❑ Go to Solar System Live:

(http://www.fourmilab.to/solar/solar.html) and get familiar with the actual position of the planets in the solar system. This interactive tool allows you to display "where the planets are" on the day you do they activity.

- ❑ Make copies of the solar system map for each participant. This will help you explain one of the weaknesses of the toilet paper model: planets are NOT lined up as it appears in the model.
- ❑ Print out cards with images of planets. These images can be found in the appendix section.
- ❑ Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.
- ❑ If you are doing the football field version of this activity, you will need to print out the diagram of a football field, found in the appendix section.

Procedure

Discussion lead-in

Ask a participant to name the 8 planets of the Solar System outward from the Sun while probing the participants for thoughts on what we know about our solar system. Pluto's status as no longer being a planet will come up and so you may want to briefly inform them that in 2006, the International Astronomical Union ruled that Pluto is no longer a planet but rather a dwarf planet. This may lead to further questions about why this decision was made among others; have the youth write their questions about this onto a piece of chart paper. These questions can be addressed at the end of the activity, either through discussion, or there are websites provided to refer them to for more information.

Inform the group that the average distance of the Solar System, i.e. from The Sun out to Pluto and Neptune, is about 6 billion kilometers (3.75 billion miles). The size of this number is difficult to grasp!

Provide the following illustration: Ask participants to estimate how long it would take to drive a mile (one minute). To drive a hundred miles (a couple of hours). A thousand miles (about two days of sane driving). And finally, to drive 3.75 billion miles (more than 7,000 years driving at 60 miles per hour 24 hours a day and never stopping – not even for a bathroom break!). In all likelihood, participants' estimates were all reasonable until the final distance; then they had absolutely no idea!

Revisit your discussion of models that was begun when you did the Modeling the Universe activity with your group—

- ❑ Why do we use models?
- ❑ When are they useful?

Bring the discussion to an introduction of your toilet paper model.

Modeling:

1. Take one sheet of toilet paper as a test sheet for the pens. Make sure the ink is not too wet, that the pens don't easily tear the paper. Also, have groups practice writing on the delicate paper with one test sheet. After they have learned the best way to write on toilet paper, throw away the test sheet.

2. Suggest they make a dot on the seam between the first two sheets of toilet paper. This is the Sun. Write the word Sun beside the dot. Or if you are using illustration cards, you can simply place the card next to the TP location where your object should be located.

3. Then your groups can use the table of numbers you have provided to mark off the distances to each of the planets' orbits. The number in the table is the number of sheets of toilet paper needed to reach the orbit of each planet. It is important to tell participants that the counts in the

table are starting from the Sun, not from the previous planet (thus, after you get to Mercury, you need 0.8 more of a sheet to get to Venus or a total of 1.8 sheets as measured back to the Sun). They should make a dot and write the appropriate planet name on the toilet paper at the distance indicated. Ceres, the largest asteroid, is used to represent the asteroid belt

4. Finally, give each group a set of images of the planets taken with MicroObservatory and ask them to place the each image next to its planet position.

Toilet Paper Solar System Model

(Distances scaled to 1 AU = 2.5 pieces of toilet paper)

Planet / Object	Squares of toilet paper from the sun to the average orbit of the planet
Mercury	1.0
Venus	1.8
Earth	2.5
Mars	3.8
Asteroid Belt	7.0
Jupiter	13.2
Saturn	24.2
Uranus	48.6
Neptune	75.3
Pluto	100.0

Scale of the Solar System for Football Field Model

Planet	Approximate Distance from Sun (in AU)	Distance from Sun (Located on the goal-line) in yards
Mercury	0.4	1
Venus	0.7	1.75
Earth	1.0	2.5
Mars	1.5	3.75
Jupiter	5.2	13.0
Saturn	9.5	23.75
Uranus	19.2	48
Neptune	30.1	75.25
Pluto	39.5	98.75

Debrief:

As you did in the "Modeling the Universe" activity, you will lead the whole group to reflect on the model they created and how useful it is to represent the Solar System. Make sure to have enough time for debriefing: it is the most important part of the whole activity.

1. Give a few minutes to each team to comment on these four questions:
   - ❑ What features of the solar system does this model represent?
   - ❑ What things does this model misrepresent?
   - ❑ What things about the solar system does this model omit, or not represent at all?
   - ❑ What questions came up as your group worked on your model?

2. Ask each team to report to the whole group their answers to the previous questions. Then ask the following questions to the whole group to further probe the participants' understanding of the model. The goal is to get the participants to articulate their thoughts, and not necessarily get the right answers. However, be sure to get at their reasoning or evidence for their stance.
   - ❑ Are there any patterns that emerge?
   - ❑ What parts of the astronomical model do you think represented the "real thing" particularly well? Why?
   - ❑ What parts of the astronomical model do you think misrepresented the "real thing"?
   - ❑ Why is representing the whole solar system a difficult challenge?
   - ❑ How can this model be used to make predictions regarding observations of the solar system? For example: where is Earth in this model and what would an observer on Earth see if they lived in this solar system?
   - ❑ What are some things you need to find out to design a better model?

3. Why do you think the outer planets so much bigger?

4. Notice that the outer planets are much further away from one another. Why do you think this is?

5. We know that the larger planets Jupiter, Saturn and Uranus are planets made mostly of gas. Why do you think this is?

6. It is appropriate at this point to connect relative distances and relative sizes of the objects in the solar systems. In two other

activities we used the Earth's diameter as a unit of measurement. The following table summarizes the size and distance of the orbit of Earth, Jupiter and Pluto from the Sun in Earth's diameters.

Object	Size in Earth diameters	Distance to the orbit from the Sun in Earth diameters
Sun	109	0
Earth	1	12,000
Jupiter	11	60,000
Pluto	0.2	480,000

7. Standing next to the position of Jupiter, ask the group to consider again this question:
   - ❑ If Jupiter is such a big planet, why does it appear so much smaller than our Moon in the MicroObservatory image?

8. Use the interactive tool at **Solar System Live** (http://www.fourmilab.to/solar/solar.html) to show participants the actual relative positions of the planets.
   - ❑ Tell the youth that this is a computer model displaying the position of each planet in its orbit around the Sun at any given time. First have the participants input their birthdays; then their full birth date (includes the year they were born).
   - ❑ Finally ask the youth if we are able to take an image with the MicroObservatory telescopes tonight. Why or why not?

Helpful hints when using this interactive website:

- ❑ When you first get to the website, you will notice the planets of the solar system are represented by symbols. This can be confusing for the participants. By clicking on "Images" and then "Update" you will get the planets represented by the typical image of that planet seen in other scientific reference materials.
- ❑ The model of the solar system indicates the orbit areas which one would be able to observe indicated by a green line. The blue areas on the orbit paths indicate the orbital area of that planet which is not visible due to the sun's light interfering with the light from these objects.
- ❑ The "Update" button on the web page will reset the model to reflect any changes in settings that a user has made.

Follow up

- ❑ Create a model of the solar system with size of the planets to scale.
- ❑ At the scale used in the toilet paper model, Jupiter would be the size of a grain of salt. To create a model with both the planets' size and distance to scale, you can use one inch to represent a hundred thousand miles in reality. In this model, the distance from the Sun to the orbit of Pluto will be a thousand yards. Rather than using sheets of toilet paper as a unit of measurement, you will be counting paces or steps (this is less accurate, but easier and just as effective).
- ❑ If you don't have the time or space to complete the model, try to get to Jupiter's orbit and note that Saturn nearly doubles the distance. The same is true of going from Saturn to Uranus.

NOTE: The distances here are between orbits, not from the Sun like they were in the previous activity.

Object	Size	Distance to pace
Sun	Any ball, diameter 8.00 inches	--
Mercury	A pinhead, diameter 0.03 inch	10 paces from the Sun
Venus	A peppercorn, diameter 0.08 inch	9 paces from Mercury to Venus
Earth	A second peppercorn	7 paces from Venus to Earth
Mars	A second pinhead	14 paces from Earth to Mars
Jupiter	A chestnut or a pecan, diameter 0.90 inch	95 paces from Mars to Jupiter
Saturn	A hazelnut or an acorn, diameter 0.70 inch	112 paces from Jupiter to Saturn
Uranus	A peanut or coffee bean, diameter 0.30 inch	249 paces from Saturn to Uranus
Neptune	A second peanut or coffee bean	281 paces from Uranus to Neptune

Pluto	A third pinhead (or smaller, since Pluto is a dwarf planet as of 2006)	242 paces from Neptune to Pluto

- ❑ If you work with high school students, you can ask them to create their own model of the Solar System. To do so they need to know the relative size and distance of the planets. It is useful to express size and distance of each planet relatively to the Earth size (diameter) and distance from the Sun. The average distance between the Sun and the Earth is called "astronomical unit" – AU for short. About 10,000 Earths lined side by side are necessary to cover the distance of 1 AU. Participants should choose an appropriate size for the Earth so that they can fit their solar system within the space available.

Object	Approximate planet size in Earth diameters	Distance to the orbit from the sun in AU (astronomical unit)
Sun	109	0
Mercury	0.4	0.4
Venus	0.9	0.7
Earth	1.0	1.0
Mars	0.5	1.5
Jupiter	11	5.0
Saturn	9.5	9.5
Uranus	4.0	19
Neptune	3.8	30
Pluto	0.2	40

Watch out for...

- ❑ One common misconception when talking about the Solar System is that the planets are actually lined up, the way they appear in diagrams and models. The planets are in fact never in a line! It may be useful to explain that the planets are constantly in motion, spinning as well as orbiting the Sun. When we do this activity, we are actually describing the distances between the orbit of the planets and the Sun.

- Some practical things to watch out for are:
  Pen tips – If pens are very liquid they may bleed through too much or tear the paper. Gel pens work well.
  Toilet Paper tips – Cheap, flat toilet paper generally works best. Textured paper is okay; printed-paper can be distracting.

- When using the Toilet paper version of this activity, it can be helpful to supply the participants with the calculations of how far the diameter of each planet is in squares of toilet paper.

Vocabulary

axis: A straight line about which a body rotates

comet: Comets are loose collections of ice, dust, and small rocky particles in the Solar System that orbit the Sun and, when close enough to the Sun, exhibits a visible coma (or atmosphere) and/or a tail — both primarily from the effects of solar radiation upon the comet's nucleus. The nucleus itself measures a few kilometers or tens of kilometers across, and is composed mostly of rock, dust and ice. Comets are nicknamed 'dirty snowballs.

diameter: The length of a straight line through the center of a circle or sphere.

dwarf planet: A celestial body that is in orbit around the Sun, having sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a nearly round shape, and is not a satellite.

Earth: The third planet from the sun, and our home planet

Jupiter: Jupiter is the fifth planet from the Sun and by far the largest. Jupiter is more than twice as massive as all the other planets combined (the mass of Jupiter is 318 times that of Earth). Jupiter is composed of mostly hydrogen and helium gas.

Mars: The fourth planet from the Sun, similar in size to the Earth and often called "the red planet"

Mercury: The smallest of the inner planets and the one nearest the sun, a star that is the center of a planetary system

Moon: A natural satellite revolving around a planet.

Neptune: The eighth planet from the sun

orbit: The path followed by an object in space as it goes around another object; to travel around another object in a single path.

outer planets: Any of the five planets, Jupiter, Saturn, Uranus, Neptune, and Pluto, with orbits outside that of Mars.

planet: A celestial body, which revolves around the Sun in an orbit.

Pluto: Once known as the smallest, coldest, and most distant planet from the Sun, Pluto has a dual identity, not to mention being enshrouded in controversy since its discovery in 1930. In 2006, the International

Astronomical Union (IAU) formally downgraded Pluto from an official planet to a dwarf planet.

scale: The ratio between the size of something and a representation of it; "the scale of the map"; "the scale of the model"

Saturn: The sixth planet from the sun and the second largest in the Solar System

Solar System: The system of the Sun and the planets, their satellites, the minor planets, comets, meteoroids, and other objects revolving around the Sun.

Uranus: The seventh planet from the Sun

Venus: The second planet from the Sun

Useful Websites

Exploratorium: Make a scale model of the solar System
http://www.exploratorium.edu/ronh/solar_system/

A Solar System Scale Model Meta Page: The idea: Making a scale model of the solar system is a useful way to learn about it. Here are various related pages.
http://www.vendian.org/mncharity/dir3/solarsystem/

Solar System Live: This web tool allows you to view the entire Solar System, or just the inner planets (through the orbit of Mars). Controls allow you to set time and date, viewpoint, observing location, orbital elements to track an asteroid or comet, and a variety of other parameters:
http://www.fourmilab.to/solar/solar.html

Star Child: A Learning Center for Young Astronomers – Solar System
http://starchild.gsfc.nasa.gov/

Solar System Exploration: This website has information about Pluto and what it means to be a 'dwarf planet.' Refer youth with questions to the 'Planets' section of the site, and then click on Pluto. (Or follow the second link below)
http://solarsystem.nasa.gov/
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Pluto

Group Portrait of the Solar System: Taking Images

Adapted with permission from *From the Ground Up!*

Goals

- ❑ Take images of objects in the Solar System to use for Group Portrait of the Solar System: Making sense of images (the following activity)

Activity Overview

Participants split into partner pairs or small teams and coordinate their efforts to image some of other planets in the Solar System and the Moon. These efforts of each group may be combined to create a complete "portrait" of the major Solar System bodies visible to MicroObservatory.

Background:

Ancient astronomers observed points of light that appeared to move among the stars. They called these objects planets, meaning "wanderers," and named them after Roman deities - Jupiter, king of the gods; Mars, the god of war; Mercury, messenger of the gods; Venus, the god of love and beauty, and Saturn, father of Jupiter and god of agriculture. The stargazers also observed comets with long dusty tails, and meteors, better known as shooting stars apparently falling from the sky.

Since the invention of the telescope, three more planets have been discovered in our solar system: Uranus (1781), Neptune (1846), and Pluto (1930). In addition, there are thousands of small bodies such as asteroids and comets. Most of the asteroids orbit in a region between the orbits of Mars and Jupiter, while the home of comets lies far beyond the orbit of Pluto, in the Oort Cloud.

The four planets closest to the Sun - Mercury, Venus, Earth, and Mars - are called the terrestrial planets because they have solid rocky surfaces. The four large planets beyond the orbit of Mars - Jupiter, Saturn, Uranus, and Neptune - are called gas giants. Tiny, distant, Pluto has a solid but icier surface than the terrestrial planets.

Preparation

Space Required: Computer Lab

Materials:

- ❑ A computer every 1-2 participants
- ❑ MicroObservatory telescopes
- ❑ A copy of the Observation Log Sheet for each participant
- ❑ A Quick-Guide to Settings for the Telescope
- ❑ Copies of the daily list of what planet is up in the sky at each of the telescope locations (optional)
- ❑ Chart paper (or white board)

Preparation time: 🕖

Activity time: 30 minutes to take images. 30 minutes to discuss images during the following session.

Gathering of materials and final preparations:

A few days before facilitating this activity take images of all planets in the solar system using the MicroObservatory telescopes.
First check when the planets are visible at each site using the "What's Up" link on the MicroObservatory web page. No planet is visible year-round. If you find that one mentioned in this curriculum is not visible, adapt the activity accordingly.

Refer to the "Exposure time" section in the supplementary *Introduction to MicroObservatory* guide to find useful exposure times and filter settings for your objects

Check your images before this session. You can then encourage participants to refer to the your images and the settings you used to get good images for their investigation.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

Procedure

Discussion lead-in:

Ask participants if they have ever seen one of the planets of the solar system in the sky: Jupiter, Mars, Saturn? If they cannot recall seeing a planet with the unaided eye, did they see pictures of the planets? What did the planets look like? What do participants expect the planets to look like when viewed through the telescope? Why do participants think that?
Take note of the predictions on chart paper.

Form groups of two or three participants.

Each person in the group will be responsible for taking two images of the Moon and one image of each of three planets. Each group will have to come to a consensus on the distribution of tasks. If necessary you can suggest something like:
Observer 1 takes images of: Moon (2), Jupiter, Mercury, Pluto
Observer 2 takes images of: Moon (2), Saturn, Venus, Neptune
Observer 3 takes images of: Moon (2), Mars, Uranus, Saturn

Plan observations.

1. Participants use the MicroObservatory Image Archive Directory (click on "Get Images": the link to the Archive is right in front of you) to look for good images of their planets.
2. They check the settings used to take those images by clicking on "Image Info" and take note of them. To plan the time of their observations, participants check when the planets are visible at each site using the "What's Up" link on the MicroObservatory web page.
3. If time is short, distribute copies of the daily list of what planet is up in the sky at each of the telescopes. Make sure participants understand how the time is given in the tables. For example: 13:00 is 1 PM and 22:00 is 10 PM.

Take images.

Participants are now ready to take images of the Moon and the planets that were assigned to them. Make sure they record the settings used in their observation in the Observation Log Sheet.

Follow up

Print the best images of planets taken by the participants. You will use these images in preparation for the "Making Sense of Images" activity.

It is possible that the participants did not succeed in taking pictures of all the planets. Print good images of the missing planets from the archive and have them ready when you discuss the group portrait of the solar system in the next session.

As some planets may not be visible at night at the time you facilitate this activity, you may elect to complete the group's portrait later on in your program and use archive images to fill in the gaps for the "Making Sense of Images" activity.

Watch out for...

- **Imaging Mercury and Venus**
  Mercury and Venus are above the horizon during the day and often best visible at twilight. Acquiring an image of either planet may require the use of the selecting the "daytime" option under the MicroObservatory web interface's "When to Take Image" section. Additionally, sometimes the planets appear too close to the Sun for the telescopes to point at without risking damage to the instrument. If this is the case, the user's image request will be rejected after attempting to submit it.

- **These are general rules that you may want to keep in mind every time you facilitate an investigation using MicroObservatory.**

  Model the use of the telescopes with participants first. If you have a video-projector and Internet access in your computer room, it is ideal to demonstrate with participants how to access the telescopes and download images.

  Have participants work in teams of two or three people. This minimizes the number of images that must be taken, and allows participants to discuss ideas important to the investigation.

  Allow time for participants to predict, plan, and reflect. These are integral parts of the computer activities.

  Manage participants' projects. Make certain that participants understand how to use the telescopes before they begin independent participant projects. Otherwise, you will be overwhelmed by individual questions from the participants once they begin.

  On using MicroObservatory:
  Difference between your eye and the MicroObservatory telescopes:
  The MicroObservatory telescope, gathers more light with its large mirror than your eye can, has sharper vision and thus see very small detail better than your eye can and records the collected light for a longer time than your eye can. All three of these functions (collect more light, has better resolution and records data longer)

make the telescope a more advanced a detecting system than your eye.

Taking pictures: Exposure time

The exposure time, or the amount of time light shines on the imaging detector, greatly affects the outcome of the image. The telescopes' detectors are very sensitive to light, even the smallest amount of light, which is a good thing since we are usually observing very faint objects. For these faint objects, we want to record all the faint light for a long time, gathering more 'light signal' than what our eyes could detect. For bright objects like the Moon or a planet, a short exposure still gathers enough "light signal."

Vocabulary

gas giant: Jupiter, Saturn, Uranus, and Neptune are known as gas giants. This is because they are basically gigantic gas balls compared to Earth and the other three rocky inner planets. The four giant planets are comprised mostly of an outer layer of molecular hydrogen and helium. However, each may have a small solid core as large as several Earth masses at their center. Sometimes they are called the "jovian planets" because Saturn, Uranus, and Neptune are considered to be very similar to Jupiter ("Jove" is variation of Jupiter in Latin).

Oort Cloud A huge spherical "cloud" that extends from beyond the orbit of Neptune and Pluto, half way out to the nearest star. It contains a trillion or more comets orbiting the Sun. This is a source of long-period comets.

terrestrial planet: The four innermost planets in the Solar System (Mercury, Venus, Earth, and Mars) are sometimes called the "terrestrial" planets because of their proximity to Earth ("Terra" in Latin) and their similarity as solid bodies with compact, rocky surfaces.

Useful Websites

Solar System Exploration: http://solarsystem.nasa.gov/

The Nine Planets: http://www.nineplanets.org

Group Portrait of the Solar System:
Making Sense of Images

Goals

- Make detailed observations of the images participants have taken using MicroObservatory
- Make detailed observations of planets found in images
- Learn that the relative size of the object in an image contains information about both its size and distance
- Evaluate the strengths and weaknesses of a model

Activity Overview

This activity is used as an activator for the modeling of the solar system activity that follows (Toilet Paper Solar System). However it can be used as a stand-alone activity as well. It can also be used as a follow-up to the Toilet Paper Solar System activity. If implemented as a follow-up, simply place the images for this activity alongside the toilet paper model and give time for the youth to look closely at the images. Then divide up some of the questions and pose them to the youth.

Background

It's a big universe out there. What does it look like? You use the telescope to image the Moon and the planets to create a "group portrait" of the solar system. In a group portrait, the tallest people are usually in the back. In your group portrait of the solar system, you will instead arrange your images from the closest to the furthest object.

Preparation

Space Required: Large room, tables

Materials:

- ❑ Images of solar system planets taken with MicroObservatory
- ❑ Images of the Moon
- ❑ White board or chart paper

Preparation time: 🕐

Activity time: 20 minutes

Gathering of materials and final preparations:

Make enough copies of the MicroObservatory images (4” X 4”) taken by the participants to have a full set (eight planets and the Moon) for each group of 3-4 people. If you don’t have images for all the planets use the MicroObservatory image archive to supply the missing pictures.

Prepare chart paper by writing 1-2 questions from each object list (moon, Jupiter and other giant planets) on the chart paper for each group. Have each group answer the question mentioned under procedure #5 “Ordering By Distance”.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

We have been taking images of the planets in the solar system and the Moon for several days to create a “group portrait” of the solar system. We will now analyze a sample of these images to learn more about these objects.

Remind participants that all images were taken with MicroObservatory and that the telescope magnification was the same for all images. In other words, MicroObservatory telescope images are all taken at the same scale.

Making sense of the images

Distribute to each group of 3-4 participants the MicroObservatory images of the planets and the Moon. Each group will have 10 minutes to reflect on the images and answer the questions assigned to their group on chart paper.

Which is the biggest “planet”?
Jupiter is the largest planet by both diameter and mass.

If Jupiter (or Saturn) is a big planet, why does it appear so much smaller than our Moon?

Far away objects appear smaller to us. The distance between Earth and the Moon is much smaller

Why don't you see any stars in the image of Jupiter (or Saturn)?
Jupiter is so bright that the exposure must be short. Therefore, the stars are underexposed.

What is the source of light for Jupiter and the other planets? Why do we see them?
Like all planets and moons, Jupiter REFLECTS light from the Sun. It does not produce its own visible light.

Ordering by distance

Then ask each group to arrange the images according to the actual distance of the object from the Earth, from the closest to the furthest from Earth.

Why does the Moon appear so much bigger than Jupiter?
Because even if the actual size (diameter) of Jupiter is 44 times bigger than the size of the Moon, Jupiter is 2000 times further away from the Earth than the Moon is. Being so much farther away does make Jupiter look smaller.

From the Earth-Moon activity we learned that it takes 30 Earths side by side to cover the distance between the Earth and the Moon. You need 60,000 Earths side by side to cover the distance between the Earth and Jupiter!

These are really big numbers. In the Toilet Paper Solar System participants are able to visualize the large distances between the objects of the solar system.

Follow up

The follow up for this activity is seeded throughout the rest of the MicroObservatory computer activities. After completing this activity, the youth in this program will have a better understanding as to how to process and make sense of the images they take form MicroObservatory.

Watch out for…

- ❑ The pictures are all taken at the same magnification however, due to the variation in distance and exposure time, it can be difficult to compare one object to another without knowing each object's distance or each object's size.

- [ ] Participants may have some of these questions; these are examples of how you might address them.

What do you think caused the craters on the Moon?
Craters were caused by impacts of asteroids, early in the solar system's history.

Why isn't the Earth covered with craters too?
Over billions of years, wind and water erode almost all of Earth's craters. But a few are still visible.

Can you detect any of Jupiter's moons?
Your image should contain two to four of Jupiter's innermost four moons.

If you took several exposures of Jupiter over time, would you expect to see the moons moving?
Yes, over four or five hours you will see the innermost two moons move detectably in that time.

What are those bright vertical bands coming out of Jupiter? How do I get rid of them? Are they part of the planet?
If you overexpose an image of Jupiter or other bright object, you'll see vertical "flares" coming from the object. These are not part of the actual scene; they are created in the silicon chip that images the scene. To get rid of them, you'll have to reduce the exposure time. But then it will be harder to see Jupiter's moons, which are fainter than the planet.

Vocabulary

exposure time: Time of the film or the CCD being exposed (open shutter) usually measured in seconds.
overexpose: To allow too much light to come into contact with film or a CCD (detector). Overexposing a film or CCD produces an image that is too light.
underexposed: To allow too little light to come into contact with film or a CCD (detector). Underexposing film produces an image that is too dark.

Useful Websites

Solar System Exploration: This is a great site to explore the newest discoveries pertaining to our solar system and its planets. It is also a great

resource for learning about each planet in our solar system; their discovery and also some fun facts:
http://solarsystem.nasa.gov

Telescopes & Light: Hands-On Telescope Activity

Some Background information taken from Telescopes From the Ground Up!
Station #3 Activity adapted with permission from Hands-On Optics

Goals

- ❑ Gain a basic understanding of optics as well as an introduction examining the behavior of light
- ❑ Develop an understanding of how a telescope forms an image.
- ❑ Look at how a telescope collects light from a distant object and focuses it to form an image of the object
- ❑ Construct a simple model of a reflecting telescope and discuss the strengths and weaknesses of a model

Activity Overview

Youth are split into 3 groups; one group will begin at a station in which they can get their hands on a real telescope. They will interact with an amateur astronomer who will explain the various parts of a telescope and what they all do. Be sure to instruct the youth to not run or carry-on when around the telescope as it is an expensive piece of equipment.

The second station will focus on constructing a model of a telescope and using a make-up mirror to produce a reflected image of a light bulb on which there is a taped-on ‘X’.

Station #3 will have the youth play with lasers and 3 flat mirrors to learn about reflection and begin to play with how to ‘focus’ the light from 3 lasers.

Background:

Originally, the only way to record the image was by hand — astronomers would make a drawing of what they saw through their telescopes. In the 1800's, photography was invented and astronomers experimented with making photographs through their telescopes. In the early 20th century, astronomers started specifically designing and building telescopes to record the image on photographic plates. The 1970's saw the invention of charge-coupled devices (CCDs) that allow the image to be recorded digitally. By the end of the 20th century, all research telescopes would use CCDs to make observations.

Constructing a model of a telescope should touch on how a telescope reflects light and produces an image, and further go over the parts of the telescope to echo the amateur astronomer's presentation.

Preparation

Space Required: A large room.

Materials:

- ❑ Curved make-up mirrors
- ❑ 100-watt round light bulb
- ❑ Light bulb clamp
- ❑ Cardboard detector, aperture, and shutter.
- ❑ 3 lasers
- ❑ 1 mister (spray bottle that sprays a mist)
- ❑ 3 flat mirrors with plastic stands

Preparation time: 🕐 🕐 🕐

Activity time: 60 minutes

Gathering of materials and final preparations:

Contact a local amateur astronomer through the online Night-sky Network at least one month ahead of time to arrange for them to come by to show the youth their telescope and do some observing.
http://nightsky.jpl.nasa.gov/
Discuss presentation and goals of hands-on the telescope time with amateur astronomer. If possible, you'll want them to set-up the telescope outdoors for some actual observing.

Tape a cutout 'X' onto the top of the light bulb. (see diagram #1) Post targets around room for Station 3. Position a chair, with a clamp lamp attached, about 12" – 16" away from a nearby wall where you have posted some chart paper. Test out reflecting the image of the light bulb onto the chart paper and focusing it onto the piece of grid paper, adjust the distance of the light source to the wall. (see diagram #1) Place a piece of chart paper at each of the three stations.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

Galileo first used his telescope to explore the heavens in 1609. Galileo's telescope and all optical telescopes that have been constructed since are collectors of light - or photons, the light carriers. The light coming from astronomical objects, and then collected by our telescopes is the only way we are able to learn about these extremely distant objects.

Before you begin, separate all of the participants into 3 separate groups so that each group will begin at one of the three stations, and rotate every 20 minutes to the next, until all participants have made it to all three stations.

Station #1 – Amateur Astronomer lead Hands-on a Telescope

1. Amateur Astronomer leads youth through a presentation on the various parts of a telescope.

2. Ideally, the telescope can be set-up outdoors so that some actual observing can be done; the moon may be a good target to focus on, if it is up during the late afternoon. Record findings/questions on the chart paper.

Station #2 – Modeling MicroObservatory Telescopes (to be facilitated by assistants and/or after-school professional)

1. First, explain to the youth that we will construct a model of a telescope and its inner workings. Hold up and have youth identify each part, the aperture, mirror, shutter, and detector.

2. Demonstrate briefly how to use the mirror to reflect the light in different directions and find the point where the image comes into focus. Then hand the mirror to a youth participant.

3. Instruct the group to make an image of the light bulb on the detector. Allow them to play around for a while. If they need guidance, ask them if they can make the image on the wall.

4. Lead a discussion about this model of a telescope. Ask the participants what the model represents accurately, what it misrepresents, and what it leaves out. Record findings on the chart paper. In the discussion,

emphasize how this model closely resembles the process of our MicroObservatory telescopes collecting light and registering the light particles that reflect off of a mirror onto a detector. One major part that is left out is that there is no tube, which is a typical part of a telescope. A tube serves to keep all of the light from other areas of the room, or from other objects in space, from hitting the detector.

Station #3 – Reflecting and focusing laser light

1. Present the challenge of positioning 1 mirror in front of the laser in order to have the laser beam hit the target. They should be limited to where they are able to place the mirror. (See diagram #2 for a possible setup for the challenge)

2. After they hit the target with 1 mirror, add another mirror and have them do it again.

3. Have them trace the path of the laser beam from the laser to the target on the chart paper, which should be beneath the setup. What can they say about the angles and the path of light as it reflects off the mirrors? They should be able to see that the angle of reflection is equal the angle of incidence.

4. Once they get the idea that the angles are equal, move the lasers and mirrors as shown in diagram #3. Make sure to put a new piece of chart paper under the setup so they are able to trace the new paths.

5. Have the youth move the 3 mirrors so each one reflects a laser back to the target that is set up behind the 3 lasers, this is called the focal point. Have the youth trace both the path of light, as well as the curve between the 3 mirrors.

6. They should notice the slight curved path that the mirrors take. Bring out a make-up mirror and/or an image of a large curved primary mirror of a telescope.

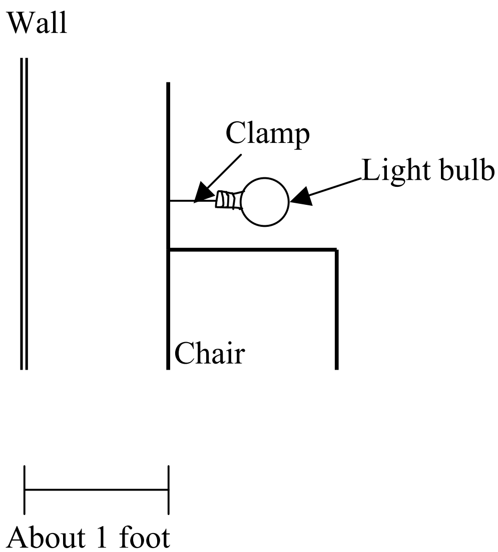
Debrief:

Lead a discussion with all of the participants using the chart paper as a guide. Ask them what they found out at each of the three stations. Record any important questions that come up as well.

Diagrams for station set-up:

Diagram #1: Light bulb setup for station #2

Side view of setup



Front view of light bulb

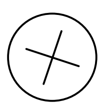


Diagram #2: Table for station #3

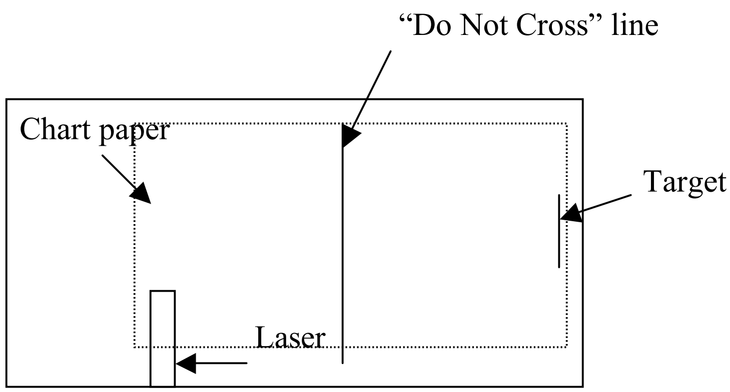
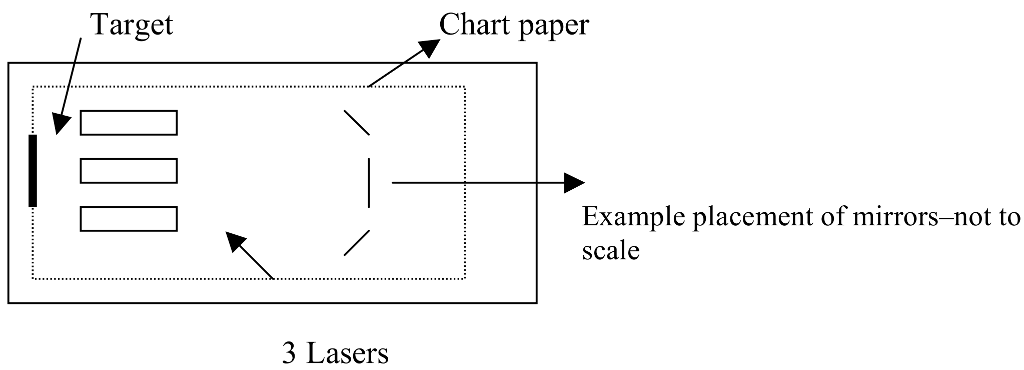


Diagram #3: Table for station #3



Follow up

Visit a real astronomical observatory if possible! A nearby observatory can be located at: http://www.skyandtelescope.com/community/organizations.

Watch out for…

- ❑ Be sure to tell the participants that shining a laser into their eye or another's eye can destroy their retina, and therefore be very dangerous to their visual health. Also when around telescopes, participants should be aware of their actions and encouraged to act accordingly, to prevent any destruction to the telescopes.

- ❑ When viewing through a telescope, magnifying glass, or microscope, the apparent size of the object being observed appears larger than it would appear with our eyes alone. This effect is magnification. An instrument may also have negative magnification. The peephole in a door or a rearview mirror on a car are both examples of optics that make objects appear smaller.

- ❑ An optical system's resolution is a measure of the smallest detail it is able to resolve. An instrument through which one can see the stitches on a baseball from some distance away would be said to have greater resolution than another through which one can only see the shape of the baseball. Counter intuitively; this attribute is independent of magnification. Two different telescopes may be pointed at the same object at the same magnification, however the one with greater resolution will present a "sharper" image than the "blurrier" picture offered by the other.

Vocabulary

color filter: A sheet of dyed glass, gelatin or plastic, or dyed gelatin cemented between glass plates, used in photography to absorb certain colors and transmit others. The filters used for color separation by MicroObservatory are red, green and blue (RGB).

in-focus: The state of maximum distinctness or clarity of such an image.

model: A generalized picture, analogy, or simplified explanation of reality

aperture: A usually adjustable opening in an optical instrument, such as a camera or telescope, that limits the amount of light passing through a lens or onto a mirror.

detector: A device used to show that something is present.

optics: The branch of physics that deals with light and vision, chiefly the generation, propagation, and detection of electromagnetic radiation having wavelengths greater than x-rays and shorter than microwaves.

reflection: The reflection of light follows certain definite laws. A ray of light striking a reflecting surface at right angles to it is returned directly along the path it has followed in reaching the surface. When, however, a ray strikes a reflecting surface at any other angle, it is reflected at an angle in an opposite direction.

focal plane: The imaginary plane perpendicular to the path of light passing through a lens or mirror where an image can be projected at its sharpest focus. For astronomical objects, it is one focal length away from the optical element.

focal point: Two parallel beams of light passing through a lens or reflecting from a curved mirror come together at a "focal point." The distance between the focal point and the lens or mirror is its focal length.

Useful Websites

The Science of Light: Light is everywhere in our world. We need it to see: it carries information from the world to our eyes and brains. Seeing colors and shapes is second nature to us, yet light is a perplexing phenomenon when we study it more closely.
http://www.learner.org/teacherslab/science/light/

Light and Color: A more technical background on light and color
http://www.fi.edu/color/

Reflection: A website with good background information on reflection and mirrors:
http://hyperphysics.phy-astr.gsu.edu/Hbase/phyopt/reflectcon.html#c1

Nightsky Network: Get updated on the wonders of the universe and hear what Astronomy clubs have to say about it!
http://nightsky.jpl.nasa.gov/

Sky & Telescope: Sky & Telescope Magazine offers a free online search utility to locate nearby observatories and astronomy clubs.
http://www.skyandtelescope.com/community/organizations

Astropoetry

Goals

- Practice making observations while creatively putting together a poem based on an astronomical object

Activity Overview

In this activity the participants are to write down as many words as possible describing an astronomical object in an image. The words should be adjectives, nouns, adverbs and verbs and be written onto small slips of paper. The slips of paper are then creatively arranged into the structure of a poem.

Background

This activity encourages the youth to look closely at astronomical images and use their imagination to create astropoetry! The act of looking at these images, and beginning to say something about the astronomical objects in the images, reinforces the first step in the image/data analysis process. Strengthening the participants' image analysis abilities is crucial when progressing into the observing project activities. Some examples of astropoetry are included at the end of this write-up.

Preparation

Space Required: Large room/discussion space

Materials:

- Several Hubble images of various astronomical objects (refer to the appendix for examples). It may be useful to use images that are objects used as part of the Tour of the Universe activity if you are planning on facilitating that activity as a follow-up.
- Chart paper
- Markers
- Slips of scrap paper, notecards, or post-it notes
- Tape

Preparation time: 🕐

Activity time: 20 minutes

Gathering of materials and final preparations:

Prior to leading this activity, you should have assembled all of the necessary materials, and you will want to have set up the chart paper in the front of the room for taking down the items as the group brainstorms. (If possible, the lists that the participants generate should be left up or should be recorded and given to the participants to keep as the course progresses.) And you should have your example items that have astronomical words in the name to start off the brainstorming.

Procedure

Discussion lead-in:

Explain to the participants that by looking closely at some images of astronomical objects, and using their imaginations, they will now create astropoetry! First model the process by providing an example. Hold up an image and say a few descriptive words that come to mind. Jot these words down on the slips of paper, and then explain that after the pairs of participants come up with about 30 words, they can then begin piecing together their poem.

Creating Astropoetry

1. Break the youth up into pairs, and distribute the astronomical images, markers, and slips of paper; hold off on providing the chart paper so that they do not rush through the activity before having 30 sufficient words.

2. Instruct participants to closely examine their image and write down on the slips of paper words that describe the image, and possibly what it reminds them of (e.g. marble, pancake, hula hoop). Mention that they should try and come up with not just adjectives such as bright, shiny, but nouns, adverbs, and verbs. Remind them to write down only one word per piece of paper or notecard.

3. Once they have 30 words on the slips of paper, have the youth arrange the words into a poem in any manner they like. Let them know that it is perfectly acceptable to add words such as: it, the, as, etc… to complete their sentences or phrases.

4. When the pairs have their words arranged into a poem that they are happy with, have them transfer the poem onto the piece of chart paper.

5. Tape the image onto the chart paper, be sure the youth have titled their poem and added their names and hang them somewhere in the room.

Sharing the Poems

Have the pairs recite their poems to the group. Participants should practice good oral presentation skill when they present their poems—speaking slowly, loudly, clearly, and not fidgeting or swaying. Often poems are read twice; have the partner read the poem through the second time.

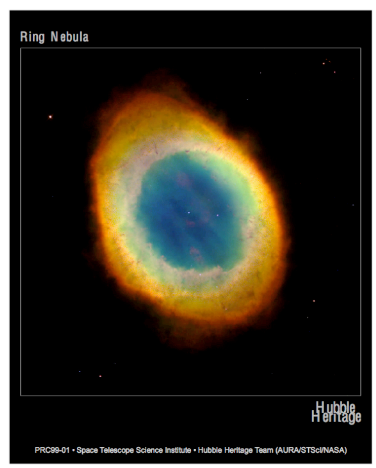
Follow up

This activity can be typed up and included as a part of the second or third observing project by some of the pairs if the image they chose relates to their project. Otherwise the activity can be done again with an image that the youth have taken or are using for their observing project. This activity can be done many times over the course of the program independently of other activities.

Watch out for…

- ❑ Encourage both participants in a pairing to be hands-on when arranging the words into the poem. Also, inform the youth that they will be sharing their poems in front of the group. If you feel as though some groups may be hesitant to do so, break the youth into smaller groups when it comes time to share the poems. However, they should still work on the good presentation skills.

Examples of Astropoetry



Dumbbell Nebula

Spreading new and old stars are dying and forming in an evolving in a bright dust
An outcast and illuminating oddball of white light is in a field of midnight blue dots
Remaining dots of light shout from clustered butterfly and crab images in outer space

Antennae Galaxy

A magnificent, bright, red, fireball-like heart is moving
An exploding fuzzy dark aura of dust is expanding
Morphing blue and yellow fire are colliding to be an origin of stars
An evil shrimp is born

Tour of the Universe

Goals

- ❑ Gain a solid understanding of where objects in our Universe are located relative to us (Earth)
- ❑ Recognize different objects in the universe and learn that they are organized into a "nested" structure
- ❑ Gain an appreciation for the huge distances between our solar system and the rest of the universe

Activity Overview

Discuss the different kinds of objects in the Universe that your group may have heard of or be familiar with. Give small groups the sets of thumbnail cards with pictures of objects in the Universe and ask them to try and place them on the "map" of the Milky Way. Wrap up activity with a debrief.

Background:

Many people often confuse the terms Solar System, Milky Way Galaxy, and Universe. They do not have a sense of scale about these entities. This session should help them realize the relationship between these very different objects, in terms of size, scale, and age.

Participants should also come to realize that our Universe is organized in to nested galaxies divided by vast distances of empty space.

The Speed of Light

The fastest thing that we know of is light which travels at a speed of 186,000 miles per second (or 300,000 kilometers per second) in empty space. To get an idea of how fast this is, light can travel about 7 times around Earth in one second! Astronomers use the speed of light to measure how far away things are in space. They use a unit called the light-year. A light-year (ly) is the distance that light can travel in one year. This is a really large distance: in 1 year light travels about 5,880,000,000,000 miles (yes, almost 6 trillion miles.). So, this distance is 1 light-year. For example, the nearest star to the Sun is about 4.3 light-years away. Our galaxy, the Milky Way, is about 100,000 light-years across, and the nearest large galaxy, Andromeda, is 2.3 million light-years away. This means it would take 2.3 billion years for the light from Andromeda to reach us here on earth. So when we look at this light, we are looking at what Andromeda looked like 2.3 billion years ago!

How to Measure Distances in the Universe

Within the solar system, distances can still be measured in miles or kilometers though you need to deal with pretty big numbers. For example, the average distance of the Earth from the Sun is about 93 million miles. The average distance of Pluto from the Sun is about 3.7 billion miles: can we even grasp such a number? To help dealing with these huge numbers, astronomers use a unit called Astronomical Unit (AU) to measure distances in the Solar System. 1 AU is the average distance between the Sun and the Earth. Using this unit, the average distance between Jupiter and the Sun is about 5 AU and the average distance between Pluto and the Sun is about 40 AU. Ok, but what happens as we move outside the Solar System? The closest stars, Alpha Centauri and Proxima Centauri, are about 24,000 billion miles away or 6,000 AU. Clearly the AU is not a useful unit to measure distances to the stars either. What to do then? One of the units used by astronomers to measure the great distances in the Universe is based on the speed of light.

If we use the speed of light to measure distances in the solar system we can find out that it takes 8 minutes for the light to travel from the Sun to the Earth (the Earth is 8 light-minutes away from the Sun) and it takes 5 hours and 20 minutes for light to travel from the Sun to Pluto.

Also, the poster of the Milky Way is not a real image. The earth is located in the Solar System that is part of the Milky Way galaxy. We are inside the galaxy itself. Based on the pictures we are able to take of other galaxies this image has been digitally created to best represent what scientists think our galaxy really looks like.

Preparation

Space Required:

A room with table or desk space and chairs for all of your participants to work in small groups. Each group should be able to easily share a set of cards.

Materials:

- ❑ Objects in the Universe image cards with description on back - one set for each group of participants
- ❑ Objects in the Universe thumbnail image cards - one set for each group of participants
- ❑ One Milky Way poster per group
- ❑ Chart paper for brainstorming
- ❑ Markers/pens for recording

Preparation time: 🕐🕐🕐 (prepare cards, review activity procedure and background information)

Activity time: 45 minutes

General activity description:

This activity is intended to help participants understand the types of objects in the Universe, from more familiar objects in our Solar System to the much more mysterious ones connected with black holes.

Gathering of materials and final preparations:

Prepare sets of the image/description cards so there is at least one set for every 3 participants (image/description cards can be printed from TourUniverseCards.pdf found in the appendix section.)

Prepare sets of the thumbnail image cards so there is at least one set for every 3 participants (thumbnail image cards can be printed from TourUniverseThumbCards.pdf found in the appendix section).

Make sure each group has a poster size map of the Milky Way to use with the thumbnail cards (Milky Way poster can be printed from milkyway.pdf found in the appendix section).

Even when scaled down the distances between objects in space are still extremely large. To be sure you do not run out of room while doing this activity, you may need to make sure you have enough room by finding where the furthest astronomical object would go according to your scale.

In this activity you will use a unit to measure distance called light year. What is a light-year? Read some of the background information on the light-year as a unit of measurement at:

http://school.discovery.com/schooladventures/universe/itsawesome/lightyears/
http://starchild.gsfc.nasa.gov/docs/StarChild/questions/question19.html

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

Explain to the group that they are going to take a tour of the Universe. Ask participants to name some of the astronomical objects that they know. Take a number of responses and write them down on a blackboard.

Using the list that you generated with your participants, ask which of the objects is

- Inside our Universe?
- Outside our Solar System but inside our Galaxy (the Milky Way)?
- Outside our Galaxy?

Take a number of responses and write them down on a blackboard.

Modeling

1. Give participants the thumbnail image cards. Give a poster of the Milky Way to each group, to be placed either on a table or on the floor. Ask the participants to place the thumbnail cards on the poster at reasonable locations that they think the objects on the cards would be in the Universe.

2. Now give them the Tour of the Universe description cards. Explain that they will read the cards loud to their peers and fill in the table regarding what they hear and learn.

3. Have participants record each object in the appropriate category: Nearby (within the Solar System); Far (outside of the Solar System but within our Milky Way Galaxy); and Really Far (outside of the Milky Way)

4. Tell participants they should write down descriptive words and observations on chart paper, record distances to each object and their relative sizes (if known).

5. Now instruct the participants to revise the locations of the objects on the poster using the scale bar in the bottom corner of the milky way poster print out.

Debrief

You may want to return to the list the group generated during the introductory discussion, and ask participants if any of the objects they named then were on the tour and if any of their earlier estimates of location have now changed.

Revisit the predictions made by the group in the initial discussion and ask participants to reflect on the following questions:

- ❑ What are all of the astronomical objects that you are now aware of?
- ❑ What are their characteristics?
- ❑ Did anything surprise you?
- ❑ Galaxies are very far from each other. What is between them?

Follow up

Ask participants for their general reactions to the tour and the different images. What did they like the most? Did anything surprise them? Do they have any thoughts about the different ways that visible light can reveal information?

Let participants know that these are just a few examples of a vast wealth of astronomical images that have been gathered in recent years. Many of them are now available on NASA web sites.

Point out that the ability to place telescopes and other instruments on satellites in space has allowed people to “see” into the Universe as never before.

If you are working with high school students this can be a good time to get familiar with the units used to measure distances in the Universe.

Watch out for...

- ❑ The scale used on the Milky Way print out may not be suitable for the space available when doing this activity. Be sure that when you create your own scale, you remark the distances to all the objects in the activity accordingly
- ❑ Participants may say that they have no idea where on the Milky Way Map they should put most of the images. That’s fine. Encourage them to reflect on the kind of objects they are looking at (Is it a planet? Is it a star? Is it a galaxy?). Then encourage participants to put the images where **they think** they might go.
- ❑ Middle school students may be confused with the size and structure of the entire Universe. The concepts that they can handle are the distances and locations of these objects relative to Earth, so the distances in the entire Universe may be far too vast for their minds to conceptualize. When you set up the posters you could make little post-its for near, far, and very far and place them on the poster in the

regions as defined above so the participants do not struggle with the meaning of the very far distances.

- ❑ When introducing the map of the Milky Way make sure to remind the participants that the map is a "cartoon", not a real image. The Earth is located in the Solar System that is part of the Milky Way galaxy. We are inside the galaxy so we cannot take a picture of the Milky Way from outside the galaxy itself. We can however take pictures of other galaxies that we think are similar to the Milky Way. This is why we can make a drawing of our own galaxy.
- ❑ Participants should learn to be careful about how they refer to objects in the Universe. By the end of this activity, participants should have a clear understanding that:
  - The Solar System is *inside* our home galaxy, called the Milky Way galaxy.
  - The Milky Way galaxy is inside the Universe.
- ❑ Distances are measured very differently within these three spaces: Distances across our Solar System may be measured in millions or billions of kilometers or miles. Usually they are measured in Astronomical Units or AU. 1 AU is the average distance between the Earth and the Sun (it is equal to about 150 million kilometers or 93 million miles).
- ❑ Distances across our galaxy and throughout the Universe are typically measured in light-years—the distance light travels in one year at its fantastic speed of 300,000 km/sec (186,000 mi/sec!). 1 light-year is equal to 63,240 AU or 9,460,000 million kilometers or about 6 trillion miles.
- ❑ As participants explore the vastness of these nearby galaxies, the question of what lays between our planet and other astronomical objects may arise. Allow for their questions to open up discussion on these topics. This will help you approach the preexisting ideas which participants may have as you provide them with the correct information to help support their ideas or guide them towards the right concepts. This link may be helpful for modeling the size and scale of the universe:
  http://cfa-www.harvard.edu/seuforum/howfar/index.html

Vocabulary

billion: The cardinal number equal to 10^9, or a one with nine zeroes after it.

black hole: A region of space resulting from the collapse of a star with a gravitational pull so strong that from a certain distance, not even light can escape it.

Cat's Eye Nebula: Three thousand light-years away, the Cat's Eye Nebula is a dying star throwing off shells of glowing gas.
Centaurus A: This galaxy is situated in the M83 group of galaxies. It is one of the most interesting and peculiar galaxies in the sky. It is of intermediate type between elliptical and disk (spiral) galaxies: the main body has all characteristics of a large elliptical, but a pronounced dust belt is superimposed well over the center, forming a disk plane around this galaxy.
Crab Nebula: The Crab Nebula is the most famous and conspicuous known supernova remnant, a cloud of gas created in the explosion of a star as supernova.
Galaxy: Any of many very large groups of stars, gas, and dust that constitute the Universe, containing an average of 100 billion (1011) stars and ranging in diameter from 1,500 to 300,000 light-years.
M51 Galaxy: Also known as the Whirlpool Galaxy, M51 is a classic spiral galaxy. At only 30 million light years distant and fully 60 thousand light years across, M51 is one of the brightest and most picturesque galaxies on the sky.
M15 Globular Cluster: M15 is perhaps the densest of all (globular) star clusters in our Milky Way galaxy. The Hubble Space Telescope has photographically resolved its super dense core, as shown in this HST image.
globular cluster: A system of stars, generally smaller in size than a galaxy, that is more or less globular (like a globe) in shape.
Great Nebula in Orion: The Nebula's glowing gas surrounds hot young stars at the edge of an immense interstellar molecular cloud only 1500 light-years away. The Great Nebula in Orion can be found with the unaided eye just below and to the left of the easily identifiable belt of three stars in the popular constellation Orion.
Jupiter: Jupiter is the fifth planet from the Sun and by far the largest. Jupiter is more than twice as massive as all the other planets combined (the mass of Jupiter is 318 times that of Earth). Jupiter is composed of mostly hydrogen and helium gas.
Light-year: The distance that light travels in one year.
Milky Way Galaxy: The galaxy containing our Solar System, visible as a broad band of faint light in the night sky.
million: The number equal to 106, or a one with six zeroes after it.
The Moon : The natural satellite of Earth
nebula: A diffuse mass of interstellar dust or gas or both. A nebula can be visible as luminous patches or areas of darkness depending on the way the dust and gas absorbs or reflects light given off either inside or outside the cloud.
Sun: A star that is the basis of the solar system and that sustains life on Earth, being the source of heat and light.

Supernova 1987A: In 1987 a supernova (designated SN1987A by astronomers) was observed in a nearby galaxy called the Large Magellanic Cloud. This was the first "nearby" supernova in the last 3 centuries, and for the first time astronomers were able to directly observe the incredible light show.
supernova: A rare celestial phenomenon involving the explosion of most of a star, resulting in an extremely bright, short-lived object that gives off huge amounts of energy.
Universe: All matter and energy, including the earth, the galaxies, and the contents of intergalactic space, regarded as a whole.
The Early Universe: Galaxies like colorful pieces of candy fill the Hubble Deep Field image - humanity's most distant yet optical view of the Universe. The dimmest, some as faint as 30th magnitude (about four billion times fainter than stars visible to the unaided eye), are the most distant galaxies and represent what the Universe looked like in the extreme past, perhaps less than one billion years after the Big Bang.
To make the Deep Field image, astronomers selected an uncluttered area of the sky in the constellation Ursa Major (the Big Bear) and pointed the Hubble Space Telescope at a single spot for 10 days accumulating and combining many separate exposures. With each additional exposure, fainter objects were revealed. The final result can be used to explore the mysteries of galaxy evolution and the infant Universe.

Useful Websites

How Big is the Universe: An exploration through space and time.
http://cfa-www.harvard.edu/seuforum/howfar/

Journey to the Beginning of Time: This interactive presentation uses a series of hands-on demonstrations to model the size and scale of the universe using everyday objects.
http://cfa-www.harvard.edu/seuforum/einstein/resources_ed.htm#pres

The Hubble Space Telescope: Time Machine to the Galaxies:
http://amazing-space.stsci.edu/news/ and then search for the article in the News Archive

A Question of Scale: A tour of the Universe from the infinitively small to the infinitively big:
http://www.wordwizz.com/pwrsof10.htm

An Ancient Universe: How Astronomers Know the Vast Scale of Cosmic Time: An overview on the universe, the process of science, the changing universe and more. From “the Universe in the Classroom” an electronic educational newsletter for teachers, youth group leaders,

librarians, and anybody else who wants to help children of all ages learn more about the wonders of the universe:
http://www.astrosociety.org

Group Portrait of the Universe: Taking Images

Adapted with permission from *From the Ground Up!*

Goals

- ❑ Take images and gather information needed to accomplish the "group portrait" task using the MO interface

Activity Overview

Similar to "Group Portrait of the Solar System," participants will be distributed into pairs or small working groups to create a collection of images of different celestial objects outside our Solar System.

Background

The Universe possesses interesting features we can image through a telescope far outside our Solar System. Many of the iconic astronomy images we see in our media are of objects nowhere near home. In 1771, the astronomer Charles Messier published a list of objects that became known as the "Messier Catalog." The Messier Catalog was the first widely distributed list of "deep sky objects" – objects in the sky, other than stars, that are not part of our own solar system. While other more exhaustive catalogs have been published, such as the New General Catalog (NGC), both professional astronomers and hobbyists often still refer to many of the brighter nebulae and galaxies in the sky by their "M Number."

Preparation

Space Required: Computer Lab

Materials:

- ❑ A computer every one or two participants
- ❑ A copy of Quick-Guide to Settings for the Telescope per participant
- ❑ A copy of Observation Log Sheets per participant

Preparation time:

Activity time: 30 minutes

Gathering of materials and final preparations:

Make copies of the Quick-Guide to Settings for the Telescope. Make copies of the Observation Log Sheet for all participants

A few days before facilitating this activity take images of stars, nebulae and galaxies using the MicroObservatory telescopes. To do so:

- ❑ First check which stars, nebulae and galaxies are visible at each site in this period of the year. To do so use the "What's Up" link on the MicroObservatory web page.
- ❑ Refer to the Quick-Guide to Settings for the Telescope to use the correct exposure time and filter.
- ❑ Check your images before this session. You can then encourage participants to refer to your images and the settings you used to get good images for their investigation.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during the activity.

Procedure

Discussion lead-in:

Brainstorm a list of objects in the universe that can be viewed with a telescope. You can refer back to the "Tour of the Universe" Participant Worksheet for help.

As participants mention different objects, ask them what they know about them. For example you can ask:

What is a planet?
What is a star?
What is a nebula?
What is a galaxy?
How far away are these things, relatively speaking?
What do you think they would look like in the telescope?
Which ones can we see without the aid of a telescope?
How could we group the objects?

Participants, who may already be familiar with putting together a portrait of the Solar System, will now plan an observation campaign to create a portrait of the universe.

Form groups

Three participants should go to each group. Each person in the group will be responsible to take images of a star or star cluster, a nebula, and a galaxy. Each group will have to come to a consensus on which objects to observe and these have to be different for each member of the group.

Plan observations

1. To plan the time of their observations, participants check when their targets are visible at each site using the "What's Up" link on the MicroObservatory web page. If time is short, you can prepare a list of targets that are visible in this period of the year with rising and setting times. Make sure participants understand how the time is given in the tables. For example: 13:00 is 1 PM and 22:00 is 10 PM.
2. Participants use the MicroObservatory Image Archive Directory (click on "Get Images"; the link to the Archive is right in front of you) to look for good images of their targets. They check the settings used to take those images by clicking on "Image Info" and take note of them.

Take images

Participants are now ready to take images of their targets. Make sure they record the settings used in their observations in the Observation Log Sheet.

Follow up

When the images have been taken, print them out and try creating a "group portrait" of the Universe. In a group portrait of people, the tallest are usually in the back. In your group portrait of the Universe, try arranging your images from the closest to the furthest object. Or from the youngest to the oldest. Or from the smallest to the largest. Ask the group how else they could be organized.

Watch out for...

- ❑ Sometimes participants can become discouraged with the resulting images. When taking pictures of galaxies or nebulae, it is almost always necessary to apply some of the image processing techniques learned in the computer activities to achieve a presentable final product.

Vocabulary

galaxy: A large assemblage of stars and interstellar gas and dust, typically containing millions to hundreds of billions of member stars. A galaxy is held together by the gravitational attraction of all its member stars (and other material) on one another. Most galaxies are either of a flattened, spiral form or a fatter ellipsoidal shape without a spiral pattern. The "Milky Way" galaxy, of which our Sun is a part, is a spiral galaxy with a disk about 100,000 light-years across containing roughly 400 billion stars. Our Sun is in the disk, about 2/3 of the way out from the center, and orbits around the center for the Milky way taking about 200 million years to go around.

nebula: A diffuse mass of interstellar dust or gas, or both. A nebula can be visible as luminous patches or areas of darkness depending on the way the dust and gas absorbs or reflects light given off either inside or outside the cloud.

star cluster: A group of stars which are held together by their mutual gravitational attraction. In the Milky Way, there are two different kinds of star of star clusters: ones called "open" (or "galactic") star clusters which are generally sparsely populated and exist only in the disk of the Galaxy, and the larger, older "globular" clusters.

Useful Websites

How Astronomers Know the Vast Scale of Cosmic Time:

http://www.astrosociety.org/education/publications/tnl/56/index.html

An overview on the Universe, the process of science, the changing universe and more. From "The Universe in the Classroom" an electronic educational newsletter for teachers, youth group leaders, librarians, and anybody else who wants to help children of all ages learn more about the wonders of the universe.

Group Portrait of the Universe:
Making Sense of the Images

Reprinted and adapted with permission from From the Ground Up!

Goals

- To create "a portrait of the universe" and use it to develop expand ideas about objects in the universe
- Learn that relative size of an object in an image contains information about both how large it is and how far it is

Activity Overview

Participants will work in groups of 3 or 4 to examine the images they took to create a portrait of the universe. The activity leader will facilitate a general discussion for each of three categories: "Stars and Star Clusters," "Nebulae' and "Galaxies." In addition, this activity is designed to specifically help participants realize that everything we know about the universe comes from studying and interpreting the light that comes to us from space. It is also designed to help participants come to the understanding that science is the art of asking questions as well as answering questions.

Background

You created a portrait of the universe by taking images of many different objects you can find in the night sky. Your images are a snapshot in time. But the "cosmic cast of characters" that you have assembled is part of the ongoing story of the universe. What kinds of stories do your images tell? What kinds of questions do they raise for you?

Preparation

Space Required: Computer lab

Materials:

- A set of images for each group taken in previous computer activities
- Chart paper
- Markers/pens Stuff

Preparation time: 🕐

Activity time: 30-45 minutes

Gathering of materials and final preparations:

Print images taken by the participants in the last several days. Organize them in 3 categories:

1. Stars and Star Clusters
2. Nebulae
3. Galaxies

Use as many images taken by the participants them selves. If participants do not have images for all three categories, they may simply use images from the archive section found on the MicroObservatory web page by going to "Get Images>Image Archive>Nebulae"

Print an image of the full moon for each group. Make enough copies of the images so that each group of 3-4 participants has one full set of images. For each set, clip together the images in each category and label each group of images appropriately.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

This activity is conducted as an extended discussion. After assembling many images to create "A Portrait of the Universe" it is now time to analyze these images and investigate the following questions:

Overview Questions

How do we get information from these objects?
All of the information we have gathered about objects in space is a direct result of studying the light from that object.

How is light important to scientists' investigations of outer space?
By studying the light from our near by and far away stars, we are able to learn about objects in space that emit their own light.

What does light tell us about objects in space?
Through studying light we can learn about the gases that make up an object, whether or not the object is moving towards us or away from us, the age of an object and much, much more.

Distribute to each group a set of images. Reexamine the notes you took at the beginning of the “A Portrait of the Universe” activity and then invite the participants to answer selected questions on chart paper. Choose 1 or 2 questions for each category or have different groups answer different questions. Participants will work in groups of 3 or 4 to examine the images.

Making sense of the images - Stars and Star Clusters

Participants will first examine images under the “Stars and Star Clusters” category. Give participants 5 minutes to examine the images then facilitate a discussion by asking some of the following questions:

Why do the stars appear as tiny dots?
Almost all stars are so far away that they appear as dots even in the most powerful telescopes — even the Hubble Space Telescope! (Only one of the closest large stars—Betelgeuse in the constellation Orion—has been resolved into a tiny, almost featureless disk.)

Then why are some of the dots wider than others? Are those stars larger?
No. If stars could be imaged exactly, then EVERY star would be less than 1 pixel wide, because they're so far away. But because the telescope is an imperfect machine, the stars get imaged into disks. The largest dots correspond to the BRIGHTEST stars, not the largest stars.

Could I ever see planets around those distant stars, using the telescope? Why? Why not?
Planets around distant stars are so faint and so small that no telescope in the world can yet image them. However there are indirect ways of telling they are there.

Do the stars emit their own light, or are they reflecting light from some other source, like the Moon?
Stars emit their own light, the same as our Sun, the closest star. In ancient times, people thought the stars were on a giant sphere, all at the same distance from Earth.

Do you think that the stars are all the same distance from Earth? Can you tell anything about their distance just by looking at your images?

The stars are at different distances from Earth, but you can't tell that just by looking at your images. Some stars look dimmer than others so they SEEM further away. It may be that those stars are inherently dimmer. Recall, for example, that a 15-watt bulb close by can appear as bright as a 100-watt bulb at a greater distance.

What would it look like if you lived near the center of one of the globular clusters of stars?
There would be so many nearby stars that the sky might never get dark at night.

Making sense of the images – Nebulae

Participants will then examine images under the "Nebulae" category. Give participants 5 minutes to examine the images then facilitate a discussion by asking (some of) the following questions:

How do the nebulae in your images compare in size to the Moon's image taken by MicroObservatory?
The Orion nebula and others may be as large as, even larger than, the width of the Moon.

If the nebula appears as large as the Moon, then why don't we see it in the night sky?
It's too faint. Many beautiful objects in the sky — such as nebulae and galaxies—would be large enough to see with our naked eye, if only they weren't so dim! And why are these objects so dim? Because they are so far away! The telescope aids us by gathering light from these dim objects in a way our eyes can not.

How does your exposure time for the nebula compare to the exposure time for the Moon?
The nebula takes a longer exposure time, because it is so faint. And not only is the Moon's exposure so short, you also need a deep gray filter to cut down even more of the Moon's light, to avoid overexposure!

Tough one: Does the nebula in your image glow with its own light, or reflected light?
Some nebulae emit their own light, while some we see only because they reflect light from nearby stars.

Why do you think there are so few nebulae compared to stars?
Nebulae are scenes from either the birth or death of stars. These processes take relatively little time, compared to the lifetime of a star. In fact, one of the ways astronomers can tell how long the stars live is through

comparing the number of stars they see to the number of star births and star deaths they see.

Making sense of the images – Galaxies

Finally participants will examine images under the "Galaxies" category. Give participants 5 minutes to examine the images then facilitate a discussion by asking (some of) the following questions:

Does your galaxy image also contain stars in the field of view?
Most galaxy images should also contain stars in the field of view.

Which do you think is further away, the galaxy or the stars? Can you tell from your image?
Many participants may think the stars are further away, because they appear smaller. But all the stars we see with the telescope are in our own Milky Way galaxy. They are MUCH closer than the galaxies in the image. However you cannot tell this just from looking at an image. A century ago, even the world's greatest astronomers were debating whether the galaxies were inside or outside our own Milky Way.

If the galaxies are further away than stars in our own galaxy, then why do they appear so large?
Each galaxy is an enormous collection of billions stars, as is our own Milky Way galaxy. It took additional information, beyond the actual images, for astronomers to conclude that galaxies are huge collections of stars.

Why can't I see the individual stars in the galaxies that I've imaged?
Because stars in other galaxies are so far away, they look like points of light of varying brightness. Large telescopes can separate the individual points of light from each other, but in the case of telescopes with small apertures, as for MicroObservatory, that is not possible. At the scale of your image, a star would be a point of light smaller than a single atom! It is truly amazing that the combined light of the stars can form the beautiful galaxy images you have created.

Why do the galaxies have such different shapes?
The shapes depend on how the galaxies were formed, whether they have collided with other galaxies in the past, and also on what angle you are viewing them from.

When I look at a galaxy, am I looking at a place where other creatures live?
No one knows for sure!

Follow up

Have participants to bring out the best of the images they took for the portrait of the universe by using the MicroObservatory image processing software.

Watch out for...

- Make sure that participants understand that MicroObservatory telescope images are all taken at the same scale (or "magnification"). This is why they can learn about the relative size of an object with respect to another also imaged with MicroObservatory. The images contain information about how large objects are or how far they are.
- When using the image processing software to process these images, remind participants that they can adjust the brightness and contrast of the images they take, but must be careful when interpreting features of that image. Image processing should help us bring out the details in the image but should not be used to create "false features" that don't belong to the object in the image.
- Try to emphasize the importance of light. Participants should realize that everything we know about the universe comes from studying and interpreting the light that comes to us from space. This is true even for objects in space that do not emit their own light, but rather, reflect light from other objects, as our moon does.
- Do not get hung up on questions that do not directly pertain to the discussion.
- Let youth express their own thoughts before asking the provided previously suggested questions.

Vocabulary

field of view: The area of the sky visible through the telescope

galaxy: A large assemblage of stars (and sometimes interstellar gas and dust), typically containing millions to hundreds of billions of member stars. A galaxy is held together by the gravitational attraction of all its member stars (and other material) on one another. Most galaxies are either of a flattened, spiral form or a fatter ellipsoidal shape without a spiral pattern. The "Milky Way" galaxy, of which our Sun is a part, is a spiral galaxy with a disk about 100,000 light-years across containing roughly 400 billion stars. Our Sun is in the disk, about 2/3 of the way out from the center, and orbits around the center for the Milky way taking about 200 million years to go around

nebula: A cloud of gas and/or dust in interstellar space. (The word nebula in Latin means "cloud"; its plural is "nebulae.") Nebulae can make themselves apparent by glowing (as "emission nebulae"), by scattering light from stars within them (as "reflection nebulae"), or by blocking light from things behind them (as "obscuration nebulae"). Some nebulae are the birth place of stars (Orion Nebula for ex.) and other nebulae are what is left after the death of a star (Crab Nebula for ex.).

star cluster: A group of stars which are held together by their mutual gravitational attraction. In the Milky Way, there are two different kinds of star of star clusters: ones called "open" (or "galactic") star clusters which are generally sparsely populated and exist only in the disk of the Galaxy, and the larger, older "globular" clusters.

Useful Websites

The Messier Catalog: Beautiful images and related information of Star Clusters, Nebulae, and Galaxies:
http://www.seds.org/messier/

Astronomy Picture of the Day: Images by category. Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer:
http://antwrp.gsfc.nasa.gov/apod/lib/aptree.html

An Ancient Universe: How Astronomers Know the Vast Scale of Cosmic Time: An overview on the universe, the process of science, the changing universe and more. From “The Universe in the Classroom” an electronic educational newsletter for teachers, youth group leaders, librarians, and anybody else who wants to help children of all ages learn more about the wonders of the universe:
http://www.astrosociety.org/education/publications/tnl/56/index.html

Nightsky Network: Get updated on the wonders of the universe and hear what Astronomy clubs have to say about it:
http://nightsky.jpl.nasa.gov/

Light, Color, and Astronomy

Adapted with permission from Cosmic Questions Educator's Guide

Goals

- Learn that the continuous spectrum of visible light can be broken into the colors of the rainbow. Develop a personal understanding of the particle nature of light and its behavior
- Learn that filters allow light of its own color to go through while blocking all light of other color
- Experiment and discuss how the information we gather from an object changes when we look at an object through a color filter

Activity Overview

Break the participants into 3 groups that will each explore light and color filters at 3 different stations. At each station there will be a piece of chart paper for the youth to record their predictions and findings. These will help facilitate the discussion that follows.

Station #1, which you will lead, where you can use an overhead projector, or a computer projector, and a diffraction grating to separate visible light into its component colors, and show participants the components of visible light. The participants will predict, record and observe what happens to the different color bands in the "rainbow" on the screen when it is viewed through three different color-passing filters: red, green, and blue.

Station #2 will repeat the above exercise with the transparency of 3 overlapping circles or the overlapping circles image on a computer screen. Encourage participants to use the filters in combination as well as individually.

Station #3 has the participants experiment with three red, green and blue color-filtered flashlights and noticing the various colors produced with the different combinations. After visiting these stations, participants will realize that everything we know about the universe comes from studying and interpreting the light that comes to us from space.

Background:

What can light tell us about the universe? People tell stories. So does light. Astronomers are learning to translate the tales light brings us from deep space.

This activity introduces participants to the visible spectrum of light and then demonstrates what happens to an image when light of various amounts of energy, or colors of light, are blocked by filters or made visible using special tools. Astronomers study the spectra of stars to learn many things, including how hot or cold stars are, whether they are moving toward or away from us, and whether they have magnetic fields. Participants will also begin to develop an idea of the particle model of light, where small bundles, or particles of light travel. Because of this, the light particles can be blocked before reaching your eye, or the detector device on a telescope.

Preparation

Space Required: A large room that can be completely darkened

Materials:

- ❑ Overhead projector or LCD projector
- ❑ Diffraction grating one large, many smaller ones, enough for each participant to have one (optional)
- ❑ Cardboard for covering top and bottom portion of overhead projector screen
- ❑ Black marker
- ❑ Colored markers
- ❑ Paper for participants to draw what the spectrum as they see it
- ❑ Masking tape
- ❑ Whiteboard or large sheets of white paper
- ❑ Red, green, and blue color filters for each participant
- ❑ Transparency or Image of three-circle RGB color diagram up on a nearby computer to be casted by the LCD projector.
- ❑ Three red, green, & blue filtered maglites for station #3
- ❑ PowerPoint slide with a white slit on a black background
- ❑ Chart paper

Preparation time: 🕐 🕐 🕐

Activity time: 1 hour

Gathering of materials and final preparations:

Obtain a diffraction grating and a set of color filters.

A note about the diffraction grating:
It is recommended that you use a high-efficiency holographic diffraction grating. A more powerful grating (with more lines per millimeter) is preferred. We suggest 750 lines per millimeter, available from Learning Technologies, Inc or Rainbow Symphony, Inc.

Obtain a set of filters (red, green and blue), large enough to cover the entire diffraction grating, handy for you to use. Have also sets of smaller filters (but big enough to cover the eyeball) to hand out to each of your participants. It is recommended that you double up the filters to increase their efficiency.

A note about the filters:
It is recommended that you use the following filters:

- ❑ Red medium red ROSCOLUX #27
- ❑ Green dark yellow green ROSCOLUX #90
- ❑ Blue primary blue ROSCOLUX #74

There are other companies in addition to Roscolux that supply “Theatrical and Stage Lighting Equipment”. They will have different code numbers. Ask for pure color filters for science experiments.

Print the image of the three overlapping color circles on a transparency, or make preparations to have one of the stations at a computer with said image displayed. The image can be found in the appendix section of this curriculum.

Darken the room you will use as much as possible. Place the cardboard on the overhead projector so that there is a slit approximately 1 cm wide on the base plate of the projector. Turn on the projector lamp. Place the diffraction grating in front of the upper lens and rotate the grating until the spectrum appears on both sides of the projected slit on a large sheet of white paper on the wall, or a whiteboard. If you like, you can attach the diffraction grating to the lens with tape for the first part of this activity.

Find an object to look at through the filters that will look different through each of the colored filters. For example, a lit up red EXIT sign is a good object to look at through the filters because it is a brighter object than many other potential objects.

Place a piece of chart paper and markers at each station for the youth to record their findings. **Make sure to have this all prepared in advance, before your participants arrive.**

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

When your participants come in, have them pick up the small diffraction gratings on the tables and look around the room through them. Ask them what they notice. They will mention that when looking at the lights present in the room, they see a spectrum or rainbow. Explain to them that as a group we will explore and discuss light, colors of light, and filters. Break the participants into three groups, and instruct them to begin their explorations at one of the three stations.

Station #1 – Looking at the Light Spectrum with Diffraction Grating

1. Create a large projected white slit on a black screen with the overhead projector, or computer projector, and diffraction grating. With the overhead projector you can do this by placing 2 pieces of cardboard and inch apart over the blank screen. Create the light spectrum by placing the diffraction grating over the slit on your overhead screen or over the LCD projector lens. Ask participants to draw what they see on the chart paper.

2. Have the participants label the colors that they can identify in the spectrum with a black marker either on the whiteboard projection or on their chart paper.

3. Ask participants to predict what they think the spectrum will look like when viewed through a red filter. On their chart paper, have them draw their predicted spectrum as a group.

   NOTE to Facilitator: The blue filter is not as precise at selecting just the blue color as the red and green filters are. Because of this, the participants may report seeing some of the green color when looking through the filter. The green is close enough to the blue to be able to pass through the filter, and there is some overlap or blending of the colors. If you are using a non-perfect blue filter, it may be confusing to the participants. For that reason, you may not want to include the blue filter in this exercise.

4. Hand out filters once group has discussed predictions of what will be seen when they look through each filter.

5. Instruct the youth to place the red filter in front of their eyes and view the spectrum. Is it as participants predicted? Have them draw

the actual spectrum as seen through the filter. Be sure to start with the red filter, then green and lastly, blue. Repeat with blue and green filters & have them record their findings on the chart paper. (Use a new piece of chart paper for each group)

Station #2 - Three overlapping circles – red, green and blue

1. Project the diagram of overlapping red, blue, and green circles using a second projector, or simply bring up the image and display on a computer screen.

2. Ask participants to predict what the diagram will look like when viewed through different colored filters. What happens if you use two filters together?

3. Have participants describe everything they notice. They should also draw a picture of their findings.

4. Next, show the secret message PowerPoint which contains the secret message Hi on the slide with the message HELP. This can be done on the same computer screen as was just used.

5. Ask the participants which color filter allowed them to read the secret message, and why?

6. Next, if there is time, have the participants look at the EXIT sign if there is one nearby. Before they look at it through the filters, have them make predictions about what it will look like when viewed through the red filter, and then the green filter. **NOTE to Facilitator:** The blue filter is not very sensitive. Because of this, the participants may report seeing some of the green color when looking through the filter. The green is close enough to the blue to be able to pass through the filter, and there is some overlap or blending of the colors. Therefore, they may see some colors near to blue along the spectrum as well.

7. Have the participants explain in their own words what is going on. Record all of these findings on the chart paper.

Station #3 - Three Flashlights – One red, one blue, and one green

NOTE to Facilitator: be sure to focus the light properly so that the middle portion of each beam of light from the flashlight is solid (in other words, there is no darkness in the middle of the beam as it hits the paper)

1. Ask participants to do the following steps:

2. Combine red and green light so that the centers of the beams overlap. Have participants record what they notice.

3. Combine red and blue light so that the centers of the beams overlap. Have participants record what they notice.

4. Combine blue and green light so that the centers of the beams overlap. Have participants record what they notice.
5. Challenge: see if the youth can create "white" light!

6. Record findings on the chart paper.

7. Challenge #2: If there is time, have the youth begin drawing their model of how filters and the various color particles of light interact and reach your eye.

Discussion

Ask participants to reflect on their findings from each of the three stations. Go around to each group to see if there are any differences in their findings or questions. Point out any findings that seem problematic, and revise them as a group. Highlight the fact that filters simulate what it is like if you can only see part of the full spectrum. Be sure that the participants are able to describe in their own words what a filter is and how it works.

How could filters be useful in astronomy?
If youth are having difficulty answering this question, ask them if we are able to travel to the star we want to study, scoop up a sample of it, take it back to the lab and study it? Clearly not, and so, explain to them that astronomers study these objects by collecting their light with telescopes, and this is the only way they can get information about these objects.

Explain: Why light is so important when learning about astronomy?
The only way we are able to learn about the characters of the universe is by studying the light from that object.

Follow up

Try using the filters with photographs or other color images. If you wish, you may incorporate astronomical images.

Watch out for...

- ❑ Many participants will incorrectly predict that the red filter will "turn" the whole spectrum red, and likewise for the blue and green filters. This activity can help these participants understand the idea that the color is in the light, not the filter, and that the filters "subtract," or absorb certain colors of light, while letting other colors through.

- ❑ Color filters: students and adults alike often find filters confusing, because the terminology in common use is often inconsistent. In photography, for example, a red filter allows red light through, but an ultraviolet filter blocks—or filters out—ultraviolet light. Does a filter pass light or filter it out? For our activities, we recommend always denoting the function of the filter by using term red passing, green passing, etc.

- ❑ Some of the youth may be colorblind, so be sure to ask the youth if any of them are colorblind before you get started. If they are, let them know that they may experience the colors differently, but to still make predictions and report what they see, and that they will still be able to grasp how the filters function.

- ❑ Some of the youth may remember from an art class that the three primary colors are red, blue, and yellow. While these are primary colors when mixing paint for example, the primary colors of light are red, blue, and green.

- ❑ Make sure that participants develop a personal understanding about the particle nature of light and it's behavior.

- ❑ If you decide to use the blue filter for Station 2 be prepared to explain to the participants that they may see some of the light from the green and red circles.

Vocabulary

absorb: To retain (radiation or sound, for example) wholly, without reflection or transmission.
diffraction grating: An optical component that acts like a prism when it is illuminated with white light. A diffraction grating disperses a beam of light (or other electromagnetic radiation) into its wavelengths to produce its spectrum.
emit: To give or send out (matter or energy)
filter: A filter is a device that removes something from whatever passes through it. In optics a filter is a device, which selectively transmits light having certain properties (often, a particular range of colors), while blocking the remainder. They are commonly used in photography, in many optical instruments, and to color stage lighting.
spectrum: The distribution of energy emitted by a radiant source, as by an incandescent body, arranged in order of wavelengths.

Useful Websites

The Science of Light: Light is everywhere in our world. We need it to see: it carries information from the world to our eyes and brains. Seeing colors and shapes is second nature to us, yet light is a perplexing phenomenon when we study it more closely:
http://www.learner.org/teacherslab/science/light/

Light and Color: A more technical background on light and color:
http://www.fi.edu/color/

Filters Puzzler

Adapted with permission from *From the Ground Up*!

Goals

- ❑ Use your knowledge of color filters to distinguish which filter was used when taking each image
- ❑ Learn that light carries a lot of information about the object from which it is emitted or reflected. Filters and detectors (scientific tools) can be used to extract and separate this information found when looking at the types of light an object emits
- ❑ Understand that when combining a set of red, green, and blue color images you will create a full-color image

Activity Overview

Begin this activity with an opening discussion on light and color.
Review the function of a color filter and the outcome of the Light, color and Astronomy Activity. Next have participants look at the three black and white images first with the red filter, then with the green filter and lastly, with the blue filter. Through looking at the images and studying their detail, the participants should be able to guess what image was taken with each filter.

Background

With training, the average person can distinguish about one million colors. That makes it all the more amazing that, for hundreds of years, artists have been able to mix almost any color from just three pigments: red, yellow, and blue (and white to lighten the mixture).

In the 1860's, the German physiologist Hermann von Helmholtz discovered that the eye has three different kinds of cells that respond to three different regions of the color spectrum. Most people thought these cells would turn out to be sensitive to red, yellow, and blue light—since these were the "primary" pigments that artists had long used. But to everyone's surprise, Helmholtz showed that the eye's three kinds of color receptors have their peak sensitivity to red, green, and blue light. These three colors are now known as the primary colors of light, since any color the eye can see can be produced by stimulating the eye with a combination of red, green, and blue light.

Inspired by Helmholtz' early experiments on color vision, the Scottish physicist James Clerk Maxwell gave an astounding demonstration to the British Academy in 1861: He was able to create a full-color image of a Scottish tartan ribbon, from three black-and-white slides projected through red, green, and blue filters to form one image. This proved that full-color could be recreated from mixing red, green, and blue light.

Preparation

Space Required: A computer Lab

Materials:
- Computers
- Color Filters
- Magnifying glass
- Sunflower images found in the appendix

Preparation time: 🕐 🕐

Activity time: 1 hour

Gathering of materials and final preparations:
- Gather all materials listed above.
- Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

Explain to participants that all colors can be created from just red, green, and blue light. These colors are called the primary colors of light.

There's a simple reason why red, green, and blue are the primary colors: your eye has three different types of color-sensing cells that respond to red, green, and blue light.

The retina of your eye is made of color-sensing cells, called "cones." There are 3 different types of cone cells: one type is stimulated by red light. Another is stimulated by green light. And a few cells are switched on by blue light. (For some reason, there are only 1% as many blue-sensitive cells as red- and green-sensitive cells.)

Note that the blue receptor absorbs light mainly at the blue end of the spectrum, and similarly for the green and red receptors. But there is some overlap among all three receptors: As a result, yellow light, e.g., stimulates both the red and the green receptors. We perceive the color yellow as a result of these two receptors being stimulated.

Therefore, if we show the eye red light plus green light, then we stimulate both the red- and green receptors, and this produces the perception of yellow. The eye has no way of telling whether it has been shown one wavelength ("yellow") that stimulates both the red and green-receptors, versus whether it has been shown two primary colors of light, red and green. This is why a television monitor, e.g., can produce all colors, using just the three primary colors of light—red, green, and blue.

Color Filters Review - remind youth of the function of color filters

1. First have participants recall the behavior of color filters. A red-passing filter allows red light to pass through, but blocks green and blue. Similarly, green- and blue-passing filters allow green and blue light through, respectively.

2. Have participants bring up on the computer monitor the spectrum at this Website:

   http://mo-www.harvard.edu/Java/MiniSpectroscopy.html

   Have participants predict what they will observe when they look at the spectrum through a red, green, and then blue filter.
   - ❑ Which part of the spectrum do you think will appear the lightest when you look at the spectrum through the red-passing filter (the filter that lets through only red light)?
   - ❑ How about the green-passing filter? Which part of the spectrum will look lightest when seen through the green-passing filter?
   - ❑ How about the blue-passing filter?

3. Have participants carry out the observations, using each of the colored filters.
   - ❑ How does what you observe compare with what you predicted?
   - ❑ Suppose you could only see black and white, which is light and dark. If you looked at the world through each of the three filters, could you tell that they are different, based on what you saw? How could you tell?
   - ❑ Will images taken with the telescope look different if you use different filters—even though the telescope only registers light and dark?

4. Participants should observe that, when viewed through the red-passing filter, the red portion of the spectrum will appear the *brightest*, and the other portions of the spectrum will appear darker. Similarly, when viewed through the green-passing filter, the green portion of the spectrum will appear brightest, while the other regions will be darker. This makes sense, since the red-passing filter lets the red light through, but blocks the other colors.

   If you were completely color-blind, you could still tell that the red, green, and blue-passing filters must be different from each other. When looking through the red-passing filter, the parts of the world that were reddish would look lighter, whereas the other filters would make the other parts of the scene appear lighter.

   Similarly, the telescope is "color-blind," because it only records in black and white (and grays). But if you image the same scene using the red-, green-, and blue-passing filters, each image will be different from the others.

Filters Puzzler

This puzzler helps you assess whether participants understand how filters behave. For this activity you will use images of a sunflower taken using the three color filters. First, ask the youth to recall their findings from the past activity, Visible Spectrum Explorations. Try and illicit from them how the color filters function, or that light particles of the same color as the filter are the only ones that are able to pass through the filter. Then, break participants into groups of two or three, and have them try to match the three black-and-white images with the filters through which they were taken. Instruct them to discuss with their group why they labeled each image as they did, and record their reasoning onto their paper. Then come back together as a large group and discuss the evidence that leads to correctly matching each image with the filter through which it was taken:

In **Image #1**, the blue sky is light, so this was probably taken with the blue-passing filter. Supporting evidence: The yellow sunflower is completely dark; yellow has red and green in it but no blue.
Image #2 looks similar to Image #3, except that the red flowers and the sunflower are very bright in Image #2, so this was taken with the red-passing filter.
Image #3 was taken with the green-passing filter. The green leaves are the lightest in this image.

Go to the Hubble website and explore the images there with the color filters

Follow up

The next step will be to create full-color images using MicroObservatory 2.0 software. In the following activity participants will create a full-color image from three black-and-white images taken through color filters, using the MO Image software.

Watch out for...

- Sensation of light: many students and adults alike think that the eye is somehow a source of light, and that this light helps us see. As evidence, participants may cite the "glow" of animals' eyes in the dark (in reality this is reflected light) or Superman's x-ray vision. The ancient Greeks pointed out that you can "see" your dreams even with your eyes closed, so a source of light would seem to come from within your eye. Today we know that the eye and brain can create the sensation of light, even though the eye produces no light of its own.
- Color filters: students and adults alike often find filters confusing, because the terminology in common use is often inconsistent. In photography, for example, a red filter allows red light through, but an ultraviolet filter blocks—or filters out—ultraviolet light. Does a filter pass light or filter it out? For our activities, we recommend always denoting the function of the filter by using term *red passing, green passing*, etc.

Vocabulary

color-blind: Color blindness in humans is the inability to perceive differences between some or all colors that other people can distinguish. It is most often of genetic nature, but might also occur because of eye, nerve, or brain damage, or due to exposure to certain chemicals.

cones: The specialized photoreceptors in the human eye that allow us to discriminate between different wavelengths of light. Our eyes contain three distinct types of cones, designated the L, M, and S cones because they are primarily sensitive to long, medium, and short wavelengths of light. (The other type of photoreceptor in the eye is known as rods. They are primarily used in low-light and peripheral vision and do not contribute to color vision.)

retina: The sensory membrane that lines the eye; it is composed of several layers and functions as the immediate instrument of vision by receiving images formed by the lens and converting them into signals which reach the brain by way of the optic nerve.

Useful Websites

Hubble Site: Behind the Pictures: The Hubble Space Telescope is noted for providing beautiful and often bizarre color pictures of galaxies, planets, and nebulae. Do the pictures really reflect the colors these objects would have if we visited them in a spacecraft? Find the answer by peeking behind the scenes — a look at how Hubble actually makes images: http://hubblesite.org/sci.d.tech/behind_the_pictures/

Modeling the Earth-Moon System

Adapted from the Annenberg/CPB Math and Science Project Teachers' Lab at
http://www.learner.org/teacherslab/pup/act_earthmoon.html

Goals

- Understand the relative size and distance between the Earth and the Moon, as represented in a scale model
- Evaluate the strengths and weaknesses of a model

Activity Overview

This activity helps participants understand the size of and distance between Earth and the Moon. The activity consists of three parts:

1. Building a scale model of the Earth and the Moon by size
2. Building a scale model of the Earth and the Moon by size and distance
3. Discussion

Background:

The Moon is the only natural satellite of the Earth and it is the second brightest object in the sky after the Sun. The Moon's diameter is a quarter the size of Earth's diameter. The Moon orbits at an average distance of 240,000 miles (roughly 387,000 kilometers) from Earth. That distance is about 30 times the Earth diameter.

Preparation

Space required: Large room with enough empty space for participants to stand and move about as they work through the activity

Materials:

- Paper and pencils
- Chart paper or white board
- A box containing spheres of differing diameters, such as softballs, golf balls, marbles, tennis balls, table tennis balls, and beads
- Small round balloons, not inflated (optional)

Preparation time: 15 minutes plus time to gather the materials

Activity time: 45 minutes

Gathering of materials and final preparations

Purchase or gather balls of all sizes that will be used in the model to represent the Earth and the Moon. Out of the bunch of balls collected a couple pairings should be thought of ahead of time. These pairings should reflect the relationship of relative sizes of the Earth and Moon (4 Moon diameters would equal 1 Earth diameter).

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

Ask participants what size they think the Moon is relative to the Earth and how far away it is. Explain that they will use spherical objects to represent the size of and the distance between Earth and the Moon. Be sure that participants understand the term "**diameter**": the length of a straight-line segment through the center of a round or spherical object.

Modeling:

1. Hand out the balls (or the balloons) so that each participant has one object.

2. Tell participants that the ball (or balloon) they are holding can represent either Earth or the Moon. Tell them to find a partner so that they can make what they believe is an accurate scale model of the Earth and the Moon. (Participants with balloons can blow them up to whatever size they think will accurately represent the size of Earth or the Moon.)

3. Once each participant has found a partner, look around to see how similar the pairings are. Did participants pair correctly? Ask participants for their observations about the pairing. Can they draw a conclusion?

4. Ask participants how many Moons they need to place in a straight line to equal the diameter of one Earth. Write their guesses on chart paper or the board. After several guesses, tell the class that four of our Moon laid in a straight line equals the diameter of one Earth. With this new information, have the participants select different partners, pick other objects from the box, or adjust the size of their balloons until in each pairing four Moon diameters equal one Earth diameter. (Suggest participants to use paper and pencil to mark a scale of the diameters.)

5. When each pair of participants has the correct set of Earth and Moon objects (you will need to check each pairing), have all the "Earths" line up in the front of the room. Ask them to lift their objects above their heads so that others can see them.

6. Have the "Moons" stand facing their partners. Tell the partners to separate the two objects until they believe they are accurately displaying the distance between Earth and the Moon.

7. Have the participants estimate how many of their Earth objects when laid in a straight line would be necessary to reach their Moon object. Write their guesses on the board.

8. Tell participants that 30 Earth objects laid in a straight line represent the actual distance between Earth and the Moon. Have the partners separate their objects so that the distance between their Earth and Moon objects is correct. Ask the participants if they are surprised?

Debrief:

Lead a discussion in which participants can express their new understandings about the Moon's size and its distance from Earth.

Follow-up

If participants wish to be more creative, encourage them to express their understanding in a story, poem, or artwork that they can work on at home and present to the after-school group next time.

Watch out for…

- ❑ Make sure to give participants enough time to come up with their own ideas about the Earth-Moon system. Avoid giving them the answer right away. To simply give the answers seldom changes young people's ideas. Teaching by telling often gives the impression that science is something participants have to accept but not understand.

- ❑ Many people believe that the Moon is much closer to the Earth than what it really is. The misconception of distance may arise from visual representations--diagrams in books and three-dimensional models--that distort the distance to fit a model on a page or a tabletop. This misconception often leads people to believe that cause of the Moon's phases is the shadow of the Earth falling on the Moon. Be sure to dispel any of these misconceptions.

- Even though it seems that the Moon is huge when it is on the horizon, this is an optical illusion. You can check this by comparing the size of the Moon at the horizon and overhead with the tip of your pinkie held at arm's length. The Moon will be the same size.

Vocabulary

diameter: The length of a straight line through the center of a circle or sphere.
The Moon: the natural satellite of the Earth.
satellite: An object that revolves around a larger primary body. Satellites may be naturally occurring, such as the Moon, or they may be man-made, such as a telescope.
system: a group of independent but interrelated elements comprising a unified whole.

Useful Websites

A Private Universe: In combination with this activity and in preparation for the Moon Journal activity we suggest that you explore your ideas about basic astronomy. Visit A Private Universe Teachers' Lab and take the five-question survey at:
http://www.learner.org/teacherslab/pup/yourideas.html

Moon Phases Activity

Adapted by permission from Annenberg/CPB Math and Science Project Teachers' Lab
http://www.learner.org/teacherslab/pup/act_moonphase.html

Goals

- Create a model to understand how the position of the Moon relative to the Earth and Sun leads to the Moon's phases and what causes the moon's phases
- Evaluate the strengths and weaknesses of a model

Activity Overview

This activity begins with a discussion of the observations and ideas the participants recorded in their Moon Journals. Participants will share their findings on the appearance of the Moon in its various phases, and the order in which these different phases occur.

Participants will then take part in an interactive modeling of the movements of the Earth and Moon in relation to the Sun that causes us to see these phases.

Background

The observed phase of the Moon is determined by its position relative to Earth and the Sun. The changing portion of the Moon's sunlit side that we see throughout the month creates for us the phases of the Moon. In a 28-day period, the Moon swells from the new Moon, through the crescent, to the first quarter, the "gibbous," and then the full Moon, before waning to the new Moon again. The Moon's orbit takes it from a position between Earth and the Sun—the new Moon—to the opposite side of Earth from the Sun—the full Moon.

Most misconceptions that youth and adults alike have about the moon phases—such as clouds block the Moon or Earth's shadow covers the Moon—are reasonable, but don't hold up under careful observation of the Moon. Once youth and adults are confronted with the inconsistencies of their private theories, they can do activities such as this one to adopt alternative explanations.

Like many concepts in astronomy, the correct explanation of moon phases is difficult to express in words, and requires strong three-dimensional spatial reasoning skills. This activity not only demonstrates the reason for moon phases but also helps youth develop spatial perception as they create a concrete model of the motions of the Sun, the Moon, and Earth.

Preparation

Space required: A large, cleared space in a room that can be darkened completely—windows blocked and overhead lights turned off.

Materials:

- ❑ One of the following: light bulb on a stand, lamp with its shade removed, overhead projector.
- ❑ Extension cord
- ❑ Styrofoam ball or ping-pong ball for each participant
- ❑ Pencil for each participant

Preparation time:

Activity time: 1 hour

Gathering of materials and final preparations:

You will need to collect enough Styrofoam or ping-pong balls to distribute one to each participant. Clear space for participants to stand and to move about as they work through this activity.

Check that the lamp or light bulb for the model Sun works properly and that it can be placed in front or in the center of the room, where everyone can see it. The room will need to be completely dark for this activity.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Discussion lead-in:

Ask participants to think about their observations of the Moon over the last several weeks and list possible explanations for the phenomena of Moon phases. Try to avoid making comments on the validity of the theories offered. Focus the participants' attention on patterns of change.

Then explain that the Moon phases occur repeatedly because of the relative motion between the Sun, Earth, and the Moon. These bodies change their relative position in complex ways night-by-night and month-by-month, affecting what we see in the sky from our viewpoint on Earth. Explain that participants will model the pattern of Moon phases.

Modeling:

1. Review with participants the order of the phases from one full Moon to the next.

2. Explain that to understand the phases of the Moon, participants need to look at models of Earth, the Moon, and the Sun.

3. Place the lamp in front of the room. (Remind participants to practice safety near the hot light bulb and electrical cord.)

4. Have participants stand in a semicircle facing the lamp. Explain that the lamp represents the Sun and that each of their heads represents Earth, with their noses being their hometown.

5. Ask participants to stand so it is noontime in their hometown. If disagreement occurs, have participants discuss this until they agree that noon is when their noses are pointed toward the model Sun. Ask participants to stand so it is midnight. (They should turn to face away from the model Sun.)

6. Then ask them to stand so it is sunrise and sunset. (From the "noontime position", they should turn by 90° to the right for sunrise and 90° to the left for sunset.) Practice the ideas of sunrise, noon, midnight, and sunset until you sense that the participants have a good understanding of these relative positions.

7. Distribute one Styrofoam ball for the model Moon to each participant. Have participants stick a pencil into the ball to make it easier to hold as well as observe the phases of the model Moon.

8. Ask participants to hold the model Moon at arm's length. Allow time for them to explore how the model Sun's light reflects off the model Moon as they place it in different positions around their heads.

9. Choose one of the Moon phases and ask participants to find where that phase occurs in the Moon's orbit around Earth. (The first quarter is a good phase to start with. To simulate the first quarter stand in the noontime position and them move the Styrofoam ball only 90° to the left.)

10. Let the participants try many positions and tell them to always refer back to the Moon Chart Encourage participants to compare their results and discuss differences. If one participant has the correct position, ask this participant to state why it is so. Then check to see whether other participants understand what to do; see if they are all standing in the same position.

11. Have participants model the other Moon phases: the full Moon, the third quarter Moon, and the new Moon. As participants learn where to hold the Styrofoam ball for each phase of the Moon, challenge them to determine the direction that the Moon travels around the Earth to create the phases in the correct order. (This can be demonstrated by moving the ball counter clockwise, getting passed from right hand to left and continuing around the body).

12. Allow time for participants to experiment with the movement of the Moon. Have them work together to draw a diagram of the relative position of the Earth, Moon, and Sun during each phase. (The spinning Earth allows us to observe the Moon rising and setting each day, but this spinning does not affect the phase of the Moon. The changing proportion of the Moon's sunlit side that we see as the Moon orbits Earth causes the Moon's phases.)

13. Eventually see that participants check their positions for the model Moon against those in a diagram of the Moon phases.

Discussion

Lead a group discussion in which participants can express their new understandings about the phases of the Moon. Then ask participants to record their new understandings in a journal. If they wish to be more creative, encourage them to communicate their new understanding also in a story, poem, essay, song, or piece of visual art.

Follow-up

Encourage participants to do this activity at home with their families or to model the Moon phases for younger participants and then write about their results.

Watch out for...

- ❑ Because the visualization in this activity can be difficult for some participants, consider doing this activity with a smaller group while the rest of the group works on a Moon phase chart or another project. You may also consider doing this activity more than once.

- ❑ Also, participants usually observe that their own shadows cover the model Moon when it is opposite the light source, simulating a Moon eclipse during the full Moon phase. Ask participant to hold the model above or below the shadow of their heads, and ignore the eclipse for the time being.

Vocabulary

eclipse: The blocking of all or part of the light from one object by another. For example, a "lunar eclipse" occurs when the Earth's shadow falls on the Moon, preventing Sunlight from illuminating all of its surface. Lunar eclipses can occur only when the Moon is on the opposite side of the Earth from the Sun (at Full Moon), while solar eclipses can happen only at New Moon. A "solar eclipse" occurs when the Moon passes directly between us and the Sun, blocking part or all of the Sun’s light from reaching us.

model: A simplified imitation of something that helps explain and understand something better. Models can take different forms, including physical devices or sculpture, drawings or plans, conceptual analogies, mathematical equations and computer simulations.

moon: A natural satellite revolving around a planet. The Moon is the natural satellite of the Earth.

orbit: The path followed by an object in space as it goes around another object; to travel around another object in a single path.

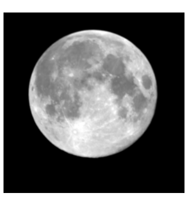
phases of the Moon: The changing appearance of the Moon as it orbits around the Earth. At "New Moon," the Moon is on the same side of the Earth as the Sun is, and we see only the part of the Moon that is in shadow (another term for New Moon is the "dark of the Moon"). A quarter of an orbit later (about a week after New Moon), we see the Moon illuminated by Sunlight from the side. Thus one-half of the disk of the Moon which faces us is in Sunlight — the right side as seen from Earth's northern hemisphere: this phase is called "First Quarter." About two weeks after New Moon, our satellite has traveled around to the other side of its orbit, and the side facing us also faces the Sun and is fully illuminated as we see it; that phase is called "Full Moon." Three-quarters of a lunar orbit after New Moon, at "Last Quarter," the Moon is again illuminated from the side (the left side as seen from the northern hemisphere). About a week after that, the Moon is New again, and the cycle starts over. Between First Quarter and Last Quarter, when more than half of the side of the Moon facing us in Sunlight, the Moon is said to be "Gibbous." From Last Quarter to First Quarter, when more than half of the side of the Moon facing us is in shadow, the Moon is said to be a "Crescent."

New Moon

Crescent Moon

First Quarter

Full Moon



Gibbous Moon

Last Quarter

rotate: To turn around a center point, or axis, like a wheel turns on a bicycle.
solar eclipse: A "solar eclipse" occurs when the Moon passes directly between us and the Sun, blocking part or all of its light from reaching us.
The Sun: The star at the center of our solar system.
waning: The act or process of gradually declining or diminishing.
waxing: To increase gradually in size, number, strength, or intensity.

Useful Websites

The Moon: It's Just a Phase It's Going Through: Gain an understanding about why the moon has phases. Learn how to demonstrate its motion around Earth:
http://www.astrosociety.org/education/publications/tnl/12/12.html

Lunar Prospector Education: Find many hand's on activities here as well as great resources for why the moon has phases and resources for further readings:
http://lunar.arc.nasa.gov/education/

Lunar Prospector: Phases of the Moon: Great diagrams showing the phases of the moon with short descriptions of each:
http://lunar.arc.nasa.gov/science/phases.htm

Project ASTRO Tucson Phases of the Moon Demos: Video clips to demonstrate why we see the phases of the moon:
http://www.noao.edu/education/phases/phases_demo.html

A Journey through the Universe

Goals

- ❑ Learn how to create a scale model of the Galaxy using everyday objects
- ❑ Gain an appreciation for the huge number of stars in our galaxy and the vast distances between them
- ❑ Evaluate the strengths and weaknesses of the models presented

Activity Overview

In this activity you will lead the participants through an interactive PowerPoint presentation in which the solar system is modeled as a cookie and the galaxy as a compact disc. The youth will confront their current conception of size, scale and distance in the universe and reevaluate their mental models based on the models presented. The activity is a follow-up to the Tour of the Universe activity.

Background

At the beginning of the 20th century, the universe was commonly thought to be a single galaxy. We now know that our own Milky Way is one of billions of galaxies that populate the universe. This interactive presentation will lead us to find our place in the universe, beginning on planet Earth in our very own Solar System, and travel outward to the realm of stars, the galaxies, and finally, the vast panorama of the observable universe.

Preparation

Space required: Large room (or stage) with space for demonstrations.

Materials

- ❑ Oreo cookies or other cookies of similar size
- ❑ CD

- ❑ "Journey to the Beginning of Time" PowerPoint presentation
- ❑ Projector

Preparation time: 🕐🕐

Activity time: 30 minutes

Gathering of materials and final preparations:

Download the ***Journey to the Beginning of Time*** presentation from http://cfa-www.harvard.edu/seuforum/einstein/resources_ed.htm#pres

Review the script associated with the PowerPoint slides and practice delivering the science content in a clear and engaging manner. Note: it may be a good idea to close with slide #6 or after slide #10 depending on which other activities your group has covered so far, or how well the participants seem to be grasping the models presented in the earlier slides.

Finally, be sure to review the definitions of the astronomy terms in the vocabulary section at the end of this activity. These terms may come up during discussion.

Procedure

Present PowerPoint:

Show the presentation providing the indicated narration written in the notes section on each slide. Ask as many volunteers as possible to join in the demonstrations.

Debrief:

Facilitate a discussion following the presentation around these questions:

How does the model of the cookie-size solar system help you understand why the discovery of planets around other stars is so amazing?

How likely do you think that there is (intelligent) life elsewhere in our galaxy?

Reflect on the challenge of trying to communicate with any potential life around other stars, or in other galaxies.

Some people say they feel insignificant after understanding the scale of the universe; others say that it makes them feel that life on earth is special; and others feel amazement at the power of the human mind.

What is *your* view?

Watch out for…

- ❑ Make sure to keep your audience engaged by involving participants in the demonstrations and asking questions frequently.

- ❑ Time management: good audiences ask a lot of questions and one can get side tracked by some of these questions. During the presentation, answer those questions that are directly connected with the topic discussed. If a question is not, do not simply dismiss it. Invite participants to write down the question that you will then address at the end of the presentation.

Vocabulary

billion: The cardinal number equal to 109, or a one with nine zeroes after it.
black hole: A region of space resulting from the collapse of a star with a gravitational pull so strong that from a certain distance, not even light can escape it.
galaxy: Any of many very large groups of stars, gas, and dust that constitute the Universe, containing an average of 100 billion (1011) stars and ranging in diameter from 1,500 to 300,000 light-years.
light-year : The distance that light travels in one year.
Milky Way Galaxy: The galaxy containing our Solar System, visible as a broad band of faint light in the night sky.
million: The number equal to 10^6, or a one with six zeroes after it.
supernova: The death explosion of a massive star, resulting in a sharp increase in brightness followed by a gradual fading. At peak light output, these supernova explosions can outshine a galaxy.
universe: All matter and energy, including the earth, the galaxies, and the contents of intergalactic space, regarded as a whole.
The Early Universe: Galaxies like colorful pieces of candy fill the Hubble Deep Field image - humanity's most distant yet optical view of the Universe. The dimmest, some as faint as 30th magnitude (about four billion times fainter than stars visible to the unaided eye), are the most distant galaxies and represent what the Universe looked like in the extreme past, perhaps less than one billion years after the Big Bang.
To make the Deep Field image, astronomers selected an uncluttered area of the sky in the constellation Ursa Major (the Big Bear) and pointed the Hubble Space Telescope at a single spot for 10 days accumulating and combining many separate exposures. With each additional exposure, fainter objects were revealed. The final result can be used to explore the mysteries of galaxy evolution and the infant Universe

Useful Websites

Our Place in Space: Explore our place in space starting from the Earth neighborhood to reach the edge of the visible universe: http://cfa-www.harvard.edu/seuforum/opis_tour_earth.htm