YOUTH ASTRONOMY APPRENTICESHIP

Activity Book

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Introduction

Youth Astronomy Apprenticeship

The Youth Astronomy Apprenticeship (YAA) program is an out-of-school time initiative that uses an apprenticeship model to promote science learning among urban teenage youth and their communities. One of the primary goals of YAA is to broaden the awareness of science education as an effective way of promoting overall youth development and practicing the skills needed to compete for today's science and technology professional opportunities.

Following the apprenticeship model, youth in YAA first participate in an after-school astronomy-training program. After the training is completed, the successful participants become astronomy apprentices who work with educators and other professionals to create astronomy outreach initiatives directed at their own communities. Through the youth's work and their presence among their communities as science ambassadors, YAA aims to promote involvement and support for science learning among the general public.

During the YAA after-school program, youth engage in a variety of astronomy explorations using a combination of hands-on and computer-based activities that are collected in the **YAA Activity Book**. As they engage in these activities, youth learn to use a network of educational telescopes called MicroObservatory, which are controlled via the Internet. Additionally, youth learn to use software tools to process astronomical images, and produce project reports that they share among their peers and an online community of MicroObservatory users. In the process, youth develop important skills, including logical reasoning, inquiry, completing self-directed tasks, collaborating with others, oral and written communication, and other employable skills used in the sciences and in many other professional fields.

What is MicroObservatory?

MicroObservatory is a network of automated telescopes that can be controlled over the Internet. The telescopes were developed at the Harvard-Smithsonian Center for Astrophysics and were designed to enable youth worldwide to investigate the wonders of the deep sky from their classrooms or after-school centers.

Users of MicroObservatory are responsible for taking their own images by pointing and focusing the telescopes and selecting exposure times, filters, and other parameters. They may select a target from a list or enter its coordinates. The educational value lies not just in the image returned by the telescope, but in the satisfaction and practical understanding that comes from mastering a powerful scientific tool. Observations can be set up in advance and run automatically.

How to Use This Activity Book

YAA was originally designed as a project-oriented program to be covered over 14 weeks, during 2-hour long after-school sessions held twice a week. However, the same program can be adapted to other situations – after-school programs with less time, summer camps, week-long school vacation programs, etc.

The YAA Activity Book is a collection of activities, grouped into three main categories (Hands-On, Computer, and Observing Projects) and further into small clusters that focus on one main theme, or are complimentary in some way. The first cluster is considered the base for all the other clusters. It contains the introductory activities needed for later activities and all programs should begin with this cluster. Then other clusters can be implemented taking into consideration time available, youth interest and the personal background knowledge of the facilitator. We encourage all programs to always include at least two observing projects in their implementation of YAA activities.

Some activities provide questions that can be used to facilitate a discussion. These questions are offset from the activity as bullet points and can be read aloud to the participants. In addition, some activities provide sample responses (in italics) that can be used by the facilitator to assess if the participants are on the right track.

All of the supplemental materials referred to in the activities are found in the appendix, available online: http://epo.mit.edu/curriculum/Appendix.zip

Why Use Ice Breakers?

Icebreakers can be a fun and effective way to start off the day's activities. They help to get participants motivated and act as an attention getter to encourage everyone to contribute to the group. Icebreakers can be particularly useful when working with a group of participants that are unfamiliar with one another. Also since icebreakers are typically not related to the subject matter of the day's activities, they are a great way to break up a cluster of more intense activities.

The following are some websites for icebreaker activities we have found useful for getting the group more comfortable with each other, encouraging communication among groups, and helping to energize the group:

- Tennis Ball
  http://www.leadersinstitute.com/teambuilding/team_building_tips/tennis_balls.html
- Cup Stack
  http://eslcafe.com/idea/index.cgi?display:967310805-599.txt
- The Human Knot
  http://wilderdom.com/games/descriptions/HumanKnot.html
- Group Juggle
  http://wilderdom.com/games/descriptions/GroupJuggle.html
- Categories
  http://wilderdom.com/games/descriptions/Categories.html
- 2 Truths and a Lie
  http://wilderdom.com/games/descriptions/TwoTruthsAndALie.html
- On all sides
  http://www.niu.edu/orientation/firstyear_conn/Res_Icebreakers.shtml

Included Icebreakers

In this Activity Book, you will notice we have included some icebreakers in the flow of the activities. For instance, the following are activities that are strategically placed in the book and serve as a good opening to the following activity.

- Astropoetry – Tour of the Universe (may be included as part of the observing projects).
- What's Different? – Observing Project #1
- Observation vs. Inference – Observing Project #2
- Comets and Asteroids – Can be done at any time, see activity write-up for details

Activities, listed by category

Hands-On Activities
Astronomy in the Marketplace
Astropoetry
Comets and Asteroids
Cosmic Cast of Characters
Cosmic Survey
Filters Puzzler
From Starlight to Image
Group Portrait of the Solar System: Making Sense of Images
Group Portrait of the Solar System: Taking Images
Group Portrait of the Universe: Making Sense of Images
Group Portrait of the Universe: Taking Images
A Journey through the Universe
Light, Color and Astronomy
Modeling the Earth-Moon System
Modeling the Universe
Moon Phases Activity
Telescopes & Light: Hands-On Telescope Activity
Toilet Paper Solar System
Tour of the Universe
Youth Generate Rules to Govern their Space

Computer Activities
Advanced Image Processing
Creating Color Images
Group Portrait of the Universe in Color: Taking Images
How to take and Save Images with MicroObservatory
Image Processing and Image Contrast
Images as Data
Introduction to MicroObservatory
Investigation of Jupiter and its Moons: Part One
Investigation of Jupiter and its Moons: Parte Two
MicroObservatory Guest Observer Portal

Observing Projects
Observing Project #1:
- Overview
- Did You Notice?
- Observation or Inference?
- Sharing & Publishing

Observing Project #2:
- Overview
- Introduction & Planning
- What Does Your Data Mean?
- Giving Feedback
- Daily Journal & Project Report

Observing Project #3:
- Overview
- Introduction & Planning
- Daily Journal & Project Report
- Creating Posters
- Presenting Posters

Activities, listed by cluster

The Base Cluster
- Modeling the Universe
- Cosmic Cast of Characters
- MicroObservatory Guest Observer Portal
- Introduction to MicroObservatory
- Image Processing and Image Contrast
- Observing Project #1

Size and Scale of Solar System
- Toilet Paper Solar System
- Modeling the Earth-Moon System
- Group Portrait of the Solar System: Taking and Making Sense of Images
- Investigation of Jupiter and its Moons: Part One
- Investigation of Jupiter and its Moons: Part Two

Size and Scale of the Universe
- Astropoetry
- Cosmic Survey
- Tour of the Universe
- Group Portrait of the Universe: Making Sense of Images
- Group Portrait of the Universe: Taking Images
- A Journey Through the Universe

The Universe in Color (digital imaging)
- Light, Color, and Astronomy
- From Starlight to Image
- Creating Color Images
- Filters Puzzler

Modeling Systems
- Astropoetry
- Toilet Paper Solar System
- Modeling the Earth-Moon System
- Moon Phases Activity
- Investigation of Jupiter and its Moons
- Tour of the Universe

Light and Color (no computer activities)
- From Starlight to Image
- Telescopes & Light: Hands-On Telescope Activity
- Light, Color and Astronomy
- Filters Puzzler

Image Processing (computer activities)
- From Starlight to Image
- Images as Data
- Advanced Image Processing
- Creating Color Images

Observing Projects
- Astropoetry
- Project #1
    - Did You Notice?
    - Observation or Inference?
    - Sharing & Publishing
    - Publishing the Project Report
- Project #2
    - Introduction & Planning
    - What Does Your Data Mean?
    - Giving Feedback
    - Daily Journal & Project Report
- Project #3
    - Introduction & Planning
    - Daily Journal & Project Report
    - Creating Posters
    - Presenting Posters

Resources

The YAA Activity Book includes activities that were adapted and further developed from the following educational resources:

Cosmic Questions Educator's Guide, Harvard-Smithsonian Center for Astrophysics and Museum of Science, Boston.
http://www.cfa.harvard.edu/seuforum/exhibit/resources/resources.htm
Project funded through the following grants: NSF ESI #9909705; NASA NCC5-261

From the Ground Up!, Science Education Department, Harvard-Smithsonian Center for Astrophysics. http://www.cfa.harvard.edu/sed/projects/groundup.html
Project funded through NSF grant ESI #9730351

A Private Universe Project, Annenberg/CPB Math and Science Project.
http://www.learner.org/teacherslab/pup/act_earthmoon.html/

The Universe At Your Fingertips, A. Fraknoi Editor, Astronomical Society of the Pacific.
http://astrosociety.net/education/astro/astropubs/universe.html

Family ASTRO, Hands-on Astronomy Activities, Astronomical Society of the Pacific
http://www.astrosociety.org/education/activities/handson.html

Hands-On Optics, Making an Impact with Light, SPIE, OSA and NOAO.
http://www.hands-on-optics.org/

Life in the Universe – Activities Manual, Prather, Offerdahl and Slater, Addison Wesley.

Beyond the Solar System: Expanding the Universe in the Classroom - DVD, Harvard-Smithsonian Center for Astrophysics. http://www.cfa.harvard.edu/seuforum/btss/
Project funded through NASA grant NCC5-706

MicroObservatory On-line Telescopes Network, Harvard-Smithsonian Center for Astrophysics. http://mo-www.harvard.edu/MicroObservatory/
Project funded through the following grants: NSF ESI # 9155723, #9454767; NASA NCC5-261, NCC5-706

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YOUTH ASTRONOMY APPRENTICESHIP

Hands-On Activities

Astronomy in the Marketplace

Adapted from *The Universe At Your Fingertips*.

Goals

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

Activity Overview

Begin by asking the group to brainstorm as many items as they can with brand names that are also astronomical terms. (This is where it helps to show examples such as the Milky Way bar or the Comet detergent package to give the participants a good idea of what they should be coming up with.)

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. (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, and Starbursts candy) Print-outs of these labels can be found in the appendix folder (appendix/hands-on-activities/astronomy-in-the-marketplace/)
- ❑ Chart paper
- ❑ Starburst candies as an added example, but also a prize (optional)

Preparation time: 🕐

Activity time: 20 – 30 minutes

Gathering of materials and final preparations:

Prior to leading this activity, 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.) Also, be sure to have the example items that share their names with astronomical terms ready in order to jumpstart the brainstorming. Some examples can be found in the appendix folder: (appendix/hands-on-activities/astronomy-in-the-marketplace/)

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. Show the example items to get the brainstorm going.

Brainstorming:

1. Once a few responses are generated as a large group, break-up the youth into smaller groups and have each group brainstorm a list on their own.

2. Challenge the teams to come up with as many examples as they can, writing their answers down on chart paper. Optionally, tell the youth that the team that comes up with the most original, accurate and longest list will receive a prize (the Starbursts).

Debrief:

1. Discuss why astronomy terms and ideas are so prevalent in our marketplace and media. In this discussion of why advertising executives and screenwriters would use astronomy terms as their product name or in their scripts, you can ask the youth:

   - ❑ Do you think that the astronomy topics presented in movies are always accurate to the real science?

2. 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” to 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, exhibit 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: An 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 serves as an outline of discussion questions which prompt the youth to engage in a discussion to accomplish the following: initiate open communication among peers, set expectations, and lay down ground rules for acceptable feedback and tone, within the learning environment.

Through discussion, youth 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 think critically and feel comfortable asking 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:

- ❑ Whiteboard 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 whiteboard 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:

Explain to the youth that they will be working very closely in groups during the program. As a result, they need to establish rules and expectations that 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?
    - ❑ What rules would be helpful in order to create a space that is comfortable for you?
    - ❑ What are some personal reactions that would make you second-guess whether or not you should ask a question?
    - ❑ 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/whiteboard and keep posted in a visible area for future reference.

Follow up

Many of the upcoming activities will require participants to work in small groups in which they will be sharing ideas and working closely on projects. Therefore, 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 attitudes as suggestions for the group. Try to prevent detractors from hindering the efforts of the group as a whole.

Modeling the Universe

Adapted from *Cosmic Questions Educator's Guide*.

Goals

- ❑ Create a model of the Universe, reflecting on the relative sizes, distances and organization of the objects within
- ❑ Discuss the strengths and weaknesses of a model

Activity Overview

Participants will think about where we fit in the universe, and create a physical model of their own mental image of the Universe. The finished models will be presented to the group and the decisions the model builders made regarding the size, shape, and relative position of objects within their model 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 participants' 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 scientist's 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/or marbles
- String
- Markers
- Scissors
- Straws
- Pipe Cleaners
- 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 above) for each group of 3-4 participants. Make sure each group also has piece of chart paper for initial 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 the youth that 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 did not have it on their own list.

5. After a couple more minutes, 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.

3. While participants 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?

Debrief – Sharing Models:

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 inside. 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 on 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 axes. 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 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. 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. These are images of objects in one of the four "What's Out There?" sections listed on 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 (appendix/hands-on-activities/cosmic-cast-of-characters/Cosmic_Cast_of_Characters_Chart.pdf)
- ❑ Cosmic Cast of Characters Table poster (appendix/hands-on-activities/cosmic-cast-of-characters/Cosmic_Cast_of_Characters_Chart_Large.pdf)
- ❑ 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 the table to 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 the group will be keeping a running list of the questions that come up, and 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:

Explain to the youth that they are about to take their first images of astronomical objects by controlling the MicroObservatory telescopes, and commanding them to take images overnight. Additionally, before the youth take images, they should think about what type of object they might want to choose as their target, and find out some information about what it means to be that type of object. In this activity, participants will get into groups and sharpen their observing skills while finding out some interesting facts about these distant objects.

Image Analysis:

1. Randomly break the youth into groups of 2 or 3, assigning each group a different category from the "Cosmic Cast of Characters" table to closely examine. Pass out a copy of the table to each 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 11" X 17" paper and post the four pages on the wall. Each week you can print some of the images the youth take and then pin/tape them onto the page that represents their group: Jupiter will go with the "bit players" and the Whirlpool Galaxy with the galaxy group, etc.

Watch out for…

- ❑ It is important that the youth gradually but steadily become accustomed 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 a model

Activity Overview

Participants will be given an explanation of the function of the cameras, 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 computer screen.

Background

A CCD camera attached to a telescope "sees" differently than 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 (appendix/hands-on-activities/starlight-to-image/Starlight_to_Image_GRID_CLRbyNUM.pdf)
- ❑ 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. (appendix/hands-on-activities/starlight-to-image/Starlight_to_Image_GRID_Blank.pdf)
- ❑ One image of the "happy face" (appendix/hands-on-activities/starlight-to-image/Starlight_to_Image_GRID_FACE.pdf)
- ❑ 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.
- ❑ Magnifying glass

Preparation time: 🕐

Activity time: 15 minutes

Gathering of materials and final preparations:

Copy the "happy face" and two grid pages (one with numbers, one without). 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, in other words, build stacks of 6 or 8 LEGO blocks to place on the corresponding boxes on the detector. 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 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 with a different brightness. 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 watch and listen to 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 more specifically 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 LEGO blocks, or particles of light, that hit each pixel on the detector. Then show the grid with the numbers on each pixel.

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 convert it into a digital image with black, white, and shades of gray pixels (Show the black and white "happy face" image).

Debrief:

- ❑ What features of the imaging process does this model represent?
- ❑ What things does this model misrepresent?
- ❑ What aspects of the imaging process does the model omit, or not represent at all?
- ❑ What questions came to mind as we went through the demonstration?

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, infrared 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

Adapted 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 survey launches participants into discussions about where objects in space are located, their size, 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:

- Cut out sets of demonstration images (appendix/hands-on-activities/cosmic-survey/Cosmic_Survey_Images.pdf)
- 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.

Finally, be sure to review the discussion notes section for the proper order of each list. Also, familiarize yourself with 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 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 participants. Have

each group set-up their chart paper 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 spokesperson.

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" section for the 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 can use these results for your evaluation if this activity is repeated towards the end of the program.

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
Whirlpool 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. For example, the number **1×10^{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
Whirlpool 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 (youth 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 “Watch out for…” section of this activity)

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
Whirlpool 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 can 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

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 step out of their comfort zones in order to improve their ability to communicate.

Background

Effective communication helps to lay the foundation of a successful partnership. In order for the youth 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 manner.

Throughout this activity, participants are expected to work in pairs and small groups. In order to do this successfully, good communication is essential among group members.

Preparation

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

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 participants to have one. There should be approximately twice the amount of balls than youth involved in the activity. Depending on where the activity is staged, there may be a need for boundaries if the space is too large.

Procedure

Discussion lead-in:

This activity is done in two parts in order to provide adequate time for reflection and discussion of the relevant skills.

Activity:

1. **Round 1**: Begin by scattering the balls randomly within the activity space. Once this is done, ask one participant from each pair to place a blindfold over their eyes and to 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 blindfolded will verbally lead their blindfolded partner around the playing space encouraging them to pick up as many balls as possible. **The blindfolded partner cannot move or pick up any balls if not instructed to do so by their partner's commands.** The team with the most balls is the winning team.

2. Discuss what made this activity difficult by asking the following questions:

   - ❑ 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 you to follow?

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

This activity is great for team building within the group. A key to fostering effective working relationships is first clearly communicating with one another. Working effectively in teams or pairs is necessary for the group-work inherent to many activities in this guide as well as the Observing Projects.

Watch out for…

- ❑ Players peering out from under blind folds.

- ❑ If the game goes on for too long, you may want to disallow the command-giving partners from blocking incoming balls.

Modeling the Earth-Moon System

Adapted from *Annenberg/CPB Math and Science Project Teachers' Lab.*

Goals

- ❑ Understand the relative size and distance between the Earth and the Moon, as represented in a scale model
- ❑ Discuss 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 whiteboard
- ❑ 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: ⏱ (plus additional 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). Including balloons in the mix of balls is helpful in this sense because one can inflate the balloon to any desired size in order to reflect the 4:1 size relationship of the Moon to the Earth.

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 come to a conclusion?

4. Ask participants how many of our Moon would 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 group 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 use paper and pencil to trace 4 Moon diameters end-to-end to get a sense of how big their Earth should be.)

5. When each pair of participants has a 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 participants estimate how many of their “Earths” 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-sized objects laid in a straight line represents the actual distance between the Earth and the Moon. Have the partners separate their objects so that the distance between their Earth and Moon is correct. Ask the participants if anything is surprising.

Debrief:

Lead a discussion in which participants can express their new understandings about the Moon's size and its distance from Earth. Ask the youth the following questions about the model they created:

- ❑ What features of the Earth-Moon system does this model represent?
- ❑ What features of the Earth-Moon system does this model misrepresent?
- ❑ What aspects features of the Earth-Moon system does this model omit, or not represent at all?
- ❑ What questions came to mind as you created and adjusted your model?

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 group the following session.

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 tabletop. This misconception often leads people to believe that the cause of the Moon's phases is the shadow of the Earth falling on the Moon. This activity attempts to dispel these size and distance misconceptions while the "Moon Phases Activity" addresses misconceptions about the Moon's phases.

- ❑ 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 from *Annenberg/CPB Math and Science Project Teachers' Lab.*

Goals

- ❑ Create a model to understand how the position of the Moon relative to the Earth and Sun causes the phases of the Moon
- ❑ Discuss 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 journals during Observing Project #1. Participants share their findings on the appearance of the Moon in its various phases, and the order in which these different phases occur. If not paired with Observing Project #1, it is recommended that the youth do some observing of the Moon either by going outside and observing it directly, or through the use of MicroObservatory, prior to doing this activity.

After the discussion, participants model the movements of the Earth and Moon in relation to the Sun. These movements cause observers on Earth to see the Moon's 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 about the Moon phases—such as clouds block the Moon or Earth's shadow covers the Moon—are reasonable, but do not hold up under careful observation of the Moon. Once participants are confronted with the inconsistencies of their private theories, they can do activities such as this one to adopt alternate 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 motion 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:

- ❑ A 200-Watt light bulb
- ❑ Any 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
- ❑ Pencils or coffee stirrers to act as a base for the Styrofoam ball

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 couple weeks and list possible explanations for the phenomena of the Moon's phases. Try to avoid making comments on the validity of the theories offered. Focus the participant's 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 a model of Earth, the Moon, and the Sun.

3. Place the lamp in front of the room and turn it on. (Remind participants to be cautious next to the hot light bulb and electrical cord. Also the bulb is very bright; warn youth to not stare directly at the bulb.)

4. Have participants stand in a semicircle facing the lamp. Explain that the lamp represents the Sun and that each of their heads represents the 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 or coffee stirrer into the ball to make it easier to hold and 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.

Debrief:

Lead a group discussion in which participants can express their new understandings about the phases of the Moon. Then ask participants the following questions:

- ❑ What features of the Sun-Earth-Moon system does this model represent?
- ❑ What features of the Sun-Earth-Moon system does this model misrepresent?

- [ ] What aspects features of the Sun-Earth-Moon system does this model omit, or not represent at all?
- [ ] What questions came to mind as you modeled the Sun-Earth-Moon system and the Moon's phases?

Follow-up

Encourage participants to record their new understandings in a journal. If they wish to be more creative, encourage them to communicate their new understanding in a story, poem, essay, song, or piece of visual art.

Participants may also do this activity at home with their families or 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."

(See chart on following page.)

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.

Moon Phase	Image
New Moon	
Crescent Moon	
First Quarter	
Full Moon	
Gibbous Moon	
Last Quarter	

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

Toilet Paper Solar System

Adapted from *Family ASTRO*.

Goals

- Gain an appreciation of the actual distances between the orbits of the planets
- Construct a model that 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. For sites with smaller activity space, a football field version is available in which participants find a given planet's distance from the Sun, then plot the planet on a print-out of a football field with the Sun located on the goal line.

In this activity the participants should also make observations in reference to how our Solar System appears. Encourage them to think of reasons why it looks the way it does. 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 (appendix/hands-on-activities/toilet-paper-solar-system/footballfield.pdf)

Materials:

- ❑ One table of distances per group
- ❑ One roll of toilet paper (TP), 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
- ❑ Planet image cards
- ❑ 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 the 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 TP model.
- ❑ Print out cards with images of the planets. (appendix/hands-on-activities/toilet-paper-solar-system/tpssplanets.pdf)
- ❑ 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 (appendix/hands-on-activities/toilet-paper-solar-system/footballfield.pdf)
- ❑ 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 a participant to name the 8 planets of the Solar System outward from the Sun while probing the participants for thoughts on what they 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. 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 youth to for more information.

Inform the group that the average size 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 are all reasonable until the final distance; then they have absolutely no idea!

Briefly 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/markers. Make sure that the ink is not so wet that the pens tear the paper. Have groups practice writing on the toilet 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 the group is using the planet image cards, youth can simply place the card alongside the point on the TP where the object should be located.

3. Groups should then use the table 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.

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 to debrief; it is the most important part of the 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 group to further probe their 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 answers.
    - ❑ 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 entire 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. It is appropriate at this point to connect relative distances and the relative sizes of the objects in the Solar System. In the activity, “Modeling the Earth-Moon System,” the Earth’s diameter is used as a unit of measurement (Recall that the Moon is about 30 Earth diameters away from the Earth). The following table summarizes the size and distance to the orbit of Earth, Jupiter and Pluto from the Sun in Earth 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

4. 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?

Further Questions:

These questions are more advanced and should only be discussed if the youth are wondering about these topics. Answering these questions could be the basis for their final project.

- ❑ Why are the outer planets so much larger than the inner planets?
- ❑ Notice that the outer planets are much further away from one another. Why do you think this is?
- ❑ We know that the larger planets Jupiter, Saturn and Uranus are planets made mostly of gas. Why do you think this is?

Solar System Live:

Use the interactive tool at (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 they can take an image of Jupiter or Saturn tonight with the MicroObservatory telescopes. Why or why not?

Tips for 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.
- This model of the Solar System has orbits that are both green and blue. The green indicates the orbit areas and planets which one would be able to observe at night. The blue areas on the orbit paths indicate a positioning when a given planet is not visible due to it being below the horizon.
- The “Update” button on the web page will reset the model to reflect any changes in settings that a user has made.
- The model is being displayed in Universal Coordinated Time (UTC). See the “Vocabulary” section of this activity for more information on this topic.

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 the 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

Follow up

- Create a model of the Solar System with size of the planets to scale (To accurately represent the size of the planets, and their distances from each other, a lot of space is required—therefore, this activity will need to be done outside).
- 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' sizes and distances to scale, use one inch to represent a hundred thousand miles. 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 do not 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 for this model are between orbits, not from the Sun like they were in the toilet paper model.

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 youth, 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 relative to Earth’s 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 the 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! Also, it may be useful to explain that the planets are constantly in motion, spinning as well as orbiting the Sun. Finally, in doing 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:
  Pens & Markers– Do not use pens that ooze ink too easily. Gel pens work well, but markers may work the best so long as participants attempt to lightly write on the TP. The key is to not have the writing bleed through or weaken the TP to the point where it tears.
  Toilet Paper tips – Cheap, flat toilet paper generally works best. Textured paper is okay; printed-paper can be distracting.

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.

Universal Coordinated Time (UTC): Universal Coordinated Time is an adaption of Greenwich Mean Time, but is maintained by over 300 atomic clocks all over the world and has features such as “leap seconds” to maintain better accuracy. It is commonly used by groups that need to share on a single time standard. Astronomers, pilots, and military organizations are common users of UTC. In the United States, Eastern Time is five hours behind UTC during Standard Time and four hours behind during Daylight Saving Time.

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 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 the planets in the Solar System and the Moon. The efforts of each group may be combined to create a complete "portrait" of the major Solar System objects 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, though reclassified as a dwarf planet in 2006). 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 (appendix/hands-on-activities/group-portrait/aquickguidetosettings.pdf)
- ❑ A copy of A Quick-Guide to Settings for the Telescope for each participant (appendix/hands-on-activities/group-portrait/telescopeobservationlogsheet.pdf)
- ❑ Copies of the daily list of what planet is up in the sky at each of the telescope locations (optional)
- ❑ Chart paper (or whiteboard)

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 activity book is not visible, adapt the activity accordingly. (Remember there are images in the MicroObservatory Image Archive of each planet.)

Refer to the "Exposure time" section in the "Introduction to MicroObservatory" guide at the start of the **MicroObservatory Computer Activities** 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, one of the Moon and one a planet. 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: the Moon, Jupiter
Observer 2 takes images of: the Moon, Saturn
Observer 3 takes images of: the Moon, Mars

Plan observations:

1. Participants use the MicroObservatory Image Archive (click on **get images**: then the link to the **Image Archive Directory** is at the top of the list of images) 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 telescope 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 of day is listed on the tables. Times are based on the 24-hour clock (military time). 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 by their group. Make sure they record the settings used in their observation on 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 digital-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. 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 activities using MicroObservatory.

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

Your eye versus the MicroObservatory telescopes
The MicroObservatory telescope gathers more light with its large mirror than your eye can. It has sharper "vision" and thus can see small details better than your eye and records the collected light for a longer time than the human eye. All three of these factors (collecting more light, better resolution and records data longer) make the telescope a more advanced 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 telescope's detector is very sensitive to even the smallest amount of light. This is a good thing since we are usually observing very faint objects. For these faint objects, we want to record all of the 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

Adapted from *From the Ground Up!*

Goals

- Make detailed observations of the images participants have taken using MicroObservatory
- Make detailed observations of planets found in the images
- Learn that the relative size of the object in an image contains information about both its size and distance
- Discuss 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, the “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? Participants have used 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 this group portrait of the Solar System, the youth will instead arrange their images from the closest to the furthest object.

Preparation

Space Required: Large room, tables

Materials:

- ❑ Images of the Solar System planets taken with MicroObservatory
- ❑ Images of the Moon
- ❑ Whiteboard 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 do not have images for all the planets use the MicroObservatory Image Archive to supply the missing pictures.

Write 1-2 questions from the Moon and Jupiter sections listed below onto the chart paper for each group. Additionally, have each group answer the question mentioned under “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:

The youth 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. They are to 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’s magnification was the same for all images. In other words, the images taken with the MicroObservatory telescopes are all on 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.

The Moon

Which direction is the Sun in your image? Why do you think that?
The Sun is the source of light for the Moon. The Moon is shining by reflected light.

Why did you have to use a gray filter?
To block some of the light: The Moon is so bright, you would need an exposure time shorter than the telescope can handle.

Why don't you see stars in the background of your Moon image?
The Moon is so bright that the exposure must be short. Therefore, the stars are underexposed.

Jupiter and other giant planets

Which is the biggest object in the solar system?
The Sun.

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 “Modeling the Earth-Moon System” 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, participants will have a better understanding of how to make sense of the images they take using 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

Station #3 Activity adapted 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
- ❑ Discuss the strengths and weaknesses of a model

Activity Overview

Youth are split into 3 groups; one group begins at a station in which they can get their hands on a real telescope. They interact with an amateur astronomer who explains 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 focuses 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’.

The third station has 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.

Ideally an adult facilitator will be available at each station, however instructions written for youth to self direct their own activities are available in the appendix.

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 1800s, 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 1970s 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 reinforce 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
- ❑ Protractors
- ❑ Instructions for youth at stations #2 and #3:
  Station #2 (appendix/hands-on-activities/telescopes-and-light/modelingtelescopes.pdf)
  Station #3 (appendix/hands-on-activities/telescopes-and-light/lasers.pdf)

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 the presentation and goals of hands-on the telescope time with the 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. Dim the lights or find a way to darken the corner of the room where you will set-up this station. Test out reflecting the image of the light bulb onto the chart paper and then try to focus it onto the piece of grid paper. Adjust the distance of the light source to the wall (see diagram #1) until you are able to bring the image of the light bulb with the ‘X’ into focus on the grid paper. 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:

Provide the youth with the following bit of history: 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. 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. The 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:

First, explain to the youth that they 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.

1. Briefly demonstrate 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.

2. 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 help, first have them use the mirror to focus the image onto the wall, then attempt to bring the other parts into the model (shutter, aperture, and detector).

3. 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 recreates how the MicroObservatory telescopes collect light, reflect it off of a mirror and 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. Participants should be restricted as to where they are able to place the mirror (see diagram #2 for the setup).

2. After the youth hit the target with 1 mirror, add another mirror and have them try to hit the target 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 initially strikes the mirror, then reflects off the mirror? They should be able to see that the angle of reflection is equal to the angle of incidence. Draw a line perpendicular to the surface of the mirror (This line is called the 'normal' and may help the youth see that the two angles are equal).

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. The spot where the 3 laser beams cross is called the focal point. Have the youth trace both the path of light, as well as the rough curve outlined by the positioning of the 3 mirrors.

6. They should notice that the mirrors take on a slightly curved arrangement. Bring out a make-up mirror and/or an image of a large curved primary mirror of a telescope. Explain how the curved mirror focuses light onto the telescope's detector—enabling astronomers to collect data.

Debrief:

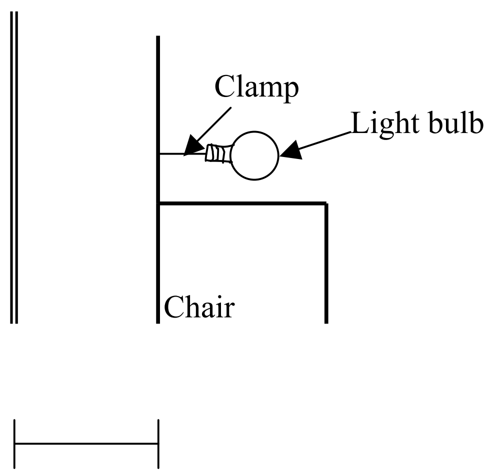
Lead a discussion with all of the participants using the chart paper as a guide. Ask them what they found out at each of the three stations. Record any important questions that come up as well.

Diagrams for station set-up:

Diagram #1: Light bulb setup for station #2

(Side view of setup)

Wall



About 1 foot

Front view of light bulb

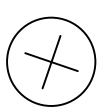


Diagram #2: Table for station #3

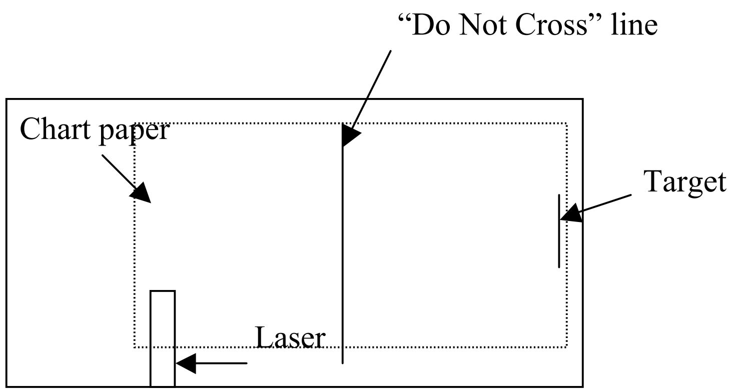
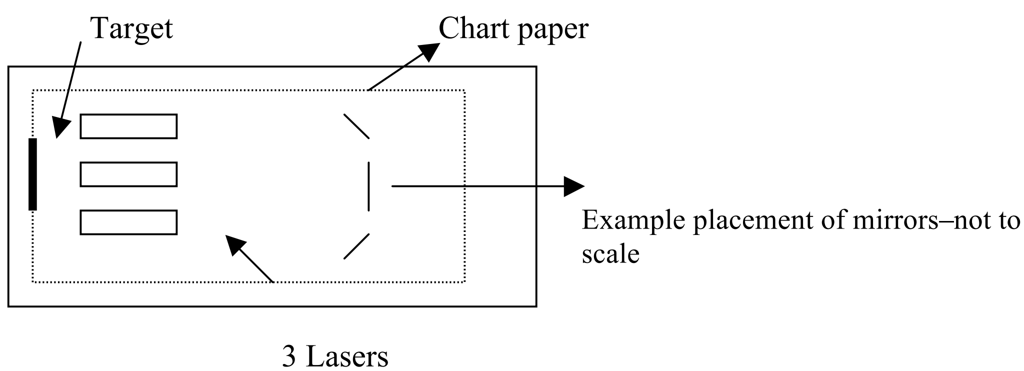


Diagram #3: Table for station #3



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 damage 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

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.
angle of incidence: The angle from which a ray of light strikes a reflecting object.
angle of reflection: The angle for which a ray of light is reflected from an object. The angle of reflection is always the opposite of the angle of reflection. For example, a particle of light that hits a mirror at a 45 degree angle will be reflected at -45 degrees.
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).
detector: A device used to show that something is present.
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.
in-focus: The state of maximum distinctness or clarity of such an image.
model: A generalized picture, analogy, or simplified explanation of reality
normal: An imaginary line that is drawn perpendicular to a reflecting optical element, like a mirror, regardless of whether or not the surface is curved.

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.

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 (appendix/hands-on-activities/astropoetry/) 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.

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. Wait on providing the chart paper so that they are not tempted to begin writing the poem before having at least 30 words needed to create a short poem.

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 not come up with just adjectives such as bright, shiny, but nouns, adverbs, and verbs. Remind them to write down only one word per slip 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, like, a, 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. Then hang the astropoetry somewhere in the room.

Sharing the Poems:

Have the pairs recite their poems to the group. Participants should practice good oral presentation skills 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

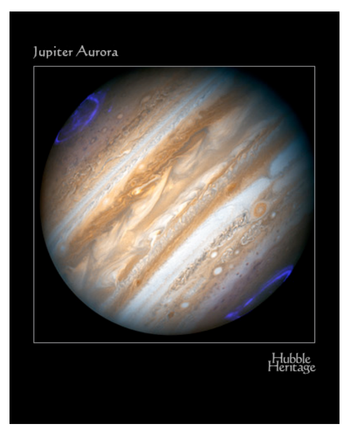
Participants' poems can be typed up and included as a part of the second or third observing project if the image they chose relates to their project. Otherwise the activity can be done again with an image that the youth have taken or are using for their observing project. This activity can be done many 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

Jupiter



Perfectly exposed aerial view of a cup with moose-track ice cream in it
Dark mole on a gigantic face
A bright striped circular marble
Gold faded tire tracks towards the center of sphere with purple and red outlines

Photo Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

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

Photo Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration

Tour of the Universe

Goals

- ❑ Gain an 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
- ❑ Discuss the strengths and weaknesses of a model

Activity Overview

Participants discuss the different kinds of objects in the Universe that they may have heard of or are familiar with. They are given sets of thumbnail cards with pictures of objects in the Universe and are asked to try and place them on the "map" of the Milky Way Galaxy. They are then provided with information about the proper location and distance of each object, and are asked to revise any inaccurate card placements. This revision includes using a long piece of string to approximate the distance to some of furthest objects away from the galaxy map in the model. The activity concludes with a debriefing.

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.

The Universe has a "nested" structure in that planets and stars are part of star systems, stars can be part of larger star clusters, star clusters are part of a larger galaxy, and there are billions of galaxies that then tend to cluster together in the Universe. In this activity this structure is broken into three categories: objects located inside our Solar System, objects outside the Solar System but still inside our galaxy, and objects outside of our galaxy.

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 deal with these huge numbers, astronomers use a unit called the 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. Still, 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 and part of the Milky Way Galaxy. We are inside the galaxy itself, and therefore cannot take a picture of it. 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 (appendix/hands-on-activities/tour-of-the-universe/tourcards.pdf)
- [ ] Objects in the Universe thumbnail image cards - one set for each group of participants (appendix/hands-on-activities/tour-of-the-universe/thumbnailcards.pdf)
- [ ] Tour of the Universe Chart for compiling the group's predictions (appendix/hands-on-activities/tour-of-the-universe/Tour_of_the_Universe_Chart.pdf)
- [ ] One Milky Way poster map per group (appendix/hands-on-activities/tour-of-the-universe/milkyway.jpg) (appendix/hands-on-activities/tour-of-the-universe/milkywaysmalla.jpg) (appendix/hands-on-activities/tour-of-the-universe/milkywaysmallb.jpg)
- [ ] Chart paper
- [ ] String
- [ ] Markers/pens

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

Activity time: 45 minutes

Gathering of materials and final preparations:

This activity requires a poster map of the Milky Way. Make sure each group has a poster-sized map of the Milky Way (milkyway.jpg). Most office supply stores can print the poster. The recommended size for the poster is 20 inches by 20 inches. Alternatively, a smaller version that may be printed on two 11x17" sheets is available in the appendix (milkywaysmalla.jpg and milkywaysmallb.jpg). When pieced together this map has the dimensions of about 15 inches by 15 inches.

Prepare sets of the image/description cards so there is at least one set for every 3 participants. (The 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).

The 20” X 20” galaxy map has a scale of 10,000 light years being equal to about 2 1/8 inches on the map (or about 5.4 cm). Using this scale, the distance to the nearest galaxy is 46 feet (from the Milky Way map to the Andromeda Galaxy). You will want to measure out a piece of string that is 46 feet long to represent this distance. When it is time to revise where the Andromeda Galaxy image was placed (towards the end of the activity) you can use this length of string to quickly walk the group out to 46 feet from the galaxy map. On the same scale the furthest galaxy included in this activity, NGC 4565, would be about 940 feet away. Regarding this object, it will not be feasible to go to this distance, therefore you should think of a local landmark or store down the street to provide as an approximation of this distance.

Note: Printing the galaxy map in halves (creating a 15” X 15” map) changes the scaled distances of objects from our galaxy. You will need to adjust the distances stated above (they will be slightly closer to the map) to account for the slightly different scale of the model.

Print the Tour of the Universe Chart (Tour_of_the_Universe_Chart.pdf) as a poster. On the poster, each group will record their guesses as to where objects in the Universe are located. If unable to create posters for each group, simply recreate the Tour of the Universe Chart on chart paper. You will want to have at least one poster version of it, or have the chart projected on a whiteboard, or interactive ‘smart’ board, so that you can tally the group’s predictions.

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 whiteboard or chart paper.

Using the list generated with the youth, 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 the whiteboard.

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 participants to place the thumbnail cards on the poster at the locations where they think each object is found in the Universe. Remind them that some objects could be outside of the galaxy.

2. Once they have placed all of their cards on the map, give them the Tour of the Universe Chart. The youth should fill out the chart to reflect where they placed each object.

3. Then give them the Tour of the Universe description cards. Have participants review the cards taking note of the actual distance and location of each object. This information should help the youth revise their chart and place 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. Using the description cards, participants should also identify a couple of interesting facts about each object. Explain that they will read the cards aloud to their peers and fill in the large Tour of the Universe Chart at the front of the room based on what they hear and learn.

5. As a group, place 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). Also make note of the actual distance to each object and its size (if known).

6. Now instruct the participants to revise their placement of the objects on their galaxy map. Knowing the actual distance in light years to these objects, they should use the scale bar in the bottom corner of the map to place the object at a reasonable location.

7. Participants will struggle to place the images of galaxies at appropriate distances. This is expected since galaxies are extremely far away. Using the 46 ft string, have one participant stand at the galaxy map and another take the other end of the string and unravel it until it is taut. Inform the youth that this string is 46 feet long and is an accurate representation of the distance to the Andromeda Galaxy, 2.6 million light years away. The spiral galaxy NGC 4565, which is 53 million light years away would be about 20 times further away, or down the street at the [name of local landmark]!

Debrief:

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

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?
- ❑ What features of the Universe does this model represent?
- ❑ What features of the Universe does this model misrepresent?
- ❑ What aspects of the Universe does this model omit, or not represent at all?
- ❑ What questions came to mind as we went through the demonstration?

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?

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 youth this can be a good time to familiarize them 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 if you adjust the scale (by printing the galaxy map on smaller paper for example), you must figure out in advance about how far the objects would be (especially the object cards of galaxies, they will be the furthest away). Keep in mind that some objects (the galaxies) may be outside of your building no matter the scale. With these objects, you may want to use the distance to a local landmark as an estimate as to where the object would be located (if they are reasonable estimates according to your calculations).

- ❑ 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 youth 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 how 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 lies 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 their preexisting ideas and provide them with the correct information to either support their ideas, or guide them towards the right concepts. This link may be helpful when guiding their inquiry: 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

A Journey through the Universe

PowerPoint presentation from *Journey to the Beginning of Time.*

Goals

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

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 (CD). 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. This 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 Galaxy is one of billions of galaxies that populate the Universe. In this interactive presentation the group will find our place in the Universe, beginning on planet Earth in our very own Solar System, and travel outward to the realm of stars, then 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
- ❑ CDs
- ❑ "Journey to the Beginning of Time" PowerPoint presentation
- ❑ Computer 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 based on 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 you can get sidetracked by some of these questions. During the presentation, answer those questions that are directly connected with the topic discussed. If a question is not directly related do not simply dismiss it. Invite participants to write down the question that you will then address at the end of the presentation or during the next session.

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.
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.
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.
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.
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.
The 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

Group Portrait of the Universe: Taking Images

Adapted from *From the Ground Up!*

Goals

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

Activity Overview

Similar to "Group Portrait of the Solar System," participants work in pairs or small teams to create a collection of images of different celestial objects outside of 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 Messier's system where each object is called 'M' and a number (For example the Andromeda Galaxy is M-31).

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 (appendix/hands-on-activities/group-portrait/aquickguidetosettings.pdf)
- ❑ A copy of Observation Log Sheets per participant (appendix/hands-on-activities/group-portrait/telescopeobservationlogsheet.pdf)

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" Chart for some examples.

As participants mention different objects, ask them what they know about them. Write down the group's responses on chart paper and post them somewhere in the room. (These notes will be useful for the follow-up activity, “Group Portrait of the Universe: Making Sense of Images.”) 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 imaging campaign to create a portrait of the Universe.

Form groups:

Three participants should make up each group. Each 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. Each group member should take two images of an object from one of the three categories of objects (star clusters, nebulae, galaxies), making sure that each category will be represented in the portrait. Note: Additional images can be taken using the MicroObservatory Guest Observer Portal.

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, prepare a list of targets that are visible in this period of the year with rise and set times. Make sure participants understand how to read the times given on the tables. The times are on the 24-hour clock in which 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 at the top of the listing page) to look for good images of their targets. They then check the settings used to take these images by clicking on “Image Info” and record the settings.

Take images:

Participants are now ready to take images of their targets. Make sure they write down the settings used in their observations on 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 desirable 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

Adapted from *From the Ground Up!*

Goals

- To create "a portrait of the Universe" to develop and expand participants' ideas about objects in the Universe
- Gain an understanding of the amount of information contained in a two-dimensional image of an astronomical object.
- Make connections between prior knowledge of astronomical objects and new observations

Activity Overview

Participants work in groups of 3 to examine the images they took to create a portrait of the Universe. The activity leader facilitates a general discussion for each of three categories: "Stars and Star Clusters," "Nebulae" and "Galaxies." The activity helps participants to realize that everything we know about the Universe comes from studying and interpreting the light coming to us from space. This information is contained in the images we take with a telescope. By analyzing the images, participants use their observing skills and make connections between their observations and prior knowledge.

The activity is also designed to help participants come to the understanding that doing science is not only about answering questions but asking them as well. The questions provided are to help keep the discussion going if a group starts to struggle (they should be posed one at a time to each group if their conversation becomes stagnant). Groups should formulate their own questions and attempt to reason through potential answers.

Background

The youth have created a portrait of the Universe by taking images of many different objects found in the night sky. However, the "Cosmic Cast of Characters" that they have assembled is just part of the ongoing story of the Universe. The images are but a snapshot in time. What kinds of stories do the images tell? What kinds of questions do they raise?

Preparation

Space Required: Computer lab

Materials:

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

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 themselves. If participants do not have images for all three categories, they may simply use images from the archive found on the MicroObservatory web page by going to **get images** → **Image Archive** → **Nebulae** (for example). Print archive images to complete the set. Additionally, print a MicroObservatory image of the Moon for each group.

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 for the youth to analyze these images, ask questions, and think about the answers to their questions. Once again, the following questions and answers are provided as a guide to help keep the discussion going. (They should not be photocopied or given to them all at once.)

1. Distribute to each group of 3 participants a set of images (either their own or from the archive). Reexamine the notes taken at the beginning of the "Group Portrait of the Universe: Taking Images" to remind youth about each type of astronomical object.

2. Ask the following lead-in questions to the entire group:

   How do we get information about 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 nearby 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?
   By 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.

3. Assign to each group one of the 3 categories of astronomical objects to focus on (either stars and star clusters, nebulae, or galaxies).

4. Instruct participants to closely examine their images and make detailed observations on chart paper. Have them list any questions that come up. Drawing from what they know about these objects, and their observations, youth should be encouraged to try and arrive at answers to their questions. (Some questions may be difficult to answer at this point, but be sure to keep track of these questions to be addressed at another time.)

5. Help facilitate the discussion by asking some of the following questions (one at a time) to the corresponding group. Groups should write their thoughts and answers on the chart paper. Once each group has time to wrestle with a few questions, have each astronomical object group summarize their findings aloud to the large group.

Making sense of the images - Stars and Star Clusters:

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?
There is no telescope in operation today that has been designed to image planets around distant stars. These planets are so faint and small that we typically use indirect methods to tell if they are there. However, the search for planets around stars other than our Sun, or extra-solar planets, is on the cutting edge of current astronomical research so check the news regularly for updates.

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. Planets reflect light from the star they orbit.

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. An example of this idea is 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:

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 cannot.

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 extremely short, you also need a 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 of 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:

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 so much further away than stars in our own galaxy, then why do the galaxies 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 relatively small apertures like 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 taken.

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 bring out the details of their images they took for the portrait 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 fact enables youth to 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 and how far they away 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 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 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.")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

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 from *Cosmic Questions Educator's Guide.*

Goals

- Learn that visible ("white") light can be broken into its component colors—all 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 colors
- Experiment and discuss how the information we gather from an object changes when we look at an object through a color filter

Activity Overview

Participants divide up 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 at the end of the activity.

This activity introduces participants to the visible spectrum of light and demonstrates what happens to an image when light with different energies, or colors, are blocked by filters.

Ideally an adult facilitator will be available at each station, however instructions written for youth to self direct their own activities are available in the appendix.

At Station #1, which you will lead, you can use either an overhead projector, or a LCD projector (depending on availability), and a diffraction grating to separate visible light into all of the colors of the rainbow. The participants will predict, record and observe what happens to the different color bands in the rainbow, or spectrum, on the screen when it is viewed through three different color-passing filters: red, green, and blue.

At Station #2 the youth examine a diagram of overlapping circles on a computer screen through red and green filters. Once again participants record their predictions, experiment by looking through the filters, and then record their findings.

At Station #3 participants experiment with three red, green and blue color-filtered flashlights observing the various colors produced with the different combinations. Then they are challenged to recreate "white" light (visible light) using the three primary colors of light—red, green, and blue.

After visiting these stations, participants reflect on the applications of light, color, and filters in the field of astronomy.

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.

Astronomers study the spectra of stars to learn many things, including how hot or cold stars are, their composition, and whether they are moving toward or away from us. Participants will also begin to develop an idea of the particle model of light, where small bundles, or particles, of light travel. Because light travels, the light particles can be blocked before reaching our eye or the detector on a telescope.

Color filters are powerful tools that scientists use to study light, specifically, to study what colors the light is composed of. A filter works by allowing only certain colors of light to pass through. We can think of these colors as different light colored particles *(the particle model of light)*. The filter will allow particles of only one color to pass through while blocking particles of all other colors. However, no filter can be "perfect." For example, a blue filter will allow several shades of blue to pass through, not just one. The same is true for both red and green (as shown in the graphs included below: notice that the shades of color that pass through the filter are those under the black line). Scientists try to choose filters that select only a narrow range of shades. In this way, they are able to determine quite precisely the color of objects in the Universe.

The filters we use in this activity have graphs that show the specifics of what colors of light pass through. Each one can be found on Roscolux's website. They are useful to explain why other colors may be visible through a given color filter.

Red filter: http://www.rosco.com/images/filters/roscolux/27.jpg
Green filter: http://www.rosco.com/images/filters/roscolux/90.jpg
Blue filter: http://www.rosco.com/images/filters/roscolux/74.jpg

Preparation

Space Required: A large room that can be darkened

Materials:

- ❑ Station #1 – Setup option A: LCD projector, PowerPoint slide with a white slit on a black background (appendix/hands-on-activities/light-color-and-astronomy/SpectrumActivities.pdf)
- ❑ Station #1 – Setup option B: Overhead projector, Cardboard for covering the sides of an overhead projector screen thereby creating only a thin vertical bar of light still projected
- ❑ Station #1 – Both setups require a large diffraction grating, and optionally many smaller ones, enough for each participant to have one
- ❑ Station #2 – Image of 3 overlapping color circles up on a nearby computer or printed onto a transparency for use on an overhead projector (appendix/hands-on-activities/light-color-and-astronomy/SpectrumActivities.pdf)
- ❑ Station #3 – 3 filtered Maglite flashlights (red, green, & blue)

- ❑ Instructions for youth at each station:
  Station #1 (appendix/hands-on-activities/light-color-and-astronomy/spectrum.pdf)
  Station #2 (appendix/hands-on-activities/light-color-and-astronomy/colordiagram.pdf
  Station #3 (appendix/hands-on-activities/light-color-and-astronomy/flashlights.pdf)

- ❑ Black marker
- ❑ Colored markers
- ❑ Masking tape
- ❑ Whiteboard or large sheets of white paper

The following three filters (http://www.rosco.com/us/filters/roscolux.asp)

- ❑ Red filter - ROSCOLUX #27
- ❑ Green filter - ROSCOLUX #90
- ❑ Blue filter - ROSCOLUX #74

- ❑ 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.

A note about the filters:
Have sets of smaller filters (big enough to cover the eyeball) to hand out to each of your participants. It is recommended that you double up the filters to decrease the amount of other colors that is passed through the filters. This will help the participants focus on how filters should work. Additionally, it is a good idea to tape the filters onto pieces of oak tag (the size of bookmarks) so that when handled, they do not become covered in fingerprints.

It is recommended that you use the specific filters listed in the "Materials" section. The reason being those particular filters have been tested to be the most effective filters for allowing light of its own color to go through while blocking light of other colors. 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 3 overlapping color circles on a transparency, or make preparations to have one of the stations at a computer with the color circles diagram 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 inch 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. This can be an added part of Station #2.

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 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 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 up the participants into 3 groups, and instruct them to begin their explorations at one of the 3 stations.

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

1. Create a large projected white slit on a screen or whiteboard 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 (see Gathering of materials and final preparations for more details). Create the spectrum by placing the diffraction grating over the upper lens of the overhead projector or over the LCD projector lens (Optional: 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.

4. Have the group make predictions regarding what will be seen when they look through the red filter. Then hand out filters once the group has discussed their predictions.

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.

6. Repeat these steps with the green filter and have participants record their findings on the chart paper. (Use a new piece of chart paper for each group.)

7. After completing steps 3-6 with both the red and green filter, discuss with the participants what they believe filters do. They should use their *observations* as the basis for their conclusions. Their observations should lead them to the understanding that a red filter allows red light through and blocks other light and that a green filter allows green light through and blocks other light. If they are not able to come to this conclusion, refer them back to their observations and their drawings on the chart paper.

8. Repeat steps 3-6 with the blue filter. They will see some green light with the blue filter, and you can explain that most filters are not "perfect" and do allow other colors to pass through. Because blue and green are very close on the visible spectrum, it is hard to find a blue filter that doesn't allow some green light to pass through.

Station #2 – Three overlapping circles:

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

2. Ask participants to predict what the diagram will look like when viewed through the different colored filters.

3. Instruct participants to check to see if their predictions were correct by looking at the diagram with the red, green, and blue filters.

   They will see some green light with the blue filter, and you can explain that most filters are not "perfect" and do allow other colors to pass through. Because blue and green are very close on the visible spectrum, it is hard to find a blue filter that doesn't allow some green light to pass through.

4. Have participants describe everything they notice. They should also draw a picture of their findings.
   - ❑ What happens if you use two filters together?

5. Next, show the secret message slide of the SpectrumActivities.pdf which contains the secret message Hi! on the slide with the message HELP (This can be done on the same computer).

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

7. 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.

8. 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 (Red. Green, Blue):

NOTE: 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.)

Ask participants to take the following steps:

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

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

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

4. Challenge #1: see if the youth can create "white" light!

5. Record findings on the chart paper.

6. 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.

Debrief:

Ask participants to reflect on their findings from each of the 3 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. This is the only way they can get information about these objects.*

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. Objects in the universe are different colors, so using filters can help us learn more about those objects.

Learning about what color light an object emits can tell us a lot about that object. If a star is blue, we know that that star is hot.

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: youth 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? In future activities, we recommend denoting the function of the filter by calling them the 'red-passing filter', 'green-passing filter', etc.

- ❑ Some of the youth may be colorblind, so be sure to ask 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 its behavior.

- ❑ If you decide to use the blue filter for Station #2 be prepared to explain to the participants why they see some of the light from the green and perhaps even the red circle.

- ❑ If you have a large group you may want to have large pieces of the color filter paper to place in front of the projector. This will simulate what your eye sees when viewing the spectrum through each of the color filters. This may be helpful if you do not have enough individual color filters for each participant to use.

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: A representation of the range of different colors that make up a given source of light. A rainbow after a rainstorm is an example of a spectrum, as the different colors making up sunlight are dispersed by droplets of water—each droplet acting as a tiny prism.

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 from *From the Ground Up*!

Goals

- ❑ Learn how to determine which color filter was used when each of 3 digital images were taken
- ❑ Learn that light carries a lot of information about the object from which it is emitted or reflected
- ❑ Understand that when combining a set of red, green, and blue color images a full-color image is created

Activity Overview

This activity begins with an opening discussion on light and color. Then there is a brief review of the function of a color filter and the outcomes of the “Light, Color and Astronomy Activity.” Next participants open the 3 digital images of sunflower in MicroObservatory. They look at the 3 black and white images and try to deduce which image was taken with which color filter. Finally, participants test their predictions by combining the images to get a full-color image. If incorrect, youth should make use of the hand-held filters to figure out where they went wrong.

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 1860s, 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.

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.

Preparation

Space Required: A computer lab

Materials:

- ❑ Computers
- ❑ Color Filters (red, green, and blue)
- ❑ Magnifying glass
- ❑ Images of sunflower taken through color filters installed on each computer
  (appendix/hands-on-activities/filters-puzzler/flower1.gif)
  (appendix/hands-on-activities/filters-puzzler/flower2.gif)
  (appendix/hands-on-activities/filters-puzzler/flower3.gif)
  (appendix/hands-on-activities/filters-puzzler/flowerRGB.gif)
- ❑ Print in color the Filters Puzzler (optional) (appendix/hands-on-activities/filters-puzzler/FiltersPuzzler.pdf)

Preparation time: 🕐 🕐

Activity time: 50 minutes

Gathering of materials and final preparations:

Gather all listed materials, and practice combining the 3 sunflower images to get a full-color image in MicroObservatory Image.

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. Tell the youth that the reason why these are the primary colors is that the eye has three different types of color-sensing cells that respond to red, green, and blue light. These color-sensing cells are 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 in the eye.)

Color Filters Review:

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. Then ask the following questions:

- ❑ Which part of the spectrum do you think will appear the brightest 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 brightest 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. Then ask them how their observations compare with what they predicted. Reaffirm that light particles of the same color as the filter used are able to pass through the filter while the other colors of light are blocked. For example, the red filter allows red light particles to pass through, while blocking the blue and the green.

4. Then ask the youth the following question:

   - ❑ Suppose you could only see black and white, or bright and dark, could you use the color filters to figure out the color of objects around you?

   Yes, you would be able to figure out what color a particular object is based on whether or not the object appeared bright or dark when viewed through the color filters. For example, you could tell that grass must be green by observing it through the green filter. The grass appears bright through the green filter and dark when viewed through the red or blue filters. (Another example, the EXIT sign from the "Light, Color, and Astronomy" activity would appear bright through the red filter, but dark through green and blue. Therefore you would know that the letters of the EXIT sign are red).

   However, it would be difficult to tell if an object is orange. When viewed through a red filter the orange object would appear bright (though not as bright if the object had been red). You may remember the secret message slide in the "Light, Color, and Astronomy" activity in which both the red and orange color particles came through the red filter to reveal the message 'Hi!' Within the word 'HELP.' Orange light contains some red light; therefore some of the light bouncing off an orange object would still pass through a red filter (causing the object to appear bright).

Filters Puzzler:

This puzzler helps you assess whether participants understand how filters function. For this activity you will use digital images of a sunflower taken using the 3 color filters and MicroObservatory or a color print-out of all of the sunflower images (However, in using just the printout the youth do not gain the basic processing experience of creating a full-color image).

1. First, ask the youth to recall their findings from the Color Filters Review portion of this activity. Try to elicit from the youth 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.

2. Break up the group into pairs, with each pair working together on one computer. Have each pair open the 4 digital images of the sunflower *flower1.gif, flower2.gif*, *flower3.gif* and *Sunflower.gif* in MicroObservatory Image (the image processing software). Explain to participants that when images are taken using the 3 different color filters the resulting image will appear bright in the areas where light came through the filter, and dark in the areas where light was blocked.

3. Each pair should examine the 3 black and white sunflower images and compare each to the full color sunflower image. They should notice what color each area of the image is in the full-color version. Then see if the youth can figure out which black and white image was taken using each of the color filters; red, green, or blue. Have them record their predictions.

4. Next, instruct the youth to add the color tables to each of the 3 black and white images corresponding to their predictions (For example if they believe a particular image was taken using the red filter, they should add the red color table). They can do this by clicking on the word **Process** in the menu bar, scrolling down to color tables, then selecting the desired color table.

5. Now that they have made their predictions, they can combine the three images by stacking them, and then converting them into an RGB image (or full-color image). **At this point the youth should close the full-color image of the sunflower they have open.** To stack the images, instruct participants to go back up to the **Process** menu, go down to **Stack**, and then scroll over and click on **Convert Images to Stack**.

6. Finally, with the images in a stack, have the youth click on **Process** again, go down to **Stack** and click on **Convert Stack to RGB**. If done correctly the resulting full-color image will look exactly like the color image of the sunflower they had open moments ago.

7. Ask the youth to review their predictions; if they were correct the sunflower image looks as it did previously. If not, they should try and figure out what went wrong by using the hand-held color filters. They can accomplish this by having all 4 images open and without color tables. If they look at the full-color sunflower image through the color filters it should look like one of the black and white images. Whichever filter they are using, that was the filter used when the matching image was taken. (Allow the youth to try and come up with this solution on their own before stepping in to guide their problem solving.)

Debrief:

1. Have participants report which of the original black and white images was taken with each of the 3 filters. Ask them how they were able to figure it out.

In **Image #1**, the blue sky is the brightest, so this was 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 brightest in this image.

2. Ask participants if anything surprised them about light, color and filters during the session. Have them write down any new questions they now have.

Follow up

The next step is to create full-color images using MicroObservatory 2.0 software. In the "Creating Color Images" computer activity participants create a full-color image from three black-and-white images taken using color filters.

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

Watch out for...

- ❑ Sensation of light: Many youth 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 perceive light, even though the eye produces no light of its own.

- ❑ Color filters: Youth 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/

YOUTH ASTRONOMY APPRENTICESHIP

MicroObservatory Computer Activities

Introduction to MicroObservatory

Overview of MicroObservatory

MicroObservatory is a network of automated telescopes - located in Cambridge, MA and Amado, AZ - that can be controlled over the Internet. Users of **MicroObservatory** are able to take their own images by pointing and focusing the telescopes, selecting exposure times, filters, and other parameters. The educational value lies not just in the image returned by the telescope, but in the satisfaction and practical understanding that comes from mastering a powerful scientific tool. Observations can be set up in advance and run automatically. Youth are actively involved in posing questions, designing investigations, gathering evidence, and interpreting their own results as they explore the Universe. Youth and after-school instructors control the **MicroObservatory telescopes** over the Internet, from the convenience of their computer labs. Youth reserve telescope time, check weather, choose targets, select exposure times, color filters and other parameters. The system is completely automated; there is no human intervention in the loop: you and your after-school group are in charge!

MicroObservatory Guest Portal

One of the easiest ways to take images with the MicroObservatory telescopes is through the **Guest Observer Portal**. All of the following activities can be completed using the Guest Observer Portal with some modifications. Approaching the activities this way removes the need to apply and enroll as a Guest Observer. It also makes the process of taking images very straightforward allowing the focus of the activity to be on the images and image processing. The drawbacks are (1) not being able to experiment with exposure times for the images, (2) having limited use of filters, and (3) only a small number of preselected objects are available for imaging.

Enrolling Participants in MicroObservatory

It is much easier if participants are enrolled in MicroObservatory prior to beginning the program. You can enroll participants as they register for the program or you can do them all at once as soon as your enrollment is complete.

By pre-enrolling the youth, you can test their **Guest Accounts** by actually logging in prior to the start of this exercise. This will significantly reduce the frustration levels of those who do not have a lot of experience using computers.

The information needed to complete the enrollment process for each participant is:

- First Name
- Last Name
- Street Address (Optional)
- Town
- State
- Zip Code
- Country
- Phone Number (optional)
- Email Address (students may use their sponsoring teacher's email address)
- School / Institution
- Profession (if applicable)
- Age
- Gender
- Grade
- Computer Experience: Novice, Intermediate, Advanced
- Username
- Password

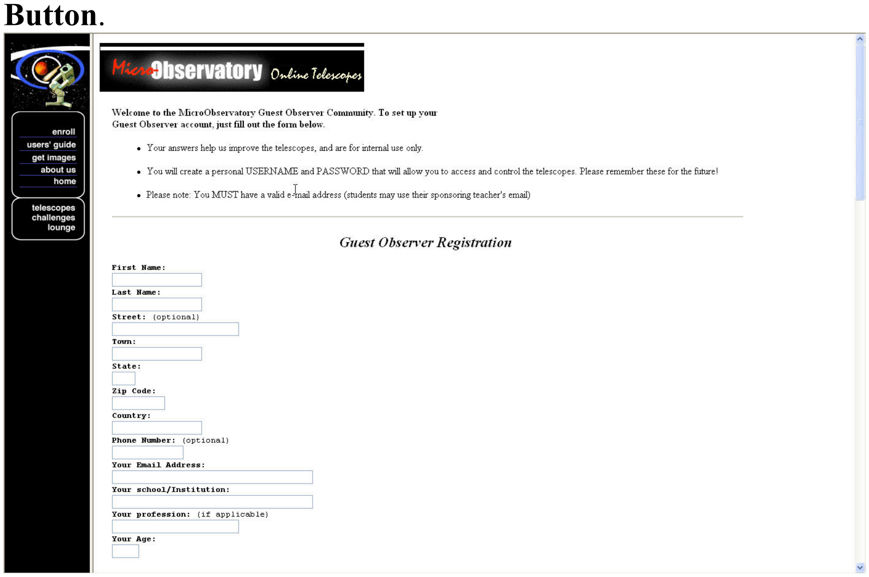
Additionally you will be asked about the browser and operating systems in use at your computer lab. Be sure to record the participants' usernames and passwords in a safe place.

- ❑ Obtain your guest access code from the staff at MicroObservatory.
- ❑ Start from the MicroObservatory main page: http://mo-www.harvard.edu/MicroObservatory/index.html

- ❑ Click **enroll** at the top of the navigation frame on the left side of the screen.

- ❑ At the Who Should Apply? Screen, click **Setting Up Your Guest Observer Account**.

- ❑ Enter your **guest code** in the text box. Click the **Display Form Button**.



- ❑ Complete the information for each participant. In assigning passwords for the youth, make sure that it is something that they can remember. The password can be changed if they forget.
- ❑ When all the information for the participant has been entered, click the **Register** button.

Repeat these steps for each person in the program.

Taking Images with MicroObservatory

Background:

You are about to use a telescope that can detect objects far beyond our own galaxy... objects so distant that their light has been hurtling through space since before the first life emerged on land, nearly a billion years ago.

This telescope will do no more and no less than what you command it to do. Learn how to use it properly, and it will take you on a great adventure out in space and back in time, across our galaxy and far beyond. Go out and look at the sky on a clear dark night. No machine can replace your own eye... or your mind's eye. Get to know the constellations, when they rise and set, how they change with the seasons. They will be your road map as you navigate the Universe. Find good star charts. Read about the sky and learn which celestial events are headed your way. Try the challenges and puzzles that we will provide from time to time (in the **Challenges** section of the MicroObservatory website, accessible from the homepage.

Above all, let your own curiosity and wonder be your guide. Get to know the mysteries of the Universe that others, like you, are trying to solve.

Enrollment:

You must be enrolled in order to control the telescopes. Enrollment is free, but is currently by invitation only. Even if you are not enrolled, you can explore all parts of MicroObservatory, including the latest images that users have taken, along with challenges and puzzles.

Web Browser & Internet Service:

You will need Internet Explorer, Firefox, Safari, or a similar **web browser** that supports "frames" (multiple windows). Your browser's window should be opened to its full width. To get more viewing area, some browsers allow you to hide or shrink the control buttons at the top. You will also need to be able to access the Internet.

Software:

You do not need special software to view images from the telescopes. However, in order to get the most out of your images, it helps to have **image processing software** that lets you adjust the brightness, contrast, or remove the background noise in your images. The telescopes can also return images in the FITS format, which contains more information, than GIF format. To view or process images in FITS format, you will need special software (see “Processing Your Image” for instructions on how to obtain the necessary software).

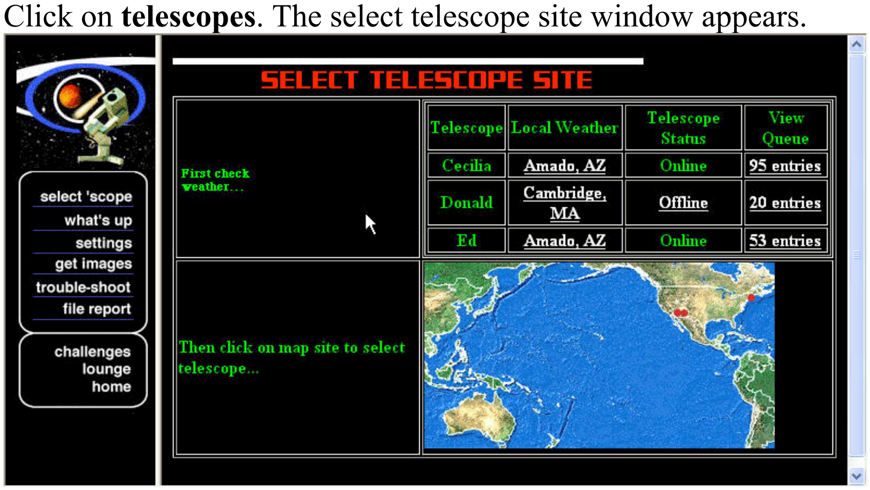
Accessing the MicroObervatory Home Page:

Start from the MicroObservatory main page:
http://mo-www.harvard.edu/MicroObservatory

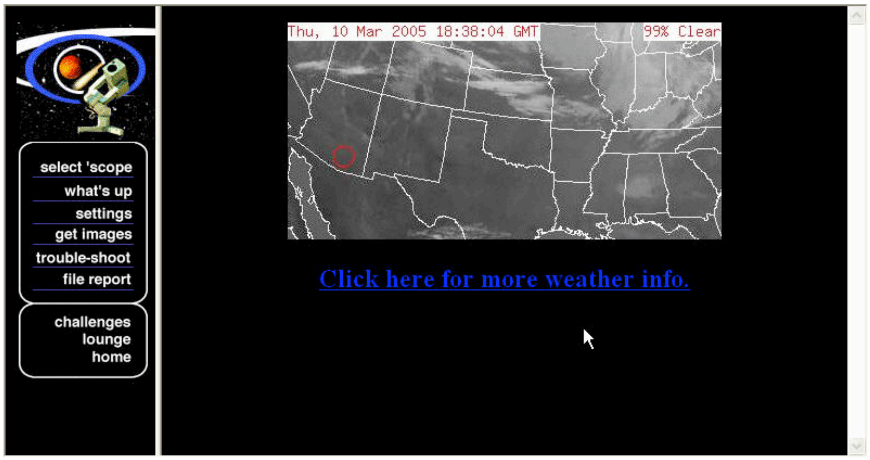
.

Selecting a Telescope:

Click on **telescopes**. The select telescope site window appears.

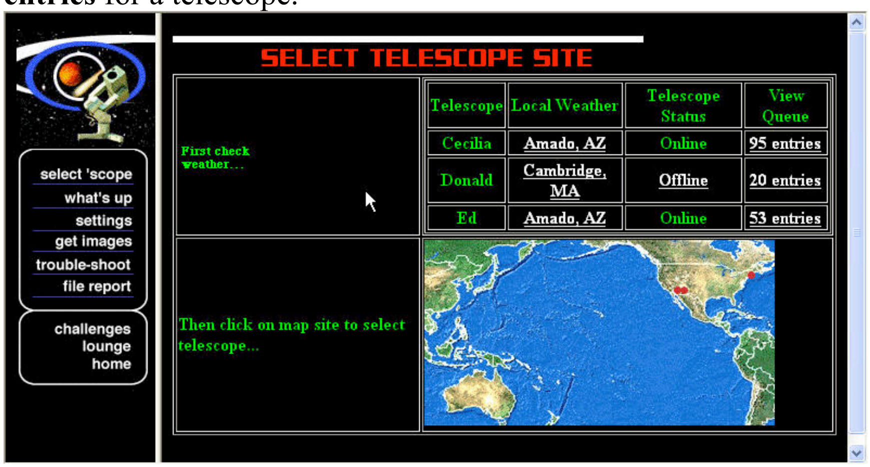


You should check the weather at a telescope's location before you use the telescope. Check the weather and forecast at a particular telescope site by **clicking name of the city** in which the telescope is located. The telescopes should only be used under clear skies.



Click **select 'scope** to return to the **Select Telescope Site** screen.

Check the availability of time slots for the telescope. Click on the **entries** for a telescope.



The number of images already scheduled for a particular telescope is displayed.

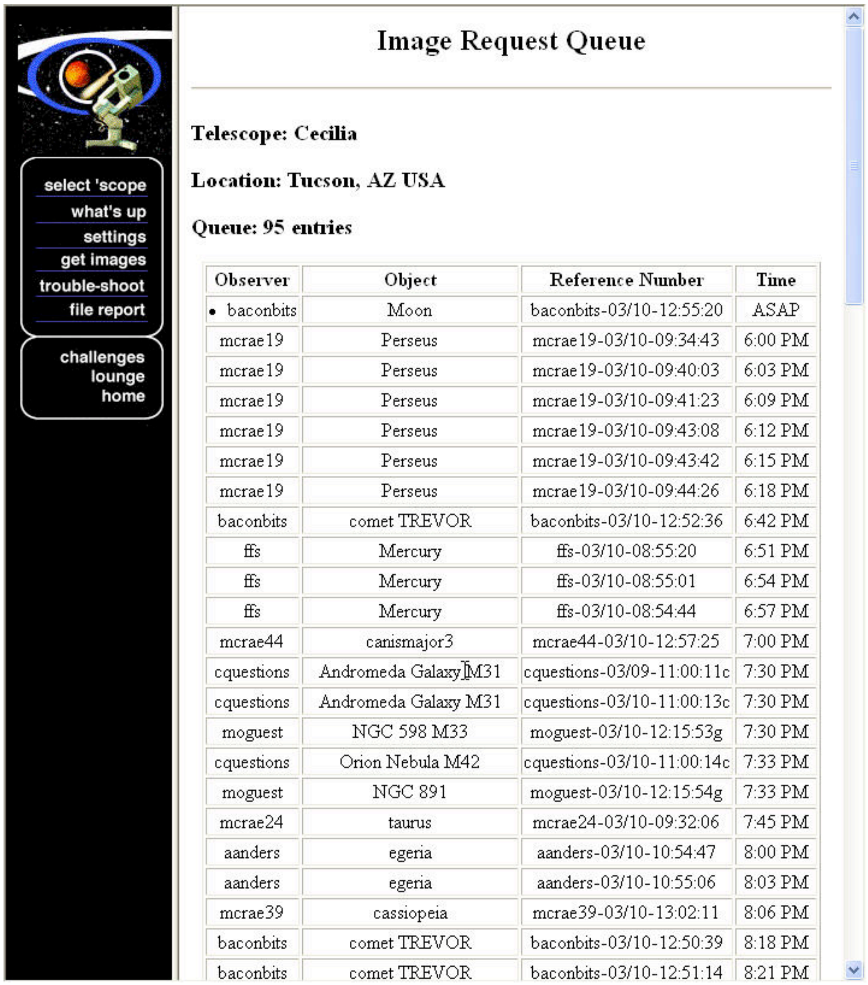


Image Request Queue

Telescope: Cecilia

Location: Tucson, AZ USA

Queue: 95 entries

Observer	Object	Reference Number	Time
• baconbits	Moon	baconbits-03/10-12:55:20	ASAP
mcrae19	Perseus	mcrae19-03/10-09:34:43	6:00 PM
mcrae19	Perseus	mcrae19-03/10-09:40:03	6:03 PM
mcrae19	Perseus	mcrae19-03/10-09:41:23	6:09 PM
mcrae19	Perseus	mcrae19-03/10-09:43:08	6:12 PM
mcrae19	Perseus	mcrae19-03/10-09:43:42	6:15 PM
mcrae19	Perseus	mcrae19-03/10-09:44:26	6:18 PM
baconbits	comet TREVOR	baconbits-03/10-12:52:36	6:42 PM
ffs	Mercury	ffs-03/10-08:55:20	6:51 PM
ffs	Mercury	ffs-03/10-08:55:01	6:54 PM
ffs	Mercury	ffs-03/10-08:54:44	6:57 PM
mcrae44	canismajor3	mcrae44-03/10-12:57:25	7:00 PM
cquestions	Andromeda Galaxy M31	cquestions-03/09-11:00:11c	7:30 PM
cquestions	Andromeda Galaxy M31	cquestions-03/10-11:00:13c	7:30 PM
moguest	NGC 598 M33	moguest-03/10-12:15:53g	7:30 PM
cquestions	Orion Nebula M42	cquestions-03/10-11:00:14c	7:33 PM
moguest	NGC 891	moguest-03/10-12:15:54g	7:33 PM
mcrae24	taurus	mcrae24-03/10-09:32:06	7:45 PM
aanders	egeria	aanders-03/10-10:54:47	8:00 PM
aanders	egeria	aanders-03/10-10:55:06	8:03 PM
mcrae39	cassiopeia	mcrae39-03/10-13:02:11	8:06 PM
baconbits	comet TREVOR	baconbits-03/10-12:50:39	8:18 PM
baconbits	comet TREVOR	baconbits-03/10-12:51:14	8:21 PM

From this screen you can determine who has requested images, the celestial objects are being photographed, and the time when the pictures are scheduled to be taken. You should scroll through the list of images to determine free times.

Images can be scheduled 3 minutes apart.

Once you have determined that skies are clear at the desired location and you know when there are free times for your telescope, click **select 'scope** to return to the **Select Telescope Site** screen.

Select a telescope on the world map. To select the telescope that you want to control, click on one of the red dots on the map.

You are now on the **Control Telescope** page. Keep in mind that the process that follows is the same independently of the telescope you choose.

Controlling a Telescope:

Enter username and password. The username and password for each participant is determined when the participant registers online.

When to take an image

You will need to know when the object you want is above the horizon and high enough for you to take a clear image. (Usually, the higher in the sky it is, the clearer the image, because the telescope has to look through less atmosphere.) You can use astronomy magazines, other websites, or the information in this site to help you figure out what's up and when. This information can be found by clicking on **what's up** on the frame at the left of the screen. (From there, most of the information you will typically need can be found by clicking on the word **list.**)

Daytime

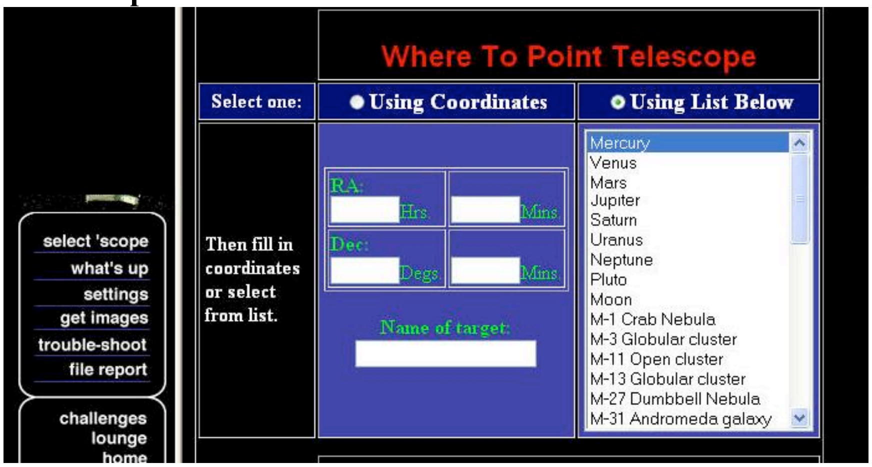
During the daytime (6 AM to 6 PM at the telescope's location), you can use the telescope "live". This is ideal for observing the Moon from your site, when it is up during the daytime. Some planets are also observable during the day! Sorry, the telescope cannot take images of the Sun.

At Night

To take an image at night, you must set the telescope controls in advance; the telescope will automatically take the image at the time you specify.

Enter the time when you would like to take an image. The time you enter will be the *local time* for the telescope. To have the telescope to take an image at night (between 6 PM and 6 AM), select AM or PM. If the time slot is already taken, the telescope will let you and the participants know right after you try to take a picture.

Point the telescope



You can point the telescope in two different ways. Be sure to select the appropriate button:
Enter the coordinate of the objects
Using the list of objects whose coordinates the telescope already knows (Simply click on the object name on the list).

Using Coordinates

You can enter the **coordinates** of the desired object. These coordinates, called **right ascension** (RA) and **declination** (Dec) are like a Zip Code that tells the location of an object on the sky. You can enter coordinates for distant objects such as stars and galaxies that are not on the adjacent list. You can find an object's coordinates from star charts and catalogs available in books, magazines, on the Web, or elsewhere on this site (through charts available under **what's up**). Note: The telescope's computer automatically takes into account the rotation of the Earth when it points the telescope.

Using List Below

Use the convenient list for viewing the Moon and planets and many popular star clusters, nebulae, and galaxies. Objects that are inside our Solar System (such as the Moon, planets, and asteroids) appear to move against the "fixed" background of distant stars, and so their coordinates change with time. The MicroObservatory computer will automatically calculate the position of the object at the desired time and point the telescope for you. Note: The Information returned with your image lists the actual coordinates (RA and Dec) used.

Controlling Camera Settings

Finder Camera

The **finder camera** has a 10-degree field of view (about half the size of the constellation Orion). Use the **finder** for observing constellations, comet tails, and other objects that spread across the sky. Normally you will be using the telescope's **main camera**.

Main Camera

The **main camera** is used for most work. Its 1-degree field of view comfortably includes the Moon, planets with their moons, and all galaxies and nebulae except the Andromeda galaxy, M31.
You will normally use the telescope's main camera. Inform the participants to always use the main camera unless you tell them differently.

Exposure time

The MicroObservatory telescope's light-sensing camera has a shutter that can remain open anywhere from 0.05 seconds to 60 seconds when you take an image. The time the shutter stays open is called **exposure time**. The longer the exposure time, the more light that the telescope can gather to make an image. The recommended exposure times for various targets are:

Object	Time of day	Select target with...	Exposure Time	Filter
Moon	Day or Night	Pull-down Menu	0.1 - .05 sec	Gray (Neutral Density Filter)
Planets	Night	Pull-down Menu	0.1 – 2.0 sec	Clear (No Filter)
Stars	Night	Coordinates	0.1 – 10 sec	Clear (No Filter)
Star clusters	Night	Pull-down Menu or Coordinates	5 – 30 sec	Clear (No Filter)
Nebulae	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
Galaxies	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
Asteroids / Comets	Night	Coordinates	15 – 60 sec	Clear (No Filter)

Filter

A filter is a device that prevents some of the light from the celestial source to reach the light-sensing camera. The default selection is **clear filter** which is really choosing to not use a filter at all. For very bright objects such as the Moon, you must use a **grey filter** (called a **neutral density filter**) to prevent the camera from being inundated with light. The grey filter reduces the light that reaches the camera by a factor of 10,000. There are other filters: **red**, **green**, **blue** and **IR (infrared) filters**. They all reduce the amount of light that reaches the camera.

Zoom In / Zoom Out

Select **zoom out**. Normally you should use zoom out, which is the default setting. Use **zoom in** only when trying to image a very small object such as the rings of Saturn. Be warned that the zoom in will not return a larger image. Instead it will return only the central part of the image you would get with the zoom out setting.

Focus

Ignore the **focus** command. The telescope focuses automatically. The default focus always produces the sharpest image. Manual focusing is only used for specialized experiments that require the telescope to be unfocused.

Taking the Picture

Click the **Take Picture** button when ready. Before selecting this button make sure you enter all the required information. When you click on **Take Picture** the server tells the telescope to take an image at the time you selected. A screen will automatically appear to confirm your request. If you have forgotten any required information, the screen will prompt you to re-enter it.

Note: On some browsers you will have to re-enter all the information again, or at least username and password. Remind the participants to take their time when entering their request; it will save time in the long run.

Take another image

After successfully taking the first image you can click on select 'scope at the top of the menu on the left to go back to the **Control Telescope** page (or click the back button on your browser) to take additional pictures of the object you initially selected or of another celestial object. If taking an image of the same object, be sure to select a new time for your observation since you just filled the time slot that is still currently selected if you returned to the Control Telescope screen by hitting back on your browser. It is a good practice to always take a couple of pictures of the same object with the same selection of parameters to make sure to get at least one good image.

Getting your image:

The telescope will take the image at the time you requested or as soon thereafter as the traffic permits. It takes from one to several minutes to take an image. This includes the time to point the telescope, take the exposure, and download the image over the Internet to the MicroObservatory server in Cambridge, MA.

The telescope will automatically send you an email when your image has been taken. If your mail-server alerts you to incoming mail only at long intervals, you may find it faster to simply check the **queue** for the telescope on the **select telescope** page. The **queue** lists all images still waiting to be taken.

When your image has been taken, it will be listed in the **MicroObservatory Image Directory**. You can access this directory from many parts of the website by clicking the button **get images**.

Images are listed in the order they were taken, with the most recent image at the top. If you prefer, you can re-sort this directory to list images alphabetically by username. Just click on the column heading, **Username**. That way, all your images will be grouped together.

Viewing your image:

Just click on the filename and the image will appear on screen, in **GIF format**. If you are viewing a series of images, you may wish to view just a thumbnail image for each (this reduces the page load time). Simply click on **info**, to the right of the filename for your image (on the Image Directory page, it can also be accessed by clicking on **Image Info** to the left of the filename from the page where you can download the image). You can keep scanning through your thumbnail images, using the arrows at top.

Viewing images in FITS format

The telescope takes images in **FITS format**, which contains more visual information that the GIF format used on the Web. The computer then converts the image to GIF format, and saves the image in both the GIF and FITS formats. The original FITS image is useful for advanced image processing, for measuring the brightness of objects, and for viewing fine detail. To retrieve a FITS image, first examine the GIF image by clicking on the filename. Then click on the **Save/Download Filename.FITS** image link at the top of the image. The browser will prompt you to save the FITS image. You will need special software to view or process this image. See "Processing Your Image" for instructions on how to obtain the software.

Information about your image

The telescope records a great deal of useful information about how each image was taken. To view this information, click on **info**, to the right of the filename of your image (on the Image Directory page, it can also be accessed by clicking on **Image Info** to the left of the filename from the page where you can download the image).

Saving (Downloading) FITS files

You should set up a folder for your images on your computer or network. The directions for saving files using common computer systems and Internet browsers are:

Macintosh - Internet Explorer
Select "Download Link to Disk"

Macintosh - Safari
Control-Click
Select **Save this Link as...**
Make sure to choose Source as the Format when saving the file.

PC (Windows) - Internet Explorer
Click on filename underlined in blue that says **Save/Download**.

Deleting an image

Images will be saved in the **Image Directory** for one week and then deleted.

Processing Your Image

There is a lot more information in a typical image than meets the eye. To bring out the fine details, you must process your image. Following is a brief description of the kinds of processing that may be useful in your experiments. During the course of this program you will learn how to process your images using the image processing software MicroObservatory Image 2.0. The software is available for free and can be downloaded from http://mo-www.harvard.edu/MicroObservatory/. (Click on **Bring out more detail in your image with MicroObservatory Image 2.0** in red at the center of the page.)

Adjusting Contrast And Brightness

This is the simplest processing you can do. It is very useful for faint and low-contrast objects like galaxies or nebulae.

Background Specks

Some (or many) of the little white dots in your image are not stars: If they are a single **pixel** ("picture element") wide, they are likely to be what is commonly called **"hot pixels"**. “Hot pixels” look bright not because of light gathered from an external source, but because of the unwanted heat produced by the electronics within the detector. “Hot Pixels” are a component of **background noise**.

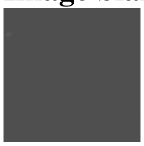
Background Noise

Any kind of signal recorded by the detector that is not produced by the light gathered by an external astronomical source. As such, this “noise” negatively affects the quality of the image. A method to correct for this noise is **dark subtraction**. In this method, you use the opaque filter and try to take a picture. However, you will not get a completely black image as you might expect. This is because the telescope's light-sensing chip itself produces electronic "noise" that is interpreted as faint light. By subtracting out this noise from your image, you can bring out faint details. To do this, you need to use an image-processing program (such as MicroObservatory Image 2.0) that allows you to subtract one image from another, that is, to subtract the **dark frame** taken with the opaque filter from the image you want to enhance. (Both images must have been taken with the same exposure time.)

Typical Image Problems

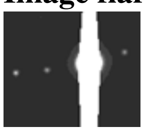
There are typical image problems that participants will almost certainly encounter when using the MicroObservatory telescope. Make sure to address these problems early on to prevent participants from growing frustrated if unable to get a "good picture." Typical image problems are:

Image blank



Exposure was too short. Opaque filter accidentally used. Overexposed (image is completely black on web, but white in MicroObservatory Image 2.0)

Image flaring

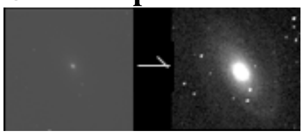


There was too much light. Cut down exposure, or for bright stars in a field, ignore. Most images of the planets show a bright vertical line, stretching top to bottom. There usually is a thicker ball of light in the middle of this vertical line. That's where the planet is located. The reason is that planets, being relatively close, reflect a lot of light from the Sun. They are very bright, much brighter than the fainter and further galaxies, nebulae and many stars. The digital detector cannot record all that light in one spot, so it 'spills over' to the next part of the detector. Just like a bucket collecting water, if it gets too full, it spills the extra over the bucket's lip. Think of the detector as a large mosaic of water buckets that catch and record light. If there's too much light in one bucket, it spills into the next one above and below it. (Note: spillage does not happen on each side!) To prevent this light 'spillage', use shorter exposure times. You might also need to use the grey filter, like you do when imaging the Moon. That filter blocks much of the light from the object.

Blurry Image

An image can be blurry for several reasons. If you changed the focus value for the telescope's camera from the default value, you will most likely get an out of focus image. If it was cloudy when the telescope took its image, the clouds can act as diffusing or blurring filters. Even large temperature changes in the telescope can sometimes cause the telescope to take blurry images. The optics and metal parts expand or shrink on the telescope, causing the precise distance between the mirror and detector to change just enough to cause a blurry image. The image might be blurry because the tracking motor slipped a little.

Contrast poor



You may want to PROCESS your image further.

How can my group take images that will come out?

Some things to consider

When is your desired object visible in the sky? Make sure you choose the correct time and place to point the telescope, and don't forget that clouds block our view of the sky when it is cloudy.

How bright is your object in the sky? Make sure you choose to leave the shutter open long enough to allow enough light onto the detector, but do not leave it open too long or the detector will saturate (fill up) and cause an image flare (see the previous example). The length of time the shutter is open is known as exposure time. Objects like single stars and planets are very bright, so they require shorter exposure times, while objects like nebulae and galaxies are faint, requiring longer exposure time.

There are other factors that affect whether or not your picture comes out. If you are looking for guidance, you can look at the MicroObservatory image archive and find a picture that you like and look at its Image Info. This will tell you what somebody else did to make a picture of that object come out. If you are taking a picture of the same object (or a similar object) you should be able to recreate a similar image, using the archived information.

Finally, getting images to come out takes practice. The more you take images yourself the better you will become at directing your participants to become experts themselves. Be persistent and methodical in your approach. Don't give up!

Overview of Computer Activities

Here is a complete list of the computer-based activities, in the suggested implementation order, with a few words summarizing what each is about.

1. **MicroObservatory Guest Portal**
    - *Use the guest portal to take first images with telescopes*
2. **Introduction to MicroObservatory**
    - *Download and save images from guest portal usage*
    - *Use the telescope control page to take more images*
3. **Image Processing and Contrast**
    - *Use image processing software to learn about image contrast*
4. **Images as Data**
    - *Relate pixel values to light captured by detector*
    - *Distinguish between observation and inference*
5. **Group Portrait of the Solar System: Taking Images**
    - *Create a set of images of the objects in the Solar System*
6. **Investigation of Jupiter and Its Moons: Taking Images**
    - *Take images of Jupiter and its moons over the course of one evening to study the motion of the moons*
7. **Group Portrait of the Universe: Taking Images**
    - *Create a set of images of the objects in the Universe*
8. **Investigation of Jupiter and Its Moons: Making a Movie/Making Sense of Images**
    - *Create a movie of Jupiter's moons*
9. **Advanced Image Processing**
    - *Learn more about image processing – false color, noise reduction, image calculator, etc.*
10. **Group Portrait of the Universe in Color: Taking Images**
    - *Take filtered (red, green, blue) images of objects in the Universe*
11. **Creating Color Images**
    - *Learn to create 3-color images using stock images, and then their own images*

Vocabulary

automated telescope: An automated or robotic telescope provides a way for observers to collect data (images) without actually "observing." An automated telescope can be programmed to take a picture (or many pictures) of stars or other objects in the night sky. It can be useful for many types of projects. Examples might be photographing Jupiter every day, or capturing images of objects that are visible only at inconvenient hours, like the third quarter moon.

browser: A program that allows a user to find, view, hear, and interact with material on the World Wide Web. Netscape Navigator and Microsoft Internet Explorer are examples of popular browsers.

download: To transfer (copy) files from one computer to another. "Download" can also mean viewing a Website, or material on a Web server, with a Web browser.

e-mail (electronic mail): Messages sent through an electronic (computer) network to specific groups or individuals. Though e-mail is generally text, users can attach files that include graphics, sound, and video. E-mailing requires a modem to connect the telephone line to the computer, and an e-mail address. E-mail addresses include the @ symbol.

internet: A "network of networks" linking millions of computers worldwide for communications purposes. The Internet was originally developed in 1969 for the U.S. military and gradually grew to include educational and research institutions. Today commercial industries, corporations, and residential users all communicate using the Internet. The World Wide Web is a collection of interactive documents accessible via the Internet.

link: A word, phrase, or image highlighted in a hypertext document to act as a navigation aid to related information. Links may be indicated with an underline, a color contrast, or a border.

upload: Copying or sending files or data from one computer to another. A Web developer, for example, could upload a document to a Web server.

web interface: A window screen that can be access through the Internet. Through this window you can interact or communicate with another device usually located away from you. In our case an observer can communicate with the MicroObservatory telescopes through a web form – the web interface - found on the MicroObservatory website.

world wide web: A vast collection of files, including text, graphics, and other data linked through the Internet.

MicroObservatory Guest Observer Portal

Adapted from *Beyond the Solar System DVD*.

Goals

- Understand that the Guest Observer Portal allows users to remotely control the MicroObservatory telescopes
- Use the Guest Observer Portal to take images
- Learn that different objects require different exposure times (optional)

Activity Overview

This activity introduces participants to the MicroObservatory telescopes through the Guest Observer Portal. Participants choose which object the telescopes will photograph. They receive an email with a link to the image after it is taken. They may explore the concept of exposure time as they choose what the correct exposure time for a given object is, although this may be left for the second time they take images with the Guest Observer Portal. See the "Follow up" section for more information.

Background

The Guest Observer Portal has 5 categories, under which, there are many celestial objects participants can choose to image.

- **Galileo** – contains some of the objects that Galileo observed
- **Colorful Cosmos** – contains nebulae that are colorful
- **Black Hole Search** – contains objects or areas of the sky known to harbor black holes**.**
- **Galaxies Galore** – contains spiral, irregular and elliptical galaxies
- **Telescope as Time Machine** – contains an assortment of objects at different distances from Earth

With the changing of the seasons on Earth, there is a change in what objects are visible in the night sky. Objects that are visible in the night sky in June may not be visible in December. These changes are a result of the

Earth's motion around the Sun – as the Earth moves along its orbit, the Sun's position with respect to the stars changes.

Preparation

Space Required: Computer Lab

Materials:

- ❑ 1 Computer for every 1-2 participants

Preparation time: 🕐 🕐

Activity time: 30 minutes

Gathering of materials and final preparations:

- ❑ Go to the MicroObservatory website: http://mo-www.harvard.edu/MicroObservatory. Add this page to the Favorites (or bookmark this page) to make it easy to return to the telescopes whenever you want.
- ❑ Become familiar with all the objects in the Guest Observer Portal. As explained in the "Background" section, some of them will not be available due to the season. These will be greyed out.
- ❑ 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:

Introduce MicroObservatory telescopes to the participants and tell them they will be able to take images of stars, planets, nebulae, galaxies and more using telescopes located around the US (currently in Cambridge, Massachusetts and Arizona).

Take Images:

1. Have participants open the MicroObservatory home page (http://mo-www.harvard.edu/MicroObservatory) and click on **Try it yourself. Visit our Guest Observer Portal!**. A new window will pop up with links to the five different categories.

2. The **Galileo** or **Telescope as Time Machine** are good starting categories, as many of the youth will want to take images of objects they are familiar with, such as the Moon.

3. Have the participants read and follow the instructions on the screen.
    - ❑ **Getting Started** – read the paragraph and have participants notice where on the map the telescopes are located. **Click Continue**
    - ❑ **Select an Object** – have participants select an object and read the orange text that appears on the screen. **Click Continue**
    - ❑ **Exposure Time** – have participants choose an exposure time for their object. Each object will have a different exposure time, based on the brightness of that object. The portal will give feedback to the participant if they choose the wrong time, and they will not be able to continue until the correct time is selected. **Click Continue**
    - ❑ **Your Info** – have participants enter their email address, and choose their age and state. **Click Continue**
    - ❑ **Review Request** – have participants review their request. If needed, they can edit their target or email address (exposure time will always be correct). **Click Submit**

Follow up

Participants can use the images they took during the first session to generate questions about exposure time verses object type. They can then go back to the Guest Observer Portal and make note of the exposure times needed for their object.

If you have requested access and have enrolled the participants, they will learn to use the Telescope Control page to take images.

Watch out for...

- ❑ There is a tendency to refer to the MicroObservatory telescopes as a website, rather than a network of telescopes, controlled remotely via a website. It is important to stress the fact that the youth are controlling telescopes, very much in the same way professional astronomers do—using a computer to schedule observing time. Where possible, refer to MicroObservatory as remotely controlled telescopes, rather than a website.

Vocabulary

bookmark: A file within a browser in which an Internet user can save the addresses of interesting or frequently used Websites, so that they are readily available for re-use.

celestial object: A natural object, like a star, planet, comet, galaxy, etc. that is observable in the sky.

exposure time: The period of time a telescope's light-sensing camera collects light coming from the source one wants to take an image of. The longer the exposure time, the more light that the telescope can gather to make an image. The recommended exposure time varies for various targets: faint targets, such as far away galaxies, require long exposure times; bright targets, such as the Moon, require short exposure times.

favorite: In Internet Explorer, a favorite is a collection of Web addresses selected by the user. Favorites are stored in a folder and are accessed by selecting the Favorites menu. Favorites provide an easy way to organize the Web addresses of interesting sites.

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.

target: In astronomy the celestial object one takes a picture of is called target.

Useful Websites

MicroObservatory Website:
http://mo-www.harvard.edu/MicroObservatory

How to Take and Save Images with MicroObservatory

Adapted from *From the Ground Up!*

Goals

- View, download, and save images taken with MicroObservatory
- Take images with full user access, using the Telescope Control page on the MicroObservatory (MO) website

Activity Overview

In this activity participants practice the process of retrieving their images and properly saving them to be able to use them in subsequent investigations. They also learn the basics of how to take an image using the **Telescope Control** page.

Background

The FITS-format contains all the original information in the image— more than in the GIF-format version. They should always use the FITS format image if you plan to measure the brightness of the image. FITS images can be viewed using the MO Image processing software.

Preparation

Space Required: Computer lab

Materials:

- A computer for each participant (or two)
- Internet access for all computers
- Personal area on computer to store images for each participant
- A Telescope Observation Log Sheet for each participant (appendix/computer-activities/all/telescopeobservationlogsheet.pdf)

Preparation time: 🕐

Activity time: 45 minutes

Gathering of materials and final preparations:

- ❑ You need to create a storage area (a folder) where each participant will save his/her images for the rest of the program. Make sure you think about this in advance to avoid changing storage systems during the program.
- ❑ Make sure to have a list of the participants' usernames and passwords that you set up when enrolling them in MicroObservatory.
- ❑ Review the process for taking images using the **Telescope Control** page by referring to the section in the introduction.
- ❑ Become familiar with the typical problems that participants may encounter when taking images. These problems can be found both in the introduction and in the "Watch out for" section at the end of 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 the activity.

Procedure

Discussion lead-in:

Tell the youth that they are about to control a powerful astronomical telescope from the convenience of the computer lab. Explain to them that this wonderful new technology has made possible a revolution in astronomy. No longer does astronomy require shivering in the cold while standing in line for a ten-second glimpse through a telescope.

Emphasize to participants that good work habits with the telescopes will save headaches further along. For example:

- ❑ Download and save image files as soon as possible after the images are taken. Images remain on the Web for only a few days; once gone, they cannot be retrieved.
- ❑ Name the image files clearly. The images may be needed again for future explorations or participant projects. (For example an image of the Ring Nebula taken with a red filter should be named RingNebula_red.FITS)

Accessing the Image

1. Have participants check their email for a message from MicroObservatory. There should be a message with a link to the image they requested with the Guest Observer Portal. They should click on the first link in the email. It will take them directly to the page with a thumbnail of the image along with information about the image.

2. They can click on the thumbnail to get to the image page where they can download the GIF or FITS file. They can also check what the weather was like when the image was taken, and all the information about how and when the image was taken.

On the image page – Saving Images:

1. Participants will need to download the image in its original FITS-format. To do this, they need to click on the link above the image.

2. The name of the image file contains the first few characters of the name of the target, followed by a string of 12 digits that tells exactly when the image was taken (2 digits for each of the following in order: month, day, year, hour, minute, second). The time the image was taken is given as *Greenwich Mean Time*, to follow a convention adopted by professional astronomers. *Greenwich Mean Time* is typically 6 hours ahead of *Eastern Standard Time*. As they save the image, they can keep this long filename or, if they prefer, rename the image.

Taking Images:

1. Either have a generated list of objects (from the pull-down list) that the youth can choose from or have them brainstorm what type of object they would like to take an image of before beginning. This will help to focus the youth once they get started. For this first time, it is best that they choose an object that is in the pull-down menu.

2. Have participants click on **telescopes** on the left navigation panel of the MicroObservatory home page.

3. The next set of steps can be done in whatever order makes the most sense to them.
   - ❑ Check the weather at the telescope sites by clicking on the city name.
   - ❑ Check the availability of times at each telescope by clicking on the queue. Remember that images can be taken 3 minutes apart.
   - ❑ Check when an object will be up by click on **what's up** on the left navigation frame of the Select Telescope page.

4. Once they have selected a telescope, object, and know when they should take the image they are ready to go to the Control Telescope page by clicking on the **red dot** on the map for the telescope they want to use. The telescope name will appear at the top of the Control Telescope page. Make sure participants check to make sure they chose the correct telescope.

5. The following steps are explained in detail in the “Introduction to MicroObservatory.”
   - ❑ Enter username and password
   - ❑ Choose **At Night** (only the Moon can be images during the day)
   - ❑ Enter the time – be sure the correct AM/PM is chosen
   - ❑ Choose the object from the list
   - ❑ Enter exposure time under **Main Camera**, max time is 60 seconds

Object	**Time of day**	**Select target with…**	**Exposure Time**	**Filter**
Moon	Day or Night	Pull-down Menu	0.1 - .05 sec	Grey (Neutral Density Filter)
Planets	Night	Pull-down Menu	0.1 – 2.0 sec	Clear (No Filter)
Stars	Night	Coordinates	0.1 – 10 sec	Clear (No Filter)
Star clusters	Night	Pull-down Menu or Coordinates	5 – 30 sec	Clear (No Filter)
Nebulae	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
Galaxies	Night	Pull-down Menu or Coordinates	45 – 60 sec	Clear (No Filter)
Asteroids / Comets	Night	Coordinates	15 – 60 sec	Clear (No Filter)

   - ❑ They can choose a filter, if needed (Grey for the moon)
   - ❑ Leave Zoom and Focus with default settings
   - ❑ Click Take Picture

Watch out for…

Here are some things to consider when taking images with the MicroObservatory telescopes.

- ❑ When is your desired object visible in the sky? Make sure you choose the correct time and place to point the telescope, and don’t forget that clouds block our view of the sky when it is cloudy.

- [ ] How bright is your object in the sky? Make sure you choose to leave the shutter open long enough to allow enough light onto the detector, but don't leave it open so long that will saturate (fill up) the detector and cause an image flare. The length of time the shutter is open is known as exposure time. Objects like single stars and planets are very bright, so they require shorter exposure times, while objects like nebulae and galaxies are faint, requiring longer exposure times.

- [ ] There are other factors that affect whether or not your picture comes out. If you're looking for guidance, you can look at the MicroObservatory image archives and find a picture that you like and look at its Image Info. This will tell you what somebody else did to get a good image of that object. If you are taking an image of the same object (or a similar object) you should be able to recreate a similar image, using the archived information (the same or similar settings that were used to take the archived image).

Vocabulary

FITS-format: FITS stands for Flexible Image Transport System, and is an image file format widely used by the astronomical community. It's great advantage over more familiar image file formats, is that it can, and often does, contain information about the imaging device used to capture the image, and more importantly, the time, date, and location of the telescope used. Additionally, each pixel of a FITS file will often be linked to the Right Ascension and Declination of the portion of the sky imaged. Moving a cursor across such a calibrated image enables an astronomer to determine the positions and names of the stars in the filed of view.

Useful Websites

Technical description of the MicroObservatory Telescopes:
http://mo-www.harvard.edu/MicroObservatory/ then click "About Us"

Quicktime Movies of the MicroObservatory Telescopes:
http://mo-www.harvard.edu/MicroObservatory/ and then click on the link on the main page.

Image Processing and Image Contrast

Goals

- ❑ Learn how to use MicroObservatory Image 2.0 to process images
- ❑ Apply newly gained knowledge of pixel value to solve a contrast challenge

Activity Overview

This activity is for youth to explore some key tools of MicroObservatory Image, the image processing software, namely **Adjust Image** – which allows them to change the contrast of the image, the **Magnifying glass** – that enables zooming in on a specific part of the image, and **Measure** – which allows the youth to find the highest and lowest pixel value in a selected area of their image.

Background

Each pixel is associated with a pixel value that is proportional to the number of light particles captured by the corresponding pixel on the MicroObservatory detector. The higher the pixel value the more particles of light were captured by the detector.

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 (the MicroObservatory telescope's detector is color-blind).

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 celestial 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: Computer lab.

Materials:

- ❑ Computer every 1-2 participants
- ❑ MicroObservatory Image software installed on each computer

Preparation time: 🕐 🕐

Activity time: 30 minutes

Gathering of materials and final preparations:

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:

Explain to the participants that the CDD camera attached to the MicroObservatory 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. But that is not all. Using MicroObservatory Image we can change the contrast of the image and how the image looks to us.

Image Processing:

1. Have participants save an image of the Butterfly Cluster or of the Pleiades in FITS image format. Beautiful images of these clusters can be found in MicroObservatory Archive (get images → Image Archive Directory → Star Clusters). Once on the page with the desired image, the youth should click on the blue filename link to begin downloading.

2. With the MicroObservatory image processing tool, have participants open the image of the star cluster or another image where stars are resolved. They should go to **File** and select **Open image on local disk**. Then choose the specific file for that image. The image will open in a new window.

3. **Adjust the image display**. Have the youth go to the **Process** menu and select **Adjust Image**. When the dialog box appears, and BEFORE they hit AUTO (**linear scale**), have them read the max and min values on the contrast scale. They may then click on the **Auto** button: the program will automatically adjust the contrast of the image.

4. **Zoom in**. Have participants click on a star in your image then, using the **magnifying glass** tool (on the upper left of the image), zoom in on the star until the individual pixels that make up the star can be distinguished.

5. **Pixel value**. Have participants click on the image and move the cursor over different parts of the image. The **Image Info** window shows the X, Y coordinates for each pixel that forms the image. **Pixel Value** indicates how many counts are associated with that pixel. The number of counts is related to the number of particles of light that have been collected by each pixel. In simple terms though we can say that, “Pixel value tells us how many light particles were captured by that specific pixel.”

6. **Find the highest and lowest pixel value in a region of the image.** Have participants use the **circle** feature (in the upper left of the image window) to make a circle on your image. They should center the circle on a star (after a circle has been made, it can be dragged to different

positions within the image). Tell the youth to go to the **Process menu** and select **Measure** from the menu. A table will appear in the upper left of the image that shows some information about the region of the image within the circle you made. *Name* is the name of the region, *Area* is the total number of pixels in the area surrounded by the circle, *Mean* is the average pixel value in that region, Total is the sum of all pixel values for that region, *Min* the lowest pixel value in that region, *Max* is the highest pixel value in that region. (note that Mean = Total/Area)

7. **Have participants use the Measure tool** to find the max and the min number of counts collected by a pixel in the area you selected. Have the youth make a circle of the same radius (the size of the circle is shown at the top of the window you are working in) in different regions in the same image and compare the mean number of counts for all regions.

8. **Changing Contrast**. In the **Adjust Image** window change the value of the min value: *What happens to the image*? Then change the max value: *What happens to the image*? By changing the max and min values we change the scale used to display the image; we change the contrast of the image. NOTE that **we only change how we *display* the information contained in the image, we do not change the information** (i.e. how much light has been collected by each pixel).

9. **Discuss with a partner**. Have participants explain to each other what the meaning of min and max value is on the contrast scale. Ask them the following questions:

   - ❑ If you change the min value what happens to the image? Why? Write down your explanation.
   - ❑ If you change the max value what happens to the image? Why? Write down your explanation.

10. After the participants write down their hypotheses, they should have the opportunity to test them by engaging in the image processing challenges.

Contrast Challenges:

Youth are divided in two groups: GROUP A and GROUP B and in each group youth work in pairs. All computers should have the MicroObservatory website open at the **Latest MicroObservatory Images** page (click on **get images**) and the MO image processing software window open side by side.

GROUP A: Whirlpool Challenge
Have participants open a good image of the Whirlpool Galaxy (use "click and drag" on Macs). Tell them to process the image using the linear scale, click **Auto**, and then adjust the contrast to get a crisp image.

Challenge the youth to change the max and/or min value **ONLY ONCE** to make the arm, which seems to connect the two galaxies, disappear (any other processing tool can be used, but min and max can be changed only once).

- ❑ How did you make the arm disappear? Explain your reasoning

GROUP B: Orion Nebula Challenge
Have participants open a good image of the Orion Nebula (use "click and drag" on Macs). Tell them to process the image using the linear scale, click **Auto**, and then adjust the contrast to get a crisp image.

Challenge the youth to change the max and/or min value **ONLY ONCE** to bring out the stars in the center of Orion (any other processing tool can be used, but min and max can be changed only once). If this is too difficult, youth can first try to isolate the star in the top part of the Nebula.

- ❑ How did you bring out the stars in the center (and make the nebula disappear)? Explain your reasoning

Discussion:

Each group then reflects on the meaning of the max and min values on the contrast scale. After working on these challenges have the youth answer the following questions again:

- ❑ If you change the min value what happens to the image? Why?
- ❑ If you change the max value what happens to the image? Why?

Compare their recent answers with the hypotheses they made earlier: Do they agree? If yes, why? If not, why?

Debrief:

All groups should share their findings. Then, as the facilitator, point out statements that seem problematic. Offer some clues about why they seem problematic and allow the youth in that group and other groups to formulate an alternative explanation. Finally, highlight the correct statements that the youth were able to formulate on their own, and improve them if necessary.

Follow up

Ask the youth who worked on the Whirlpool challenge to facilitate the activity for those that worked on the Orion challenge and vice-versa. By teaching others, the youth will come to understand the importance of giving clear directions and explanations. It will also help them understand their activity better.

Watch out for...

- It is important that for this activity the youth have a practical understanding of the particle model of light. In this model a beam of light can be compared to a stream of tiny particles all moving at the same speed (the speed of light). Each particle is characterized by its energy, or color. A beam of white light is a stream of particles of all the colors founds in a rainbow. When light hits a CCD detector each individual light particle is captured by one of the pixels of the detector and is counted. Pixels that have large counts have collected more light particles than pixels with small counts.

- Watch closely your own vocabulary to make sure to convey the message that by changing values on the contrast scale we are **changing the display of the image not the original pixel values that formed the image**. An image is a collection of pixels, and each pixel is associated with a number, the pixel value.

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.
contrast: Contrast is the difference between the darkest and lightest areas in an image. The greater the difference, the higher the contrast.

Useful Websites

Starizona: http://www.starizona.com/ This website is designed to teach you 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!.

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

Images as Data

Goals

- Relate the exposure time of an image to the amount of light captured in the image
- Learn that the pixel value associated to each pixel in the image provides information about how much light, emitted by the target object (source), has been collected by that pixel

Activity Overview

In two groups, participants will open a series of images in the MicroObservatory Image software and make observations. They will learn how to read a **FITS header**, how to measure the amount of light a given pixel has detected, and make comparisons between images before discussing their findings.

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 celestial 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: Computer Lab

Materials:

- ❑ Computer every 1-2 participants
- ❑ MicroObservatory Image software installed on each computer
- ❑ A Telescope Observation Log Sheet for each participant (appendix/computer-activities/all/telescopeobservationlogsheet.pdf)

Preparation time: 🕐 🕐

Activity time: 60 minutes

Gathering of materials and final preparations:

In the week before you facilitate this activity practice the activity as if you were a participant and try to anticipate any factor that would distract the participants from their main task—making observations. 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:

Explain to the youth that the ability to make good observations is a crucial skill in all sciences, and in everyday life as well. Because observations constitute the evidence on which scientific models are based, it is important to practice good observations skills and to be able to distinguish between an observation and an inference.

In astronomy observations are mostly limited to what can be seen when looking at an object and what can be measured; i.e. the light from that object that has been collected by a telescope's detector. For example, observations can be based on the appearance of the object in the image and on the information about the amount of light displayed by each pixel in the image. This information is data.

Explain to the participants that they will first observe and describe to each other what they see in some MicroObservatory images. They will make observations about the image: shape, size, different shades of grey. Have youth focus on the details, and remind them about the difference between observations and inferences. In addition, mention that observations are not only about what we see in an image, but are also based on the information associated with each pixel in the image.

Make sure participants use all the MicroObservatory Image software tools that enable them to find out how much light was captured by each pixel.

Form two groups:

Group A will work with images of the Andromeda Galaxy (taken using different exposure times), Group B will work with images of the Orion Nebula (taken using different filters).

Youth in both GROUP A and GROUP B work in pairs.
All computers should have the MicroObservatory website open on the **Latest MicroObservatory Images** page (click on **get image**) and the MO image processing software window open side by side.

GROUP A
Download the following images from the MicroObservatory Image Archive and open them in the MO Image processing software, (on Mac machines you can "click and drag" the FITS file link into MO Image).

Get images → Image Archive Directory → YAA General

abdi	M-31Andromed103106014513.GIF	31-Oct-06 01:45 MA	Ed
abdi	M-31Andromed103106013920.GIF	31-Oct-06 01:39 MA	Ed
abdi	M-31Andromed103106013528.GIF	31-Oct-06 01:35 MA	Ed

Have the youth set the contrast settings for these images to: Max = 850 and Min = 650 (use these values to start, then you may use other Max and Min values, though try to use the same values for all images).

If some pairs are faster than others going through the process, ask them to make predictions as to what would happen if the exposure time for taking the Andromeda images were set to 5 sec. Ask participants what the image would look like. After they make their predictions, youth can check if they were correct by using this image (exp. time = 5 sec)

abdi M-31Andromed103106012355.GIF 31-Oct-06 01:23 MA Ed

Group A usually goes through this activity more quickly. The additional piece above can be given to participants of this group at any time during the activity so that both groups finish at about the same time.

GROUP B

Download the following images from the MicroObservatory Image Archive and open them in the MO Image processing software, (on Mac machines you can "click and drag" the FITS file link into MO Image). Set the contrast settings for each image as indicated below.

Get images → Image Archive Directory → YAA General

iporro M-42OrionNeb112407060026.GIF 24-Nov-07 06:00 MA Donald
Contrast settings: Max = 1100 Min = 550
iporro M-42OrionNeb112407055421.GIF 24-Nov-07 05:54 MA Donald
Contrast settings: Max = 600 Min = 275
iporro M-42OrionNeb112407055131.GIF 24-Nov-07 05:51 MA Donald
Contrast settings: Max = 600 Min = 275
iporro M-42OrionNeb112407054842.GIF 24-Nov-07 05:48 MA Donald
Contrast settings: Max = 600 Min = 275

For both GROUP A and GROUP B:

1. Under **Window** choose **FITS Header**
   This file provides important information about when and how this image was taken and who took it. Some of the information in this file may not be very familiar to the participants immediately. For the time being they should focus on the following important pieces of information:

   FILE = name of the file
   DATE = when the image was taken
   EXPTIME = exposure time
   START-OBS and OBS-END = Starting and ending time of the exposure
   FILTER = filter used when taking this image
   TELESCOPE = name of the telescope used to take this image
   OBSERVER = who took the image
   OBJECT = name of the object in the image

Observations can be based on the appearance of the image and on the information provided by each pixel. This information is data.

Have the youth observe and describe to each other what they see, focusing on details and making observations about the image (shape, size, different shades of grey). Remind them to make distinctions between observations and inferences. We are interested in observations only (for example: an image does not show stars. The image shows white dots, some bigger some smaller. Some dots are white, other are grey, different shades of grey, and so on).

- ❑ Record some of your key observations on chart paper. Can you identify any pattern in what you observed? Describe the pattern(s) in your own words.

2. Have the participants focus on the information provided by each pixel. Instruct them to click on one image and move the cursor over different parts of the image. The **Image Info** window displays the X, Y coordinates for each pixel that forms the image. The term **pixel value** tells how many counts are associated with a given pixel. The number of counts is related to the number of particles of light that have been collected by each pixel. In simple terms, we can say that pixel value tells us how many light particles were captured by that individual pixel.

3. Introduce (or reintroduce) participants to the **circle** and the **measure** tools. The **measure tool** is under the process menu, while the circle tool is found at the top of the image itself—these tools can be used to compare the same region in the images. Have the youth take a circle of the same radius (size of the circle is shown at the top of the window you are working in) and center it on the same region for all 3 images. Then instruct participants to click on the process menu and then click on **Measure**. They should compare the pixel values for the same region in all images and compare the mean number of counts for all images (this information appears in a table after clicking on **Measure**).

   - ❑ What image has the highest mean number? What image has the lowest mean number? Why do you think is that?

   Ask them to make a hypothesis and explain their reasoning. They should record their observations and any suggested explanations on chart paper.

4. After making several observations about these images, participants should describe what is the same and what is different in the images.

Can they identify any pattern in what they observed? Have them describe the pattern(s) in their own words.

- ❑ What do you think the reason is for the differences in the images? Make your hypothesis and explain your reasoning. Can you test your hypothesis?

Group Discussion:

Question for GROUP A: How does the exposure time of the observation affect the image that MicroObservatory takes?
Example of answer based on observations: *Images taken with longer exposure times show dots that look bigger and bigger as the time increases. Or: If each pixel collects light, then longer exposure times result in more light collected by each pixel, and in the whole image.* Or: *Longer exposure times allow more light to be captured by the telescope and the images show more details. Etc…*

Question for GROUP B: How does the use of different filters affect the image that MicroObservatory takes?
Example of answer: *We see different "things" when we use different filters,* for example, *the dots in the images taken with a filter look smaller, and some dots do not show up at all. Or: When we use a filter there is always less light in the image (lower pixel values) than when we use NO filter. Or: Filters cut the amount of light that reaches the detector. Or the blue filter seems to block most of the light and the red filter seems to block the least amount of light. The neutral density filter also blocks a lot of light.*

GROUP A and GROUP B share their findings:

1. Form new pairs with one person from Group A and one from Group B. Person A and person B describe to each other what they observed in the images and the conclusions they got to.

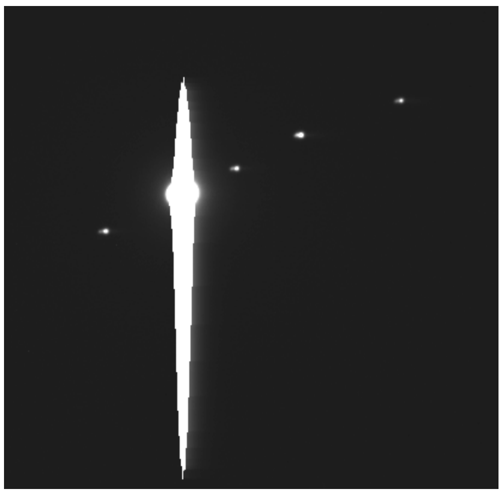
2. Have larger groups with representatives from both GROUP A and GROUP B discuss the following prompts:

   - ❑ How do exposure time and filters affect an image taken with MicroObservatory?
   - ❑ What is similar, what is different?
   - ❑ How would you use them in combination?

Follow up

The Jupiter challenge is an integral part of the activity and enough time should be allocated so that it can be introduced (Note: In case Jupiter is not visible in the sky when you do this activity, Saturn and its moons can be used instead. If neither Saturn nor Jupiter is visible, ask youth to make their predictions and then have them find evidence to support their predictions using the images stored in the Image Archive Directory).

Present the following challenge: An image of Jupiter taken with 1 sec exposure time and no filter allows you to see the moons of Jupiter but Jupiter itself looks overexposed.
How we can we get an image of Jupiter where you can see the moons, but Jupiter itself is not overexposed? (note: both images were taken with Zoom in).



Jupiter and its Moons
Exposure time = 1 sec, no filter

Jupiter and its Moons

Ask participants to provide three different settings for the telescope that they predict will result in an image like this one. Have them write down their settings and take images of Jupiter using all the proposed combinations.

Watch out for…

- This activity is about making observations and reflecting on them. To make sure that youth can get the most out of this activity, they should already be familiar with the basics of searching for images on the MicroObservatory Image Archive Directory, and savings FITS files and opening them in MO Image.

- Make sure that youth are familiar with the basic software tools that they will have to use: Adjust Image, Zoom in (magnifying glass), and Measure. The Measure tool is very useful but it may be more difficult to understand for some youth. DO NOT require that they all use this tool. However, youth must be able to read the information in the Image Info window, and to scan over the image to find the pixel value for specific pixels.

- The Jupiter challenge is a key component of the activity; make sure that each pair of participants takes images using at least three different combinations of settings. Allow time during the next session for the youth to check their images, verify which settings worked the best and reflect on why that was the case. Before next session you need to make sure to review the participants' images and select the one that produces the right results. Have a set of best images ready with the telescope settings that they used. Emphasize the fact that there is not just one way to get the image right—different combinations of exposure time and choice of filter can provide the same result. This is because filters and exposure times are ways to control how much light strikes the detector, and so there may be many ways to allow just the right amount of light to be collected.

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 "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.
contrast: Contrast is the difference between the darkest and lightest areas in an image. The greater the difference, the higher the contrast.
data: A collection of facts or information from which conclusions may be drawn. In computer science, data is used to describe information that is stored and/or processed digitally.

inference: A deduction or conclusion made from facts that are suggested or implied rather than overtly stated. Drawing meaning from a combination of clues in a given context without explicit reference to that context. "The sky was dark and cloudy so I took my umbrella." We can infer that it might rain even thought there is no reference to an actual observation of a rain storm.

observation: The process of using one's senses to perceive and record information about some aspect of the natural world. Also, the act of making and recording a measurement.

Additional sets of images that can be used for this activity

IMAGES for GROUP B

Orion Nebula

Get Images → Image Archive Directory → YAA General

iporro M-42OrionNeb112407060026.GIF 24-Nov-07 06:00 MA Donald

Contrast settings: Max = 1100 Min = 550

iporro M-42OrionNeb112407055421.GIF 24-Nov-07 05:54 MA Donald

Contrast settings: Max = 600 Min = 275

iporro M-42OrionNeb112407055131.GIF 24-Nov-07 05:51 MA Donald

Contrast settings: Max = 600 Min = 275

iporro M-42OrionNeb112407054842.GIF 24-Nov-07 05:48 MA Donald

Contrast settings: Max = 600 Min = 275

Lagoon Nebula

Get Images → Image Archive Directory → Light and Color

acontos M-8LagoonNeb050201135546.GIF 02-May-01 13:55 HI Ben

Contrast settings: Max = 800 Min = 400

acontos M-8LagoonNeb050201142831.GIF 02-May-01 14:28 HI Ben

Contrast settings: Max = 540 Min = 360

acontos M-8LagoonNeb050201143223.GIF 02-May-01 14:32 HI Ben

Contrast settings: Max = 440 Min = 360

acontos M-8LagoonNeb050201143606.GIF 02-May-01 14:36 HI Ben

Contrast settings: Max = 390 Min = 450

With this set of images the compare and contrast activity can be also made using the log scale and then Auto. The pixel values don't change of course, only the way the data is displayed.

Using the log scale has the great advantage to clearly show that each image is different from the other (region that is visible, size, shape, intensity of light coming form different regions). The disadvantage is that the Min and Max value on the contrast scale have a different meaning then when using the linear scale: in particular, increasing the Max value does not meaningfully affect how the image is displayed.

M-3 Globular Cluster

Get Images → Image Archive Directory → Light and Color

abwo2 M-3Globularc032801075753.GIF 28-Mar-01 07:57 AZ Donald
Contrast settings: Max = 404 Min = 193
abwo2 M-3Globularc032801080107.GIF 28-Mar-01 08:01 AZ Donald
Contrast settings: Max = 210 Min = 193
abwo2 M-3Globularc032801080628.GIF 28-Mar-01 08:06 AZ Donald
Contrast settings: Max = 249 Min = 193
abwo2 M-3Globularc032801080932.GIF 28-Mar-01 08:09 AZ Donald
Contrast settings: Max = 305 Min = 193

Crab Nebula

Get Images → Image Archive Directory → Nebulae

esalazar M-1CrabNebul031404063044.GIF 14-Mar-04 06:30 AZ Cecilia
Contrast settings: Max = 450 Min = 350
esalazar M-1CrabNebul031404063329.GIF 14-Mar-04 06:33 AZ Cecilia
Contrast settings: Max = 325 Min = 320
esalazar M-1CrabNebul031404063644.GIF 14-Mar-04 06:36 AZ Cecilia
Contrast settings: Max = 340 Min = 325
esalazar M-1CrabNebul031404063931.GIF 14-Mar-04 06:39 AZ Cecilia
Contrast settings: Max = 355 Min = 325

Dumbbell

Get Images → Image Archive Directory → Nebulae

catherine M-27Dumbbell121303020354.GIF 13-Dec-03 02:03 AZ Cecilia
catherine M-27Dumbbell121303020635.GIF 13-Dec-03 02:06 AZ Cecilia
catherine M-27Dumbbell121303020921.GIF 13-Dec-03 02:09 AZ Cecilia
Contrast settings: Max = 350, Min = 315

NOTE: Image taken with “clear” filter is not available in this set
Same exposure time, different filters

Investigation of Jupiter and its Moons: Part One

Goals

- ❑ Build a model illustrating Jupiter and its moons
- ❑ Using the model created to describe the Jupiter and moons system, make predictions about future positions of the moons

Activity Overview

Over the course of two activities, participants will recreate Galileo's process of discovering the moons of Jupiter. The youth will be presented with set of images from MicroObservatory of Jupiter and its moons taken at different times. They will first hypothesize on what these objects are, and then create a three-dimensional model of the system demonstrating their predictions. The model will be a representation of their thoughts on how these moons move. Finally, the youth take their own images.

Background

When Galileo Galilei peered through his telescope in 1610, he observed a row of four dots surrounding Jupiter in the sky. Initially believing them to be background stars, he made a sketch of his observation and continued to explore the sky. On subsequent observations, he was astounded to find that these "stars" appeared to move back and forth around the planet. Galileo had discovered the four largest moons of Jupiter.

Galileo successfully predicted that these objects orbited Jupiter in circles around the planet, rather than simply moving back and forth, following a straight line. He did this by imagining how motion that would seem to follow a circle when seen from above would appear when viewed edge-on.

His discovery was important, because it showed that not everything in the heavens revolved around the Earth. The idea that these four specks of light clearly revolved around the planet Jupiter was a useful contribution to a body of evidence that Earth was not the center of the Universe.

He could not have imagined what amazing worlds these moons would turn out to be. Today, nearly four centuries later, we have close-up views of these four moons, sent to us from spacecraft that have made the long journey to Jupiter, revealing four very different worlds.

Preparation

Space Required: Computer Lab

Materials:

- ❑ A computer for every 1-2 participants
- ❑ An Observation Log Sheet for each participant (appendix/computer-activities/all/telescopeobservationlogsheet.pdf)
- ❑ Copies of the daily list of what planet is up in the sky at each of the telescope locations (optional)
- ❑ Images of Jupiter and its moons
- ❑ Foam balls of various sizes and modeling materials

Preparation time:

Activity time: 45 minutes

Gathering of materials and final preparations:

Download images of Jupiter from the MicroObservatory Image Archive. There are several sets taken over short periods of time in the "Jupiter" section. Alternatively, you may take some yourself over the course of a few days. Make note of the proper sequence of your images and print copies for each group. (You may want to invert the color so as to not waste a lot of ink printing the black background of space in each image. This can be done in MO Image under **Process** and down to **Invert Color**.)

Print the images. Label with the date and time they were taken. Check to see that Jupiter is above the horizon at night so that it can be imaged from the MicroObservatory telescopes. Make copies of the Observation Log Sheets. 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 the activity.

Procedure

Discussion lead-in:

Tell the story of Galileo's first observations of strange "dots" near Jupiter as outlined above. You should refrain from using the word "moon" through the first part of this activity. Galileo continued observing these objects and, in doing so, made a discovery that contributed to our modern understanding of the Solar System. Now the participants will conduct a similar investigation.

Examining the images of Jupiter:

1. Divide the participants into groups of two to four and distribute a set of the images to each group. The images should be presented with the date and time they were taken.

2. Ask the youth to make observations of the images and make note of any interesting features. Some questions to ask:

   - ❑ Does anything change between these images?
   - ❑ Does anything stay the same?
   - ❑ Are there any objects that appear in only some of the images?

3. Inform the participants that these images were taken of Jupiter over the course of several hours or several nights, depending on the set you choose. Make sure to call attention to the "dots." Ask them to begin thinking about what these "dots" surrounding the planet might be, if they haven't already.

4. Have the participants record what they think the "dots" might be and why they think any changes in their position relative to Jupiter might have occurred.

5. Present the balls and modeling materials to the youth. Ask them to create a three-dimensional model that accurately represents the system they are observing in the images. The models should be dynamic and changing in that they may be rearranged to represent any of the images the youth have just examined.

6. Have participants share their models with another group and explain them.

Making Predictions and Taking Images:

1. Ask the participants to discuss any changes they believe might occur in future images and to sketch them out.

2. Invite the participants to take their own sequence of images of Jupiter explaining that the images they take will help to show whether or not their model is accurate.

Depending upon the frequency of your sessions, you may choose to either coordinate a series of observations of Jupiter over the course of one night, have the youth take images at least once every day from home, or both. Images taken over a short period of time will emphasize the motion of the inner moons, while an observing campaign that lasts several days will better show the motion of the outer moons.

Follow up

In the following activity, "Investing Jupiter and its Moons: Part Two," participants will make an animation from the images they take as part of their sequence and test that their model is accurate.

Watch out for...

- ❑ This activity asks that participants draw inferences from two-dimensional images and make predictions on the three-dimensional system they represent. This is a difficult jump conceptually. To prepare, it may be helpful for you to consider how a photograph of an every day object is actually a two-dimensional representation of its real world counterpart.

- ❑ Your participants may create a model of the Jupiter system that has its moons, or "dots," move back and forth along a straight line, rather than following a circular orbit. Encourage the model builders in this situation to rethink their model. Ask them if the moons and Jupiter are on the same line, if so, do they collide into each other?

- ❑ Jupiter is not visible at night at all times of year. If conducting this activity at a time when Jupiter is not visible, omit the imaging portion of the activity.

- ❑ As the participants make observations of Jupiter with the MicroObservatory telescopes, it is important that they be especially careful to keep a good record of their work on their log sheets. They will be helpful in sorting out the images later. The regularity and quantity of the images they take will improve the quality of the animation they put together later.

- ❑ Most image sets of Jupiter show the planet with a long "spike" running up and down through it. This happens as a result of imaging a very bright object. Participants may get hung up on making observations of the spike, rather than the "dots."

Vocabulary

Callisto: The second largest of Jupiter's satellites. Callisto is not geologically active and has a thin atmosphere. This combination means it has a very "old" surface, remaining almost entirely unchanged except for accumulating craters, much like our own Moon. Its diameter is about 2980 miles (4800 km) and takes about 16.7 days to orbit Jupiter.

Europa: The fourth largest of Jupiter's satellites. Europa is a large, dense, icy moon of Jupiter. Its surface is covered with long, crisscrossing track ways (but few craters) and frozen sulfuric acid. Its diameter is less than 2,000 miles (3,138 km), smaller than the Earth's moon. It takes Europa 3.55 days to orbit Jupiter. Its mean distance from Jupiter is about 420,000 miles (670,900 km). It was discovered by Galileo and Simon Marius (independently) in 1610.

Ganymede: The largest of Jupiter's satellites, with a diameter slightly larger than Mercury's. It is the only moon known to have a liquid core generating its own tiny "magnetosphere." A compass would probably work on Ganymede. It is 3,270 miles in diameter (5262 km) and takes 7.15 days to orbit Jupiter.

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.

Kepler's relation: Also known as Kepler's third law. Kepler's third law of planetary motion says that the average distance of a planet from the Sun cubed is directly proportional to the orbital period squared. Newton found that his gravity force law could explain Kepler's laws. Since Newton's law of gravity applies to any object with mass, Kepler's laws can be used for any object orbiting another object.

Io: The third largest of Jupiter's satellites and the closest to the planet. Io is the only body in the Solar System, other than Earth, to currently have active volcanoes. Photographs taken by visiting unmanned spacecraft have revealed smoke plumes hundreds of miles high. Unlike Callisto, these volcanoes are constantly changing the surface of the planet.

Period: The amount of time it takes for a planet to complete one revolution, or one orbit about the sun.

Useful Websites

Galileo Mission to Jupiter:
http://www.jpl.nasa.gov/galileo/education/teacherres.htm
Windows to the Universe: Tour to Jupiter:
http://www.windows.ucar.edu/tour/link=/jupiter/jupiter.html

Investigating Jupiter and its Moons: Part Two

Adapted from *From the Ground Up!*

Goals

- Evaluate and revise existing ideas about the motion of moons based on patterns seen in data (images)
- Learn how to create animations using MicroObservatory Image software
- Discuss the strengths and weaknesses of a model

Activity Overview

The youth will create an animation from the images they took in Part One. They then compare the animation to their previously generated model and consider what their model accurately represents and what it does not accurately represent when compared to real observations.

Background

Please refer to the background information in the first part of this activity.

Preparation

Space Required: Computer Lab

Materials:

- A computer for every 1-2 participants
- MicroObservatory Image software installed on each computer
- The Observation Log Sheets from the previous activity
- Models from the previous activity
- Chart paper (or white board)

Preparation time: 🕐 🕐

Activity time: 60 minutes.

Gathering of materials and final preparations:

A few days before you facilitate this activity, take images of Jupiter and its moons yourself. Save a complete set of 4-6 images (taken by you or the participants) and print several sets of them black on white. You will use these sets for the initial discussion (reflecting on images). Make sure you create an animation with your own images: by doing that you will be better prepared to assist participants during their work.

Review the definitions of the astronomy terms in the vocabulary section at the end of the previous activity.

Procedure

Discussion lead-in:

With the models from the previous activity displayed, remind the participants of their prior work with the Jupiter images. Have them briefly recall what their models predicted.

Creating a Jupiter animation:

1. Have the participants download their images of Jupiter from the previous activity and save them to a single appropriately named folder.

2. Participants should rename their files "1.FITS," "2.FITS," "3.FITS," etc. in chronological order from oldest to newest. Both Windows and Mac OS will order the images appropriately when the files are left with their default names and sorted alphabetically, so the youth should start at the top when renaming the files.

3. Have participants open their files in MicroObservatory and check to see that all the images came out. Close any images where the planet and moons are not visible.

4. Have participants select **Process → Adjust Image** and use the **Auto** tool with the **Linear** button selected for their images.

5. Have participants click on their images in reverse order - "3.FITS," "2.FITS," "1.FITS." This step organizes the order of the frames in their animation. When properly arranged, the number 1 image is the top frame. This is easily accomplished by going up to **Window** on the menu bar and clicking on the images in reverse chronological order as mentioned above.

6. Have participants select **Process → Stack → Convert images to stack**.

7. Using the arrow buttons at the bottom right of the resulting windows, have the participants scroll through each of their frames. Jupiter will most likely seem to “jump” from place to place. This indicates that the images need to be aligned.

8. Have participants select **Process → Shift**. They will select a single image as the **background** frame and select another image for the **foreground** frame. The foreground frame is layered over the background frame and made slightly transparent.

9. The youth should align the foreground frame’s picture of Jupiter against the background frame. They should disregard the positions of the moons and instead focus on lining up the “Jupiters”. This step is repeated for the remaining images by selecting each one as a foreground frame and repeating the alignment procedure. Click **OK** when done.

10. Have the participants scroll through their frames again using the arrow keys. If they have aligned their images well, Jupiter will not appear to jump. If there are any obvious errors, they should repeat the previous step.

11. Have participants select **Process → Stack → Animation** options and enter a value of “12” in the **Frames Per Second** field. They should then click **OK**.

12. Instruct participants to select **Process → Stack → Start Animation** to view their work. Selecting **Process → Stack → Stop Animation** will stop the new clip.

13. The frame rate and alignment of images are still editable when the animation has stopped. Participants may revise these if an image is obviously out of alignment or if a different frame rate may be more comfortable to watch.

14. Select **File → Save as → Animated GIF** and name and save the file normally.

15. Animated GIF images may be opened in a web browser, even when Internet access is not available.

Testing the model:

1. The youth should observe their animation and note the motion of the “dots.”

2. Have the youth compare their models with the animation they have just created.

3. Ask the participants if they can recreate the motion of the "dots" in the new animation.

Debrief:

- ❑ Were the models an accurate representation of this system? Explain why.
- ❑ What was shown accurately and what was not?
- ❑ What aspects of Jupiter and its moons were left out of the model? How could the models be improved?
- ❑ What questions do you now have after creating and testing your model?

Follow up

Jupiter and its moons are much like a tiny solar system themselves. The system is a rich topic for further investigation for individual and small group projects.

Watch out for…

- ❑ The fifth step in creating the animation can be a significant source of frustration. At this time, MicroObservatory Image lacks a good interface for arranging the frames of an animation in sequence. Managing more than a few frames can clutter the workspace and make things difficult. In addition, a carefully ordered series of images can be undone by clicking on another image without thinking. As such, a systematic approach is required. All image processing should be completed before any attempt to sequence the images is made. One approach to make the sequencing step more intuitive is to have the youth drag the windows into "piles," rather than just clicking on them. If an image is accidently selected, its window rises to the top of the pile, making it obvious that the order needs to be repaired.

- ❑ It is important that when shifting their images, the youth center each frame on Jupiter. If the sequence is aligned to a specific moon, the other bodies will appear to orbit it rather than the planet.

Vocabulary

Please refer to the vocabulary words from the previous activity ("Investigating Jupiter and its Moons: Part One").

Advanced Image Processing

Adapted from *From the Ground Up!*

Goals

- ❑ Learn about color tables, noise reduction and other advanced image processing tools
- ❑ Gain a greater understanding of how images can be manipulated to show information about the light received by the detector

Activity Overview

Participants will experiment with the different color tables in MicroObservatory Image and learn to use an image taken with the **opaque filter** to remove background noise from an existing.

Background

False Colors: The colors we see in the world around us are the result of the way that the human eye and brain perceive different wavelengths of light in the visible part of the electromagnetic spectrum. A CCD camera attached to a telescope however “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. It is possible to produce real color images of astronomical objects. We will learn how to do so using color filters and image processing software in “Creating Color Images”. For now though, image processing software allows us also to create what are sometimes called "false color images." That is because the colors used to make them are not "real" but are chosen among a selection of **color tables** to bring out important details. The color choice is usually a matter of personal taste, and is used as a type of code in which the colors can be associated with the intensity or brightness of the light from different regions of the image.

Background Noise: Since astronomical CCDs are designed to image faint objects they must be extremely sensitive even to small amounts of light (or a small number of light particles). One drawback to this sensitivity is that the detector also picks up light particles generated by heat within the camera. To minimize this effect, astronomical CCD cameras are equipped with cooling systems. These systems are capable of lowering the camera's operating temperature 20 to 60°C (about 40 to 100°F) below ambient temperature. Even this however is not enough to remove all the extra photons produced by heat within the camera. These unwanted photons are called **background noise**. What does background noise look like? When you take a digital image with a CCD detector, like the one used for MicroObservatory, you can notice some (or many) little white dots in your image that are NOT stars: If the dots are a single **pixel** ("picture element") wide, they are likely to be background noise. We call these pixels "hot pixels." To be able to get rid of the background noise, CCD detectors can be used to take a **dark frame**. A dark frame is an image taken with the camera's detector covered. This image contains only the background noise. Image processing software then allows you to subtract the dark frame from the original image to obtain a much clearer image (one with much less noise).

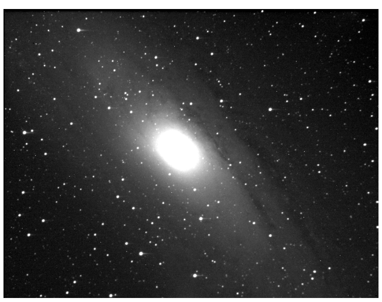


Image of Andromeda taken using a "Clear" filter (i.e. using no filter at all): The image recorded both the signal (light) from the object and the noise produced by the detectors electronics.

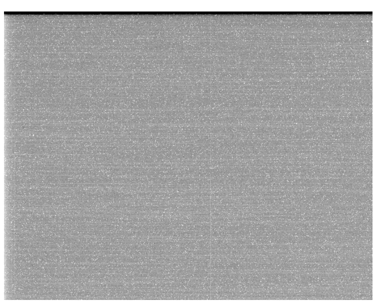


Image of Andromeda taken using the Opaque filter (i.e. with the camera's shutter closed). The grey and white squares on the images are called "hot pixels." (These are more easily seen when a dark frame is opened in MO Image.)

Preparation

Space Required: Computer Lab

Materials:

- ❑ A computer for every 1-2 participants

- ❑ Image-processing software: MicroObservatory Image on every computer
- ❑ An Observation Log Sheet for each participant (appendix/computer-activities/all/telescopeobservationlogsheet.pdf)

Preparation time: 🕐 🕐

Activity time: 60 minutes.

Gathering of materials and final preparations:

In preparation for this activity remind the participants to take images of their favorite objects. However they will have to take two images of their object each time: one image using the **clear filter** and one image using the **opaque filter**. It is important that the exposure time used for both images is the same.

Prepare a few sets of images of the same object taken with the clear and opaque filters to have ready in any case. You can find many of these sets in the Image Archive Directory.

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:

Remind participants that when they open an image with the processing software, the image displayed on the screen is made up of thousands of pixels. Each pixel is associated with a number that says how many particles of light were gathered by the camera in that area of the image—as shown in the "From Starlight to Image" hands-on activity. They can see this for themselves when they put the cursor over the image on the screen. The **Image Info** box in the upper right of the screen shows the coordinates of the pixel the cursor is on, as well as, the value corresponding to the number of particles of light collected by that pixel. (You should try to elicit this information from the youth. Only fill in the gaps or add clarity when needed.)

Downloading and opening an image:

1. Have participants save 3-4, or at least two, of their good images in FITS image format.

2. Use the MicroObservatory Image application, which should already be on your computer. Go to **File** and select **Open image on local disk**.

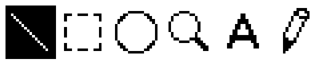
Then select the file to be opened. The image will open in a new window.

Adjusting the image display:

Have participants go to the **Process** menu and select **Adjust Image,** then change the brightness and contrast as desired. (They should try to adjust the contrast in such a way so that all of the object in the image can easily be seen.)

Measuring features within the image:

1. Have the youth identify an interesting object in their image.

2. Instruct the youth to click on the **line** button below the image window's title bar.


3. Participants should now click on one side of the object in the image and drag the cursor to the other side of the object before releasing. This draws a line across the object. The coordinates of the first point of the line and its length in pixels will be reported below the window's title bar.

4. Have participants measure the object in their image with the line tool, and record its length. Note: The length measured using this tool is in pixels and is useful only when comparing images taken with the same settings. (For example, comparing the size of two objects both taken using the main camera and unzoomed.)

Giving false colors to the image:

1. Have participants go to the **Process** menu, select **Color Tables** and any of the options available there.
   - ❑ What happens to the image?

2. Instruct the youth to go to the **File** menu and select **Save As** and **GIF** within the submenu. When the dialogue box appears, they should label their files so that you can remember the color table used for each image. (For example an image of the Ring Nebula with the fire color table added should be named "RingNebula_fire.FITS".)

Comparing the images:

After the participants have saved the false color images, ask them to open one of the color images and its original black and white version side by side on their computer. Ask them to compare the images and discuss the answers to these questions:

- ❑ Which image do you like most? Why?

- ❑ Which image seems to help you see the most details in the image? Why? What details can you see?

Removing the background noise:

1. Have participants choose a set of images taken with the **clear** and **opaque filters** of the same object. Have them open both images next to each other with MicroObservatory Image.

2. Instruct them to click on the image taken with the clear filter. Under the **Process** menu, they should select **Image Calculator**.

3. In the resulting dialog window, the youth will now subtract the image taken with the **opaque filter** from the image taken with the **clear filter**. To do so, the image taken with the clear filter must be selected as **Image 1,** and **Image 2** the image taken with the opaque filter. As for **Operation**, make sure to change **add** to **subtract**. When all is set they should press **OK**. (It is advisable to click on **create new window** so that the new image will open in a new window.)

4. A new window will open (named "untitled"). The image in this window is the original **clear filter** image with the information from the **opaque** image, containing mostly noise, removed. Instruct participants to find new **min** and **max** values in the **Adjust Image tool** to better display its content (changing the contrast).

Follow up

The Hubble Site has a great tutorial about color imaging (http://hubblesite.org/sci.d.tech/behind_the_pictures/). Using some of the best images we have seen from Hubble Space Telescope the tutorial explains how color is used in the following ways:

- ❑ To depict how an object might look to us if our eyes were as powerful as a telescope, or as the Hubble Space telescope itself
- ❑ To visualize features of an object that would ordinarily be invisible to the human eye
- ❑ To bring out an object's subtle details

This tutorial is a must read and play (great interactive tools) to learn and enjoy using color with MicroObservatory imaging.

Encourage the participants to take images with the opaque filter, especially when they start taking images using the three color filters to create RGB images. They will have to subtract the image taken with the opaque filter from all three images; then combine the images to create an RGB image.

Watch out for…

- ❑ Make sure that participants understand that the choice of a color table needs to meet at least two criteria: to please our personal taste (a perfectly good reason to choose one color scheme instead of another) and to help our eye to see details better (for example, these might be details on the surface of the moon or details about the illumination of the surface itself).

- ❑ Make sure that participants subtract the image taken with the opaque filter from the actual image of the object and not vice-versa.

- ❑ Make sure that participants change add to subtract.

- ❑ Images taken with the opaque filter should be taken very close in time to the actual image of the object and the exposure time needs to be the same.

- ❑ The product of the subtraction is a new image for which the scale on Adjust Image changes dramatically. Participants will need to adjust the value of the scale again to best view the image (clicking **auto** is a good starting point).

- ❑ Be prepared to explain to the youth that the subtraction of the dark frame does not remove *all* the background noise. However the new image should be an improvement.

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.
dark frame: A dark frame is an image taken with the CCD’s shutter closed. This image records only the electronic noise due to the detector itself. When a picture is taken of the night sky it records both the object in the sky as well as the noise. The dark frame is subtracted from this image to leave only a clear image of the object.
electromagnetic spectrum: The full range of frequencies, from radio waves to gamma rays, that characterizes the different “colors” of light. There is a relationship between the amount of energy

electromagnetic radiation (light) carries and the frequency. Radio waves are low frequency and low energy radiation while gamma rays at the other end of the spectrum are high frequency and high-energy radiation. Visible light, that our eyes can see, is also part of the electromagnetic spectrum.

opaque filter: This is not actually a filter. When using MicroObservatory you select "opaque" in the filters selections when you want to take an image with the camera's shutter closed.

Useful Websites

Hubble Site - Behind the Pictures:
http://hubblesite.org/sci.d.tech/behind_the_pictures/
In astronomy imaging we often use color as a tool, whether it is to enhance an object's detail or to visualize what ordinarily could never be seen by the human eye. Learn how scientists that work with images of the Hubble Space Telescope do that (we follow the same process to create color images with MicroObservatory)

Guide to CCD Imaging: http://www.starizona.com/ccd/
This website is designed to teach you 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.

Astronomy Picture of the Day: http://antwrp.gsfc.nasa.gov/apod/

Group Portrait of the Universe in Color: Taking Images

Adapted from *From the Ground Up!*

Goals

- Take images and gather the information needed to create a "group portrait" of astronomical objects in color using the MicroObservatory interface
- Practice using the MicroObservatory telescope interface efficiently as a tool to gather data

Activity Overview

In teams, participants will take images using MicroObservatory's three color filters (red, green, and blue) in preparation for assembling them into a single full color image in "Creating Color Images."

Background:

The human eye can sense red, green, and blue light. Combinations of these three colors are perceived as full-color. Any color scene can be separated into its red, green, and blue components and then reconstructed to form full color. When creating an image, scientists may have to make choices about what to display, and these choices may affect the interpretation of the image.

The Universe tells us its story largely through the light that it sends us, and color plays a key role in the story. To the eye, most of the objects in the night sky look white, except for the planet Mars and a few stars, such as Antares, whose reddish glow is noticeable if you look carefully. But through a telescope, the Universe is aglow with color. What can these colors reveal?

Colors reveal temperature

Stars that are cooler glow red, while medium-hot stars like our Sun glow yellow, and very hot stars glow a bluish-white. In fact, *all* objects at the same temperature will glow with the same color. Ceramic pots in a kiln heated to a temperature of several thousand degrees glow with the same dull red color as a star at the same temperature halfway across the Universe. If we could heat the pots just a thousand degrees more, they would glow yellow like the Sun.

Colors reveal chemical composition

Every chemical element absorbs and emits light at sharply defined colors of light which are characteristic of that element. Neon, for example, emits the warm orange light familiar from neon signs. Chemical elements in the atmosphere of the Sun absorb specific colors of sunlight as this light passes through its atmosphere. The Sun's spectrum shows dark lines in different color bands. By matching the pattern of these lines to known patterns from laboratory experiments, astronomers can tell which elements are present in stars and other objects, and in what amounts.

Preparation

Space Required: Computer Lab

Materials:

- ❑ A computer for every 1-2 participants
- ❑ An Observation Log Sheet for each participant (appendix/computer-activities/all/telescopeobservationlogsheet.pdf)
- ❑ A copy of the Suggested Targets for Color Imaging table for each participant (appendix/computer-activities/group-portrait-of-the-universe-in-color-taking-imates/SuggestedTargets_ColorImaging.pdf)

Preparation time: 🕖

Activity time: 30 minutes

Gathering of materials and final preparations:

Make copies of the "Suggested Targets for Color Imaging" table from the appendix. (appendix/computer-activities/group-portrait-of-the-universe-in-color-taking-imates/SuggestedTargets_ColorImaging.pdf)

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 how they could make a full-color image of an object using color filters. Take note of the answers on a whiteboard or chart paper.

Have participants discuss with their team what kind of object they would like to image. Remember that large objects such as nebulae often are the best subjects. Planets are not be good choices, because they are small and will show little color variation through the MicroObservatory telescopes. Have each team develop an outline for how to proceed. They will be able to use:

- ❑ The telescopes
- ❑ The telescope's filter wheel, containing filters that pass red, green, and blue light
- ❑ MO Image software for combining the red, green, and blue information to form a color image

Taking Images:

1. Participants work in teams of 3. Have each team select an astronomical object they would like to image, using either the list of suggestions provided on the table, or another target. It does not matter if several teams image the same object. (Teams that choose the same object will be able to compare their results.)

2. Make sure that participants understand they have to take 3 images for each astronomical object: one each through the red, green, and blue-passing filters.

3. To increase their chances of taking successful images, help participants with these issues:
    - ❑ Make certain that the targets they have chosen are visible in the night sky at this time of year; remind them to use the **what's up** feature on the MicroObservatory menu.
    - ❑ Remind the youth to refer to the Quick Guide of Settings to figure out an appropriate exposure time for their selected object. Stress that when using the color filters to image an object, the filters block some of the light, so using an exposure time on the higher end of the range is the best practice (i.e. the full 60 seconds).
    - ❑ The red, green, and blue filtered images needed to create a full-color image should all be taken using the ***same*** exposure time. Often the youth will try and vary the exposure times, but to get a complete set, the exposure times need to be the same.

Follow up

In "Creating Color Images" participants will learn how to combine their black-and-white images taken with the three color filters to create a full-color image.

Watch out for...

- ❑ Sometimes participants duplicate the use of a filter or forget to take an image with one altogether. The log sheets are especially helpful in this activity. Make sure participants fill out their logs *as they submit their requests* and record what filter they use each time. You may want to have teams double-check each other's work.

- ❑ Similarly, it's possible that a needed image may not come out for reasons beyond anyone's control. If possible, a good preventative measure is to have participants take extra images on different telescopes.

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).

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/

Creating Color Images

Adapted from *From the Ground Up!*

Goals

- ❑ Learn how to combine red, green, and blue color-filtered images into a full-color image
- ❑ Reflect on their existing ideas about the color of objects in the Universe and revise them based on their experience creating color images

Activity Overview

Participants will create their first full-color pictures from their 3 black-and-white images (taken using color filters). First they will see how this process works with images of a sunflower. Then they will go on to create RGB (or full-color) images of astronomical objects, first of a nebula, then with their own images.

Background

Taking color pictures with Earth and space based telescopes is much more complex than taking color pictures with a traditional camera. For one thing, these telescopes do not use color film—in fact, they do not use film at all. Rather their cameras record light with special electronic detectors, called CCDs. These detectors produce images of astronomical objects not in color, but in shades of black and white. The background section of "Image Processing and Contrast," contains more information on these devices.

Finished color images are actually produced by combining two or more black-and-white exposures of the same object. Each exposure is given a different color during image processing (by adding the color tables); then the images are combined. The given color corresponds with the color of the filter used when the image was taken. (For example, the red color table is added to an image taken with the red color filter.)

We often use color as a tool, whether it is to enhance an object's detail or to visualize what ordinarily could never be seen by the human eye.

Preparation

Space Required: Computer lab

Materials:

- ❑ Computer for every 1-2 participants
- ❑ MicroObservatory Image 2.0
- ❑ Images of sunflower taken through color filters
  (appendix/computer-activities/creating-color-images/flowerB.gif)
  (appendix/computer-activities/creating-color-images/flowerG.gif)
  (appendix/computer-activities/creating-color-images/flower.gif)
  (appendix/computer-activities/creating-color-images/flowerRGB.gif)
- ❑ Images of Orion Nebula taken through color filters
  (appendix/computer-activities/creating-color-images/
  M-42OrionNebula_Red.FITS)
  (appendix/computer-activities/creating-color-images/
  M-42OrionNebula_Green.FITS)
  (appendix/computer-activities/creating-color-images/
  M-42OrionNebula_Blue.FITS)
- ❑ Images taken by participants from previous computer activity

Preparation time:

Activity time: 1 hour

Gathering of materials and final preparations:

Make an extra effort to familiarize yourself with the nuances of the process outlined in this activity. The skills developed here are among the most important when using the image processing software.

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 the participants to summarize some of the skills they have developed in MicroObservatory Image. This activity represents a culmination of the image processing techniques covered before. Explain that they will be assembling color images from the seemingly black-and-white data they received when taking their exposures with the color filters. Stress that this process is used by professional astronomers to create the brilliant pictures of faraway objects that they might have seen.

Sunflower Color Image:

1. Have the participants locate the files with the three black-and-white sunflower images that you previously downloaded.

2. Have the participants launch the MicroObservatory Image software on their computers.

3. Tell the youth to open *flowerR.gif*. This is the red portion of the full color flower image. Under the **Process** menu, have them select **Color Tables → Red.** This automatically colors the image red. In the same manner, have them open the other files, *flowerB.gif* and *flowerG.gif* and color them appropriately using the same steps.

4. Then, under the **Process** menu, they should select **Stack**, and select **Convert Images to Stack**. Have participants take a moment to scroll through the stack, using the arrows at the bottom edge of the image. Note that the three images contain very different information about the picture. The third image is very dark, because there is no blue in the scene, except for the sky.

5. To create the color picture, go to the **Process** menu, select **Stack,** then **Convert Stack to RGB** (which stands for red, green, blue color). The result should be a full-color picture of the sunflower.

   If participants mix up the color of the images by coloring the red-filtered image green, for example, they will get a strangely colored picture that will not be the color of the original image.

Orion Nebula Color Image:

Explain to the youth that they are now ready to use MicroObservatory to create a full-color image of an object in the night sky. Model this process using the FITS images of the Orion Nebula found in the appendix. Select one or two participants to sit at adjacent computers and coach them through the following procedure while the rest of the group gathers around to watch. This approach works much better than lecturing the group as you demonstrate the process on your computer.

1. Explain to the participants that when the telescope has taken the images and posted them on the Web, they need to download the 3 images in FITS format.

2. They should be sure to name their files clearly so that they know which image was taken through which filter (e.g. "Orion_Red.FITS").

The filter color is listed in the Image Info file and FITS header (under **Windows → FITS Header**) that comes with each image.

3. **Opening the three images**. Ask the youth to launch the MicroObservatory Image processing program on their computers and open the images taken through the red, green, and blue filters. Under the **Process** menu, ask them to select **Adjust Image.** When the Adjust Image window opens, select the **Auto** button to get a good first look at each image.

4. Instruct the participants to further adjust the brightness and contrast for each image if necessary. The purpose is to get a good representation of the object in the image.

5. **Coloring each image red, green or blue.** Working with the red-filtered image first, have participants click on the **Process** menu and select **Color Tables → Red**. Their images will turn red. Then work with the green-filtered image, selecting **Process → Color Tables → Green** to turn the image green. Finally, color the blue-filtered image blue.

   Explain to the participants that the areas in the original scene that had a lot of red became the ***brightest*** areas in the red-filtered image. In turn, these bright areas in the red-filtered image will become the ***reddest*** areas in the final image. The same holds for the green and blue-filtered images.

6. **Aligning the images.** Each of the images will most likely be slightly out of alignment. They will need to be aligned, or "shifted" so that when they are combined the result is not blurry. Under the **Process** menu, have the youth select **Shift**. As prompted, they should select one of the images as the **background** image over which they will shift, or align, the other two images. The red image usually makes the best background. Then have them select a **foreground**. (You should see the background image through the slightly transparent foreground image.)

   Using the mouse or the keyboard keys "I, J, K, and L," have participants align the two images. Once satisfied with the alignment, they should select the remaining image as the foreground and align it against the same background. Once this is done, they may click the **OK** button.

7. **Stacking the images.** Under the **Process** menu, have participants select **Stack → Convert Images to Stack**. They can flip through these images using the arrow keys at the bottom of the new window to view them individually and check that they are well aligned.

8. **Creating the final color image.** Under the **Process** menu, have participants select **Stack -> Convert Stack to RGB**. The program now merges the red, green, and blue images to create the final full-color image.

9. **Saving the final image.** Have participants make sure to save their final images as GIF files and label it with a clear filename.

Participants' Color Images:

1. Have participants download the 3 images of their target that they took using color filters—one each using the red, green, and blue-passing filters.

2. Have participants download the 3 images in FITS format. Tell them to name the files clearly so that they know which image was taken through which filter (e.g., "MyTarget_Red.FITS"). The filter color is listed in the Image Info file.

3. Follow steps 3 through 9 of the procedure for creating the Orion Nebula Color Image.

Make sure that participants take new images with the MicroObservatory telescopes using the color filters to create new color images.

Debrief:

Reflecting on the results that the youth obtain in this activity is very important. If possible, while participants are working on their images, engage 2-3 of them at a time in a conversation using some of the following questions. Alternatively, you can engage the whole group in a general discussion on the results of their activity following these questions:

- ❑ Does the color of the object in your image tell you anything about the object? What?

  Colors reveal temperature
  Stars that are cooler glow red, while medium-hot stars like our Sun glow yellow, and very hot stars glow a bluish-white. In fact, all objects at the same temperature will glow with the same color. Ceramic pots in a kiln heated to a temperature of several thousand degrees glow with the same dull red color as a star at the same temperature halfway across the Universe. If we could heat the pots just a thousand degrees more, they would glow yellow like the Sun.

Colors reveal chemical composition

Every chemical element absorbs and emits light at sharply defined wavelengths which are characteristic of that element. Neon, for example, emits the warm orange light familiar from neon signs. Chemical elements in the Sun absorb specific wavelengths of sunlight passing by; the Sun's spectrum is darker at these wavelengths. By matching the pattern of these lines to known patterns from laboratory experiments, astronomers can tell which elements are present in stars and other objects, and in what amounts.

- ❑ The telescope's light sensor is not equally sensitive to red, green, and blue light. How might this affect the color of your final image?

  The telescope's light-sensing silicon chip is most sensitive to red light, and least sensitive to blue light. This means that reddish objects will appear comparatively brighter than bluish objects in your black-and-white images. And when you reconstruct the color scene, the final image will appear redder than the actual scene in nature.

- ❑ When you added the three images together, did you boost the brightness of any of the images? If so, how did this affect the color image?

  *It's possible to compensate for the lower sensitivity in the blue if desired by boosting the brightness of the image taken through the blue-passing filter. This is done by adjusting the image's contrast so that it appears brighter prior to colorizing the three black-and-white images (A more advanced way to boost the image taken with the blue filter is explained in the "*Watch out for*" section of this write-up).*

- ❑ How closely do you think that your image captures "reality" -- and why?

  Astronomers try to learn as much as they can from the images they take. This does not always mean producing an image that most closely resembles what you would see with your eyes. For example, by enhancing the contrast of a scene, you can bring out details of the image you might never have noticed if you produced the most natural-looking image. Scientists sometimes alter the color of their images for the same reason, to bring out details that might otherwise be missed.

- ❑ How would you determine the best color balance, or the best image processing?

Follow up

Participants should continue to take images with the filters and assemble them into color images. This skill is frequently used in developing projects utilizing the MicroObservatory telescopes and software.

Watch out for...

- ❑ As participants carry out this activity, they must make a decision that faces astronomers every day—whether and how much to "boost" the red, green, or blue images before combining them. The decision will affect the color of the final image. You might think that to get accurate color in the final image, each of the 3 component images should be processed in exactly the same way. However, the telescope's light-sensing chip is less sensitive to blue than to red light. Therefore the blue image will generally be fainter than the red and green images, and so it will need to be brightened during image processing relative to the other images. Also, the 3 color filters do not pass equal amounts of light. This also will affect the accuracy of the color in the final image. Although it is not necessary to correct for these factors, participants should be aware that the color of their final product might not be an accurate rendition of the scene. In fact, in much of astronomy, *there is no such thing as "true color,"* because the astronomer must make unavoidable and sometimes arbitrary choices about how to display the image.

- ❑ Since the light-sensing chip in the detector is about fifty percent less sensitive to blue light than it is for red light, we may want to compensate for this using image processing software. In MicroObservatory Image, one can use the **Math** and **Multiply** option under the **Process** menu to multiply the blue-filtered image by a value of 2 (note this will also double the noise in this frame). The image looks completely white at first, but click on **Auto** again on the **Adjust Image Toolbar** to see the object. Another way to go about boosting the blue-filtered image is by initially taking two blue-filtered images, and then using the **Image Calculator** tool to add the two images together. (In this method, the "hot pixels" are not doubled, because they do not appear in the same places on two different images.)

- ❑ When combining filtered images, MicroObservatory Image will report an error message if the user has extra images open. When selecting **convert images to stack**, an error prompt will read, "All slices must have the same width, height, and bit depth." The problem may also be caught when selecting **convert stack to RGB**, where the prompt will say, "You need one red, one green, and one blue slice to make an RGB image! Use the Color Tables menu item to do this." Simply close the extra image/images to remedy the problem. If a stack has already been made, the user may select **convert stack to images** to take out any image that should not be part of the stack.

Vocabulary

silicon chip: A wafer-thin slice of silicon that contains thousands of microscopic electronic circuits.

Useful Websites

Hubble Site: Behind the Pictures:
http://hubblesite.org/sci.d.tech/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.

YOUTH ASTRONOMY APPRENTICESHIP

Observing Projects

Observing Project #1: Overview

Note: This is the description of the first observing project. The project should last 3-4 sessions.

Goals

- ❑ Understand that doing science is driven by asking well-defined questions based on observations
- ❑ Learn how to make detailed observations
- ❑ Learn the difference between an observation and an inference
- ❑ Clearly communicate their findings to others in oral and written form

Activity Overview

This is the first in a series of observing projects which introduce the participants to the skills required to make observations, keep detailed observation journals, analyze data and draw conclusions. Participants gain observing skills as they carefully view the Moon over several days, or even weeks. They also begin to keep a journal of observations and thoughts that mimics the work of scientists engaged in research. The focus of the first project is on the beginning stages of any scientific research question – making observations and posing answerable questions. The participants publish their work from each project online, through the MicroObservatory website's **lounge**.

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.

The most common misconceptions that youth, and adults alike, have about the moon phases, such as clouds block the Moon as well as Earth's shadow covers the Moon, are reasonable, but do not hold up under careful observation of the Moon.

MOON PHASES AND TIME OF DAY

Phase	Rises	In Eastern Sky	Highest in Sky	In Western Sky	Sets
New	[~sunrise]	[morning]	[noon]	[afternoon]	[~sunset]
Waxing Crescent	[just after sunrise]	[morning]	[just after noon]	[afternoon]	just after sunset
First Quarter	~noon	afternoon	~sunset	night (pm)	~midnight
Waxing Gibbous	afternoon	~sunset	night (pm)	~midnight	night (am)
Full	~sunset	night (pm)	~midnight	night (am)	~sunrise
Waning Gibbous	night (pm)	~midnight	night (am)	~sunrise	morning
Third Quarter	~midnight	night (am)	~sunrise	morning	noon
Waning Crescent	just before sunrise	[morning]	[just before noon]	[afternoon]	[just before sunset]

[ ] Means moon is not actually visible during this time
~ Approximate time estimate

Note: The table is to be used by facilitators only; it should not be shared with participants.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants. At certain points, use of computers will be needed – the best scenario is one computer per participant.

Materials:

- ❑ Small notebooks, which you can provide, or ask your participants to supply.
- ❑ Computer lab for taking images of the Moon with MicroObservatory

Preparation time:

Activity time: 2 weeks (4 sessions)

Gathering of materials and final preparations:

Make sure each participant has a journal. Participants should not use a section in another notebook or the backs of other pieces of paper—this should be a dedicated space for all of their observations for the duration of the after-school program. Before beginning this observing project, make sure to check the rise and set times of the Moon, in order to have the first session land on a day when the Moon will be visible **during** the after-school session.

Procedure

The following activities will be done over the course of 2 weeks, either one session right after another, or with one or two small coordinated activities mixed in (see the list of clusters for suggestions of possible activities). Most sessions have a separate write-up, following this overview.

1. **First session:** "Did You Notice?" (30 min)

2. **Second session:** "Observation or Inference?" (25 min)

3. **Third session:** Check in with participants about project. Make sure everyone has begun making observations. Take images of Moon with MicroObservatory. (15 min) This check-in and image taking session may be added onto the end of the second session if time allows and there have been opportunities for data collection i.e. the Moon has been up with clear skies.

4. **Fourth session: "**Sharing and Publishing" (60 min)

Follow up

"Observing Project #2" – Participants will conduct another observing project in which they will look at astronomical images and build upon the skills of observing they learned during this activity.

Watch out for...

Refer to each individual activity.

Vocabulary

Refer to each individual activity.

Useful Websites

The Moon: It's Just a Phase It's Going Through...:
http://www.astrosociety.org/education/publications/tnl/12/12.html from ASP's "The Universe in the Classroom" No. 12 - Winter 1988-89

Observing Project #1: Did You Notice?

Note: This is the write-up of the first session of Observing Project #1.

Goals

- Learn how to make, and record detailed observations
- Brainstorm ideas for their first observing project

Activity Overview

This is an introductory activity to familiarize the participants with the Observing Projects, which they will be engaged in during the program. The youth observe small changes in each other's appearances in order to prepare them for making observations about the Moon over the course of the next week. It is important to start this project when the Moon is visible during the hours of the after-school session.

Background

By conducting a simple observing project based on the Moon, participants can gain observing skills and data analysis skills while investigating a topic of their choosing. Keeping a journal of observations and thoughts mimics the work of scientists engaged in research. The journal may be online or on paper, based on preference and/or access to online journaling tools.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants.

Materials:

- Small notebooks for each participant (or access to an online journaling tool)
- Chart paper

Preparation time:

Activity time: 25 minutes

Gathering of materials and final preparations:

- ❑ Gather small notebooks, one for each participant.
- ❑ Check the current rise and set times for the Moon. It is useful to start this project with a large group observing session of the Moon.

Procedure

Discussion lead-in:

Explain to the participants that they are about to play a game called, "Did You Notice," in which they will focus on making observations of details.

Activity:

1. Ask for 1 volunteer to stand in front of the group. The group studies the volunteer for 1 minute. The group then turns around, so the group members cannot see the volunteer while she changes 1 small thing about her appearance. When she is ready, the group turns around again and has to try to notice what changed. Repeat this process with a series of new volunteers.

2. Discuss what was easy and/or difficult about this task. Were there certain types of changes that were easier to notice than others?

3. Lead a discussion about observing, and be sure to highlight the importance of *detailed* observations. Questions that may help facilitate discussion:
    - ❑ Why is it important to be able to make good observations?
    - ❑ Think of a situation in which not being observant could be a problem.
    - ❑ Scientists have to be able to make very detailed observations. Why do you think this is?

4. Hand out journals and explain that these journals will be used to record ALL observations and thoughts as participants conduct this, and other observing projects. Suggest that they use their own vocabulary, expressions, and personal codes when recording entries to their journals. They will not need to share what is written, but they will need to understand what they wrote!

5. Introduce the first project – "Observing Project #1." This project is a simple observing project aimed at getting participants accustomed to making and recording detailed observations. It is also an introduction to how scientists conduct research.

6. Explain that each of them will be observing the Moon over the course of the next week or two.

7. As a group, go outside and look at the Moon. Ask for observations from the participants. After everyone has given at least 1 observation, go back inside and lead a brainstorm on what sorts of things they could make ongoing observations about.

8. Write their ideas onto chart paper. Have youth choose 1 of these as their own to be the focus of their project.

9. As they are leaving for the day, remind youth to make observations over the next couple of days.

Follow up

Second session – “Observation or Inference?”

Watch out for…

- ❑ Remind participants to bring the notebook with them to each session for the next three weeks.

Useful Websites

The Moon: It's Just a Phase It's Going Through…:
http://www.astrosociety.org/education/publications/tnl/12/12.html from ASP’s “The Universe in the Classroom” No. 12 - Winter 1988-89

Observing Project #1: Observation or Inference?

Note: This is the write-up of the second session of Observing Project #1.

Goals

- ❑ Practice making and writing detailed observations
- ❑ Learn the difference between an observation and an inference
- ❑ Understand the relationship between observations and inferences

Activity Overview

Participants spend a small amount of time looking at objects and writing observations. Group discussion follows wherein the participants reflect on the difference between observations and inferences.

Background

Scientists need to be able to make observations and draw conclusions based on data. This means having the ability to distinguish between facts and inferences. This activity gets at the tendency of most people to make small inferences when attempting to report their observations. **Observation** is the process of gathering objective data, and **inference** is the process of making some decisions about what the data means. Observation is contact with the world through the use of the senses and provides us with the material for thought, reflection and judgment. One can be trained to be a more effective observer.

Moreover, we draw inferences on the basis of observations. Inference is the interpretation of facts. (A statement of fact is an observation statement that can be verified by the use of the senses.) Valid inferences are based on sufficient and relevant evidence. Our training and background provide a basis for our inferences. Inferences enable us to assess and evaluate conditions and make predictions.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants.

Materials:

- ❑ Small notebooks for each participant
- ❑ Pens/pencils
- ❑ Chart paper and/or a board
- ❑ Items you wish to observed

Preparation time: 🕐 🕐

Activity time: 15 minutes

Gathering of materials and final preparations:

Make sure you have a few different kinds of objects for them to observe. Good objects are ones about which inferences are easily drawn:

- ❑ Film camera from the 1970s – easy for participants to think that it is an old camera. – Old is actually an inference; there is no direct observation of age. Observations such as the type of material, style, number of scratches, or date of manufacture lead to the inference of the camera being old.
- ❑ A photograph taken outdoors. Some participants may be able to deduce what season it was when the photo was taken and then put "taken in winter" as an observation.
- ❑ Other potential options are other objects from a certain time period or photographs containing a family (the youth may infer the familial relationship). Also, an image of something that is difficult to figure out what it is can be a good option because the youth will likely infer what the subject of the photo is.

Procedure

Discussion lead-in:

When participants first come in, have them to gather around the table with a pen and their notebooks. Have them begin inspecting the objects you have collected on the table.

Activity:

1. Instruct participants to write down detailed observations about the objects. A good way to elicit detailed observations is to suggest they imagine they are describing the object to someone on the phone. This person is not in the room and cannot see the object, but should be able

to have a clear mental image of it when they are done describing it. This should last for about 5 minutes.

2. Have them share their observations. Someone should make a list of all the observations either on the board or on chart paper.

3. After everyone has shared observations, take a moment to define both observation and inference.

4. Go back to the list of observations. Ask participants to look for inferences in the list.

   Example of list, generated from the two example objects above (a film camera and a photograph of people, standing outside) with <u>inferences underlined</u>:
   - ❑ Camera: black and silver, 3 round knobs on top, threaded hole on bottom, <u>old</u>, one knob has numbers, <u>doesn't have film in it</u>, black lens, <u>no digital parts</u>
   - ❑ Picture: 3 people standing, <u>picture of a family</u>, <u>taken in winter</u>, lots of trees in background, snow on ground, <u>people are happy</u>, <u>it was cold</u>, sky is blue with a few clouds

5. Discuss why some of the participants' observations are actually inferences.
   - ❑ <u>Old</u> – no date of manufacture, a few observations combined would lead to that thought
   - ❑ <u>Doesn't have film</u> – film counter was set at 0 might be the observation, or participant opened it
   - ❑ <u>No digital parts</u> – can't see inside to confirm – no screen/digital display
   - ❑ <u>Picture of family</u> – assumption based on the people in the photo's variation of gender and age and perhaps some resemblance to each other.
   - ❑ <u>Taken in winter</u> - assumption based on snow and perhaps type of clothing
   - ❑ <u>People are happy</u> – smiling = observation happy = inference
   - ❑ <u>It was cold</u> – type of clothing suggests temperature, but it's not a direct observation.

6. Finish with a discussion of why it is important to know the difference between observations and inferences. Asking the question, "What did you notice/see that lead you to think that?" is a good way to get at the observations they made that have lead them to actually make inferences. For example, they make the statement that the camera is old. By asking the above question, they cite the size and fact that there

is no digital display as evidence. These bits of evidence are observations; the statement that the camera is old is an inference.

Points to make: Scientists need to look at data without a bias. They must be mindful of how they are processing data or making observations to ensure that they are not including their own assumptions as evidence for their conclusions.

7. Have participants take images of the Moon using either the Guest Observer Portal or the Control Telescope page (depending on their experience with MicroObservatory).

8. Inform the youth that, as part of the Observing Project, they will be sharing their thoughts, images and observations with the group and then ultimately online through the MicroObservatory **Users' Lounge**.

Follow up

In the next session of this project (or in this session, if there is time), check in with the participants to make sure they are observing the Moon and have them take more images of the Moon with MicroObservatory. It is best to have the participants take images of the Moon more than once, so there is a greater chance each of them will have at least 1 good image to use with their report.

Watch out for...

- ❑ Participants talking to one another rather than writing down their observations.

- ❑ When sharing, be sure to ask them to read from the lists they made.

Vocabulary

observation: A piece of data gathered by looking at a subject.
inference: A conclusion based on observations.

Observing Project #1: Sharing & Publishing

Note: This is the write-up of the fourth session of Observing Project #1.

Goals

- Generate a list of possible questions that can be answered by observing the Moon
- Learn how to turn "I wonder…" statements generated from observations into an observing project
- Publish thoughts and images online

Activity Overview

In this session, participants share their questions and thoughts generated by their observations of the Moon. After a group discussion, a list of answerable questions is generated. Each participant chooses one question and brainstorms how they could answer it through further observations. The final step of this project is to publish their thoughts and images on the MicroObservatory website.

Background

It is important that the youth develop good questions for scientific investigation, below is an overview of what these questions look like (see the "Useful Websites" section for more information on this topic).

Good questions are ones that:

- Lead easily to a procedure to gather data to answer the question:
  How are the phases of the Moon and the time of day when it is up in the sky related?
- Are NOT yes or no questions:
  Does the phase of the Moon relate to when it rises and sets?
- Are simple, with one or more variables clearly addressed:
  How does the position of the Moon in relation to the Earth and the Sun affect its appearance to an observer on Earth?
  (NOT) What makes the Moon change appearance?

Procedure

Sharing:

Have each person share their observations and any sort of pattern they may have noticed. It is not necessary for patterns to have emerged, but they should be able to generate a good list of questions that came up as they made their observations, or ones that were generated as they listened to other participants' observations.

1. Write the questions down on chart paper.

2. Discuss which of the questions are **answerable**, i.e. which of these questions can be answered through making observations and analyzing the data.

3. Identify those questions that are answerable and have each participant choose one.

4. They should brainstorm a way to answer the question using some sort of observing/gathering data. Stress the use of MicroObservatory images, as well as night-sky observing.

Publishing:

Once they have an idea of how they might carry out an experiment, they should begin to type up the project using the prompts below.

Part 1

- ❑ Introduce yourself with a few sentences. What would you want someone to know about you?
- ❑ Similarly, describe what your project is about. What did you do?

Part 2

- ❑ Participants post their images of the Moon (in GIF format)

Part 3

- ❑ How did you make your observations? What did you notice that was interesting?

Part 4

- ❑ When doing science, we often find more questions than answers. Over the course of your project, what were some of the things you found yourself wondering about?
- ❑ What question did you choose to further investigate?
- ❑ What do you think you could do to answer it? Describe how you would do it.

5. After they are done, they will copy and paste each part into the input fields on the MicroObservatory website (refer to the following write-up "Observing Projects: Publishing the Project Report" for detailed

instructions to publish the report to the website). The headings may not match exactly with the content for each part, but just instruct them to copy and paste their content as follows:

- ❑ **Part 1 – Introduction**
- ❑ **Part 2 – Images & Data**
- ❑ **Part 3 – Explanation of Observations & Data**
- ❑ **Part 4 – Conclusions, Questions, Recommendations**

Watch out for…

- ❑ Chosen questions need to be answerable by making observations and analyzing data. Sometimes questions can be interesting and creative, but cannot be easily answered by doing science.

Useful Websites

What Makes a "Good Question" in Science?
http://misclab.umeoce.maine.edu/boss/classes/SMS_491_2007/GoodQuestionSci.pdf
This is a article provides some additional guidance regarding good science questions.

Observing Projects:
Publishing the Project Report

Goals

- ❑ Publish observing project reports to the MicroObservatory website

Activity Overview

In this session, participants share their projects with the rest of the group and other MicroObservatory users online.

Background

One of the most interesting features of the MicroObservatory website is the tool that allows registered users to post images and text on a bulletin board. Any registered user in the world can then view and read about the work that someone is doing with the telescopes. This activity introduces your group to the **Project Report** feature of the MicroObservatory website.

There are many purposes to science writing; the following list provides many examples that you may want to use as the basis for a short discussion with your group:

- ❑ To display knowledge and understanding of a topic; or to expose misconceptions so that they can be corrected.
- ❑ To demonstrate that a task has been completed effectively.
- ❑ To present a convincing case.
- ❑ To stimulate a controversy.
- ❑ To explain an unfamiliar idea.
- ❑ To inspire interest and excitement about a particular topic in science.

Procedure

1. When participants have typed up all the sections of their current observing project they should spell-check and proofread their work for errors.

2. Then instruct participants to go to the MicroObservatory website, and navigate to the **Publish Observers' Project Reports** screen:
   - ❑ Go to the MicroObservatory home page.
   - ❑ Click on the **lounge** selection from the menu on the left.
   - ❑ Click on **publish data** from the menu on the left.
   - ❑ Click on **Publish Observers' Project Reports** - you will find yourself at the opening screen.

   Note: If the youth ever need to edit or make changes to their reports after initially submitting their report online, they must substitute the last bullet above and instead click on **Edit Your Observers' Project Reports**.

3. Once on the page with the empty input fields, participants should copy and paste each part of their project from the word-processing document into the input fields on the MicroObservatory website. The headings may not match exactly with the content for each part, but just instruct them to copy and paste their content as follows:
   - ❑ **Part 1 – Introduction**
   - ❑ **Part 2 – Images & Data**
   - ❑ **Part 3 – Explanation of Observations & Data**
   - ❑ **Part 4 – Conclusions, Questions, Recommendations**

Watch out for…

- ❑ Only .GIF image files can be uploaded to the website and published in a report. Be sure that all of the participants' images are saved with a .GIF attached to the end of the filename. Filenames cannot be longer than 15 characters in all so longer filenames will have to be changed before they can be posted.

- ❑ Users without a guest code and using the Guest Observer Portal are encouraged to post their images and report on their personal website or blog.

Observing Project #2: Overview

Note: This is the description of the second observing project. It should last 5 sessions.

Goals

- ❑ Develop a question or topic to be the basis for the second observing project
- ❑ Develop a data collection plan and learn how to make sense of observational data
- ❑ Understand that professional science is driven by asking well-defined questions that are based on observations
- ❑ Learn to use MicroObservatory FITS images (info and headers) as data sources
- ❑ Reinforce the difference between observations and inferences
- ❑ Become comfortable giving and receiving feedback from fellow participants
- ❑ Improve oral and written communication skills by completing a project report to be published online and presenting the report to others

Activity Overview

This is the second observing project in which participants choose a topic or question to be the focus of the project, reinforce the observing skills from “Observing Project #1”, analyze data and draw conclusions. They also keep a journal of observations and thoughts that mimics the work of scientists engaged in research.

Participants can make use of their notebooks to do night-sky observing, but a digital journal will be the primary means for the youth to keep track of their work during this project. (A word-processing document that they add to and save each session is all that is needed.) There are question prompts for the journal that are paired with specific sessions. These are listed in the overview of the project contained in this write-up. The spelled out prompts themselves can be found in the activity, “Observing Project #2: Daily Journal & Project Report.”

At the conclusion of this project, participants publish their work online, through the MicroObservatory website's lounge.

Background

When doing science asking good questions is often just as important as finding the answers. We must collect data, make observations, and analyze the data to make meaning of it, to then find answers and generate new questions. The emphasis of this project is on the youth developing a plan to answer a question of their own or one they have selected from a list. Be sure to follow the same process of making observations and journaling as modeled in “Observing Project #1”. This time around however, the youth are pressed to think critically and analyze their data to come up with a conclusion.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants. At certain points, use of computers will be needed – the best scenario is one computer per participant.

Materials:

- ❑ Small notebooks, which participants should have already.
- ❑ Word processing document—digital journal
- ❑ Computer lab

Preparation time:

Activity time: 5 sessions

Gathering of materials and final preparations:

Return to the list of good questions generated at the end of “Observing Project #1.” The youth that had asked those questions should be encouraged to use those questions as the basis for this second observing project. Encourage the youth that do not have a lingering question, which would make a good research question, to select a project concept from the list below. The following list of potential projects should be written on a whiteboard or chart paper:

- ❑ How are the phases of the Moon and the time of day when it is up in the sky related?
- ❑ What are the objects surrounding Jupiter and how do they behave?
- ❑ How can we classify galaxies according to their shape?
- ❑ How can we classify nebulae?
- ❑ How can we organize galaxies or nebulae based on their size?
- ❑ Is there color in the Universe? How do we create full color images?
- ❑ How does the image of my favorite astronomical object change when taken with different exposure times?

- ❑ Why are some objects only up in the sky during certain times of year? Compare an object inside our galaxy vs. one outside of our galaxy.

Procedure

What follows is a general overview of each of the five sessions that are a part of this project. The journal prompts are a reference to the prompts that participants will answer in their journal during the suggested session day (refer to "Observing Project #2: Daily Journal & Project Report" for the prompts). The answers to these prompts will be the basis for the project report.

Overview:

1. **First Session:** "Introduction & Planning" (45 min) The question or topic for the project is developed and a plan for collecting data is spelled out. Data collection begins, scheduling observations, and/or downloading images from the image archive. Journal prompts – 1, 2, 3

2. **Second Session:** Image processing and "What Does Your Data Mean?" Participants gain an understanding of how to make sense of the data they have collected and do some image processing. Journal prompts – 4, 5, 6 (State which computer activities they may have already gone through?)

3. **Third Session:** Image processing, data analysis, and begin write-up. Journal prompts – 4, 5, 6 begin 7, 8, 9

4. **Fourth Session:** Data analysis and write-up. Journal prompts – 7, 8, 9, 10

5. **Fifth Session:** "Giving Feedback" (30 min) Participants learn how to effectively give feedback to help one another improve their projects. Participants publish project report (refer to the previous write-up "Observing Projects: Publishing the Project Report" for detailed instructions).

Follow up

"Observing Project #3" – Based upon their understanding of the astronomy topic of their choosing, participants make a prediction at the start of the process, then follow the same steps as "Observing Project #2" to reach a conclusion. Additionally they will reflect on the entire process and suggest improvements to their methods.

If there is not enough time following "Observing Project #2" to begin #3, skip ahead and apply the participants' reports to producing and presenting posters in "Observing Project #3: Creating Posters" and "Observing

Project #3: Presenting Posters" (part of Session 5 and 6 of "Observing Project #3").

Watch out for…

- ❑ "Observing Project #2" and "Observing Project #3" can be lengthy endeavors; it is not recommended that these sessions be structured to consist solely of work on these projects. Many of the youth will start to lose focus after being on the computer for an hour or more. Some potential activities to mix-in to break up the computer time are the modeling activities included in the Hands-On Activities. "Modeling the Earth-Moon System", "Moon Phases Activity", and "A Journey Through the Universe" are all options to facilitate. Additionally, you may want to suggest that the youth incorporate aspects of these models, or a model of their own design, into their presentation of the second or third observing project. The addition of a model can add a lot of clarity and explanatory power to a project if done well.

- ❑ Before attempting this project participants should have a solid foundation using MicroObservatory, an understanding of many of the computer activities, and quite a bit of content knowledge from the hands-on activities.

Observing Project #2: Introduction & Planning

Note: This is the write-up of the first session of Observing Project #2.

Goals

- Develop a question or topic to be the basis for the second observing project
- Develop a data collection plan and learn how to make sense of observational data
- Understand that professional science is driven by asking well-defined questions that are based on observations
- Learn to use MicroObservatory FITS images (info and headers) as data sources

Activity Overview

This is an introductory activity for the second observing project. In this activity, participants develop a research question to be the focus of their second observing project. This question could come from any of the following:

- The good question reached at the conclusion of "Observing Project #1". (Go back and review what the youth had asked as their final question about the Moon. Encourage those with good questions and an interest in continuing with this topic to do so.)
- A new question that the youth have come to as a consequence of engaging in past activities. (Make sure this question is a 'good' question. Review background of "Observing Project #1: Sharing & Publishing" for information about what makes a 'good' question for scientific investigations.)
- A question from the suggested list of questions that is interesting to the youth and answerable given the tools at hand (see suggested list under Gathering Materials section).

Note: If as a facilitator you are not experienced leading inquiry-based activities, coaching the youth through the process of developing their own project may be exceedingly difficult. It is recommended that the list of questions be used if this is the case.

Participants should write down in their journals any information that they already know about their chosen topic, especially findings from past activities. Review and reinforce the observing skills from “Observing Project #1”—explaining how to go about collecting data, recording daily progress in a journal, and making detailed observations. The journal entries should all be dated and log the participant’s daily activity, observations, and findings.

Next, go over some potential sources of data—the FITS header for example. Finally, participants develop their plans for collecting their data and record it in their journals. For example, a participant with the question: Do all galaxies look the same? They might decide that, over the course of the next couple sessions, they will take images of many galaxies, and compare their data with images from the MicroObservatory Image Archive.

Background

When doing science asking good questions is often just as important as finding the answers. To be able to do either of these however, we must collect data, make observations, and analyze the data to make meaning of it. In addition to visual observations made by looking at an object in the sky, or from images, a wealth of information is available from the **FITS header** of an image. This file provides important information about when and how this image was taken and who took it. Some of the information in this file may not be very familiar to you right now. For the time being you can focus on the following important pieces of information:

FILE = name of the file
DATE = when the image was taken
EXPTIME = exposure time
START-OBS and OBS-END = Starting and ending time of the exposure
FILTER = filter used when taking this image
TELESCOP = name of the telescope used to take this image
OBSERVER = who took the image
OBJECT = name of the object in the image

To access this information, find your image on the Latest Image Archive page on the MicroObservatory website and click on **Image Info**. Also, opening the FITS image with the MO Image software and clicking on the menu bar under **Window**, then clicking on **FITS Header** pulls up the information.

If there has been a considerable amount of time since completing Observing Project #1, reviewing the background information on how to conduct scientific observations is recommended.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants. At certain points, use of computers will be needed – the best scenario is one computer per participant.

Materials:

- ❑ Small notebooks, which participants should have already.
- ❑ Word processing document—digital journal
- ❑ Computer lab

Preparation time: 🕐

Activity time: 30 hours

Gathering of materials and final preparations:

The following list of potential projects should be written on a whiteboard or chart paper. For their second project many of the youth should use the question they posed at the conclusion of their first observing project. Encourage the youth that do not have a lingering question that would make a good research question to select a project concept from the list below:

- ❑ Why does the Moon look different night after night?
- ❑ What are the objects surrounding Jupiter and how do they behave?
- ❑ How can we classify galaxies according to their shape?
- ❑ How can we classify nebulae?
- ❑ How can we organize galaxies or nebulae based on their size?
- ❑ Is there color in the Universe? How do we create full color images?
- ❑ How does the image of my favorite astronomical object change when taken with different exposure times?
- ❑ Why are some objects only up in the sky during certain times of year? Compare an object inside our galaxy vs. one outside of our galaxy.

Procedure

Discussion lead-in:

Introduce the second observing project as a continuation of the first, in that the youth will be using the observing skills sharpened while working on that project. Also, some may want to now address the final question and data collection plan developed then, as the focus for this project. Explain that the topic or question does not have to be about the Moon and project #1, it could stem from a previous activity that they found particularly engaging and would like to pursue further. For those unsure about what their topic could be, they may select one from the provided list of potential topics that has been transferred onto the board.

Finally, mention that asking a well-defined question, which will be the focus of their project, is critical to the success of their work. Also, inform the youth that asking questions, making careful observations and then arriving at conclusions is the process that professional scientists go through in their research.

Project Selection & Planning:

1. Participants first select their research question or topic for their project. Once this is chosen, have the youth write in their journals any information or ideas they have about this topic.

2. Go around the room and see if any of the youth have selected the same or similar topics for their projects; try and pair up participants by topic (some of their project ideas may be more complimentary topics than similar, but explain to them how they may fit together in these cases).

3. Review the skills needed for scientific observing:
    - ❑ Being well-organized (dating journal entries)
    - ❑ Recording detailed observations
    - ❑ Making sure that observations are not actually inferences

4. Review the idea of an image as a piece of data. Use the information in the FITS Header as examples of the data that can be extracted from an image (see the Background section for more on FITS headers).

5. Direct the youth to the MicroObservatory Image Archive and remind them of the extensive collection of data available there.

6. The youth should now be able to develop a plan for their collection of data. This plan should be recorded in their journals.

7. If there is time participants should begin gathering their data and taking the first steps that they outlined in their plans.

Follow up

Most, if not all, of the youth need to take images as part of their data collection plan. Be sure to allow time at the end of the session for them to schedule these observations.

"Observing Project #2: What Does Your Data Mean?" Participants make detailed observations of their data and begin to analyze it.

Observing Project #2: What Does Your Data Mean?

Note: This is the write-up of the second session of Observing Project #2.

Goals

- ❑ Learn how to make sense of observational data
- ❑ Reinforce the difference between observations and inferences

Activity Overview

This is an activity to familiarize the participants with the difference between an observation and an inference, building on the previous activity on observations and inferences ("Observing Project #1: Observation or Inference?"). Participants start to see how to make meaning of data and draw conclusions based on observational data. Before facilitating this activity, give the youth the chance to take a closer look at the images they have taken with the MicroObservatory telescopes or downloaded from the image archive for their project. They should record their observations in their journals.

Background

People make inferences and draw conclusions all the time. Scientists need to be more careful about what inferences and conclusions they make and be able to back up each one with evidence. This activity helps participants to interpret evidence from their data and form conclusions.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants.

Materials:

- ❑ Chart paper

Preparation time: 🕐

Activity time: 20 minutes

Gathering of materials and final preparations:

Come up with a provocative conclusion using everyday observations (an example conclusion is provided in the "Discussion lead-in"). Remember to give the youth some time at the start of the session to make observations in their journals of the MicroObservatory images that they are using for their projects if they have not done so already.

Procedure

Discussion lead-in:

Present a provocative conclusion on the board. Example: *People that wear shoe brand 'X' are smarter than those that wear shoe brand 'Y'.*

Discussion:

1. Allow participants to react and discuss the conclusion on the board.

2. Lead a discussion about what data might have been gathered that lead to this conclusion. The key point in this discussion is the need for evidence to back up conclusions.

3. Discuss observations vs. inferences. Where in their own data have participants already arrived at their own conclusions? In pairs, have them go through their observations and make sure that if there are inferences being made, that there is evidence in the form of concrete observations to support these statements.

4. By the end of the 20-minute activity, participants should have a solid conclusion, based on their observations.

Watch out for…

- ❑ Many people tend to link correlation with causation – meaning that when two events take place at the same time (or in the same place), it is easy to think that one caused the other to happen. A good way to explain this faulty reasoning is to make the claim that "Eating ice cream causes people to commit crimes." Data show that during certain times of the year when ice cream sales are higher, crime rates are also higher. (This is actually true.) But what is left out of this equation is the fact that both ice cream sales and crime rates tend to rise in the summer months in most places. So does that mean eating ice cream caused people to commit crimes? Or that when people commit crimes they crave ice cream? No, there is no evidence that suggests a causal link between ice cream and crime. Just because these two items seem to be correlated does not mean that one is causing the other to occur.

- [ ] Remind participants that they will be putting together posters of their own observation projects at the next session.

Vocabulary

causation: The relationship that results when a change in one variable is not only correlated with but actually produces a change in another variable.

correlation: A measure of how two variables are related.

Useful Websites

Correlation vs. Causation examples:
http://www.statistics-help-online.com/node50.html

Observing Project #2: Giving Feedback

Note: This is the write-up of the fifth session of Observing Project #2.

Goals

- ❑ Become comfortable giving and receiving feedback
- ❑ Reflect on the challenges of communicating effectively and learn how to communicate more clearly

Activity Overview

In this activity participants practice giving feedback in a non-judgmental, and constructive manner. Youth are broken into pairs. One participant makes a very simple shape/structure (keep it 2-D for simplicity) behind an upright 3-ring binder. That person then verbally instructs their partner to create the same shape. While receiving the instructions and attempting to recreate the structure, this participant also jots down feedback related to the instructions given (both positive and negative). After all the instructions have been given, the finished structure is revealed and participants share their thoughts on why they were successful or unsuccessful in reproducing the structure. The participant that received the instructions provides constructive feedback to the initial builder.

Background

Giving and receiving feedback from others is an essential part of completing projects and arriving at the best possible product. In a collaborative work environment, possessing the skills to effectively communicate one's feedback to a group without upsetting anyone else's feelings is absolutely essential. This feedback is only useful if it is clearly communicated, and this activity gets the youth to consider and practice these essential skills.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants.

Materials:

- ❑ Small notebooks, which you can provide or ask your participants to bring.
- ❑ 3-ring binders, enough to have 1 for each 2 participants
- ❑ Toothpicks, straws, LEGOS, or another set of materials broken into small baggies – one baggie of 10-16 pieces. If you are using LEGOS, or other possibly non-identical pieces, make sure to have 2 of each piece (in order to place one in each baggie).

Preparation time: 🕐 🕐

Activity time: 15 minutes

Gathering of materials and final preparations:

- ❑ Make sure to have enough baggies of materials for each pair of participants.
- ❑ If you are using materials that are not necessarily identical (e.g. LEGOS, k-nex, etc.), make sure you have 2 of each one (2 blue short tubes, 2 yellow rectangles, etc) so each person has the same materials to build the shape.

Procedure

Discussion lead-in:

Introduce this as a fun activity that will help youth improve their communication skills, with the emphasis on providing feedback.

Building the structure:

1. Pair up the participants. Try to have the pairs be random; this activity works better with pairs who do not know each other well. Instruct one participant in each pair to build a simple 2-D structure out of the materials provided without showing it to their partner.

2. Then the initial builder verbally instructs their partner to build the same structure from the same materials, but without the aid of seeing how their partner is interpreting the instructions.

3. The receiver of the instructions should note any confusing or unclear instructions on paper. This feedback will be shared after the structure is finished being built, during the discussion about communication.

Debrief:

After the pair is finished building, instruct the pairs to remove the binder, look at the two structures, and discuss the process of communication with each other. Use the following prompts to facilitate the discussion:

- How close to duplicating the original structure was the second structure?
- What aspects of your partner's communication style were helpful in creating the same structure? What aspects needed improvement or clarification?
- What would you change about your instructions if you had to do this challenge again? Be specific.
- Is it easy to receive feedback on how to improve your performance? Identify elements of giving or receiving feedback that make it a constructive process.

The main issue that will arise is clarity of communication. Describing the orientation of the pieces usually causes confusion. ("Hold it flat" can mean completely different things to each person.) The focus should be on giving feedback to the person who gave the directions in a constructive manner. Explain to the youth that getting feedback from others is extremely important because it can help a person improve a project or presentation, or even further develop skills.

Follow up

Have the youth switch roles and try the challenge again, or try it again with the same roles but incorporating the feedback supplied by the second builder.

The participants who have completed the final conclusions section of the project report write-up should exchange papers and provide each other with feedback on how to improve their report. This feedback should follow a simple what was done well, what needs some work, and what needs to be changed format.

You may want to demonstrate for the youth what it means, or what it looks like, when someone is giving non-judgmental, constructive feedback versus someone giving a harsh judgmental critique. This can be done in short skits. An example of the negative could be an angry fan at a soccer match critiquing the coach of the team. While an example of good feedback could be an encouraging and positive diving coach talking to a diver in-between dives.

Observing Project #2: Daily Journal & Project Report

Goals

- ❑ Develop better organizational skills by keeping track of daily progress and findings in a scientific journal
- ❑ Analyze and interpret data to make connections and draw conclusions

Activity Overview

The Daily Journal is an ongoing activity added to during each session. The journal helps the youth keep their work and progress organized while reflecting on their data. This reflection helps the youth make meaning of their data and reach a conclusion. Refer to the "Observing Project #2: Overview" to see what prompts are to be answered in each of the sessions.

During the final session days for this project, participants should open their word processing document containing their daily journaling. Present them with the task of completing each of the 4 parts of the project report, using their answers to the daily prompts as the basis for each part of the report. Have the youth type their answers into a document that does not include the Project Report Prompts (see separate page titled "Observing Project #2: Project Report"). You may want to print out the Project Report Prompts page or transfer them onto a whiteboard or piece of chart paper for the participants to reference. Additionally, it is not expected that the youth complete the entire project in one session, and so splitting up the report prompts is recommended. That way the number of questions does not overwhelm them. Finally, be sure that the youth answer the questions of the report prompts with a series of complete sentences. Make sure that they do not just copy and paste notes from their daily journal.

Follow up

- ❑ The 4 parts of the project report are to be posted online on the MicroObservatory website as part of the published project report (refer to the write-up "Observing Projects: Publishing the Project Report" for detailed instructions).

Daily Journal Prompts

1. What is my research question? How did I come up with it? What information do I already know about my object or topic?

2. What is the title of my project?

3. How can I answer my question? What is my plan for taking data?

4. Describe the process of collecting and analyzing your data? Are there any new developments to report today?

5. Look at your image and describe what you see, list any observations related to the features of the object, for example, size, shape, color, location.

6. Describe any patterns or changes that occur between the images. Compare and contrast the images.

7. What did I learn? What would I like to teach someone else?

8. What questions do I have now? How would I answer them?

9. Summarize and evaluate your process in doing this project. Was there any part of your method that worked really well? Was there anything that could be improved?

10. Do you have any personal conclusions that in doing this report you came to realize?

Observing Project #2: Project Report

Part 1- Introduction:

Part 2 - Images and Data:

Part 3 - Explanation of Observations & Data

Part 4 - Conclusions, Questions, Recommendations

Project Report Prompts

Part 1- Introduction:

- ❑ What was the question you investigated in your project? How did you come up with it?
- ❑ How did you try to answer your question? Did you have a plan for taking data? What was it?

Part 2 - Images and Data:

(This is the section in which you will place your saved .GIF images)

Part 3 - Explanation of Observations & Data

- ❑ What were the most important and most interesting observations you made? Describe them.
- ❑ Were there any patterns between your images? What stayed the same between some or all of them? What changed?

Part 4 - Conclusions, Questions, Recommendations

- ❑ What was interesting that you found out from this project? What new ideas did you come up with? Explain how you would convince someone else of your findings (recap your evidence).
- ❑ You underwent a process of planning your images with MicroObservatory and making observations. Was there any part of your method that worked really well? Was there anything that could be improved?

Observing Project #3: Overview

Note: This is the description of the first observing project. It should last about 6 sessions.

Goals

- Develop a question or topic to be the basis for the third observing project
- Develop a data collection plan and build upon skills used to make sense of observational data
- Understand that professional science is driven by asking well-defined questions that are based on observations
- Understand how to access MicroObservatory FITS images (info and headers) as data sources
- Reinforce the difference between observations and inferences
- Able to give, receive, and incorporate feedback from fellow participants to produce an improved final product
- Improve oral and written communication skills by completing a project report to be published online and presenting project to others
- Improve oral and written communication skills by organizing project report into a PowerPoint/poster and presenting project to others

Activity Overview

This is the third observing project in which participants choose a topic or question to be the focus of the project, reinforce the observing skills from "Observing Project #1" and "#2", analyze data and draw conclusions. It should be noted that if there is not time enough to complete a brand new project with a new topic, the youth should be encouraged to go deeper into their topic for "Observing Project #2" and then skip ahead to create the PowerPoint presentation and poster (written up as part of the third observing project and called "Observing Project #3: Creating Posters").

During this project, participants keep a journal of observations and thoughts that mimics the work of scientists engaged in research. A digital journal will be the primary means for the youth to keep track of their work during this project. (A word-processing document that they add to and save each session is all that is needed.) There are question prompts for the journal that are paired with specific sessions. These are listed in the overview of the project contained in this write-up. The spelled out prompts themselves can be found in the activity, "Observing Project #3: Daily Journal & Project Report."

At the conclusion of this project, participants publish their reports online through the MicroObservatory website's lounge.

Background

When doing science asking good questions is often just as important as finding the answers. To be able to do either of these however, we must collect data, make observations, and analyze the data to make meaning of it. In this project, as in "Observing Project #2", the youth develop a plan to answer their own question or one selected from the list below (in the "Gathering of materials" section). However the expectation this time is that participants, based on what they have learned throughout the program, come up with a prediction of what they expect to find out at the completion of their project. Be sure to follow the same process of making observations and journaling as modeled in "Observing Project #2". In addition, at the conclusion of the project the youth will be asked to reflect on ways to improve their research methods.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants. At certain points, use of computers will be needed – the best scenario is one computer per participant.

Materials:

- ❑ Small notebooks, which participants should have already.
- ❑ Word processing document—digital journal
- ❑ Computer lab

Preparation time: 🕗 🕗

Activity time: 6 sessions

Gathering of materials and final preparations:

If there is time enough to begin an entirely new project separate from "Observing Project #2", encourage participants without already a question to be the basis of the new project to choose one from the list below. The list of potential projects should be written on a whiteboard or chart paper:

- ❑ Why does the Moon look different night after night?

- ❑ What are the objects surrounding Jupiter and how are they moving?
- ❑ How can we classify galaxies according to their shape?
- ❑ How can we classify nebulae?
- ❑ How can we organize galaxies or nebulae based on their size?
- ❑ Is there color in the Universe? How do we create full color images?
- ❑ How does the image of my favorite astronomical object change when taken with different exposure times?
- ❑ Why are some objects only up in the sky during certain times of year? Compare an object inside our galaxy vs. one outside of our galaxy.

Procedure

What follows is a general overview of each of the 6 sessions that are part of this project. The journal prompts are a reference to the prompts that participants will answer in their journal during the suggested session day (refer to "Observing Project #3: Daily Journal & Project Report" for the prompts). The answers to these prompts will be the basis for the project report.

Overview:

1. **First Session:** "Introduction & Planning" (45 min) The question or topic for the project is developed and a plan for collecting data is spelled out. Data collection begins, scheduling observations, and/or downloading images from the image archive. Journal prompts – 1, 2, 3, 4

2. **Second Session:** Participants begin to make sense of the data they have collected by processing their images, closely examining their images, answering the following journal prompts – 5, 6, 7

3. **Third Session:** Image processing, data analysis, and begin write-up. Journal prompts – 5, 6, 7, begin 8, 9, 10, 11.

4. **Fourth Session:** Data analysis and write-up. Journal prompts – 5, 6, 7, finish 8, 9, 10, 11. Participants publish project report (refer to the previous write-up "Observing Projects: Publishing the Project Report" for detailed instructions).

5. **Fifth Session:** "Creating Posters" and begin "Presenting Posters"

6. **Sixth Session:** "Presenting Posters"

Follow up

When all projects are published you may want to print all of the word processing documents of the project reports, complete with images, as a booklet to give to all participants to take home.

Watch out for…

- "Observing Project #2" and "Observing Project #3" can be lengthy endeavors; it is not recommended that these sessions be structured to consist solely of work on these projects. Many of the youth will start to lose focus after being on the computer for an hour or more. Some potential activities to mix-in to break up the computer time are the modeling activities included towards the end of the Hands-On Activities. "Modeling the Earth-Moon System", "Moon Phases Activity", and "A Journey Through the Universe" are all options to facilitate. Additionally, you may want to then suggest that the youth incorporate aspects of these models, or a model of their own design, into their presentation of the second or third observing project. The addition of a model can add a lot of clarity and explanatory power to a project if done well.

Observing Project #3: Introduction & Planning

Note: This is the write-up of the first session of Observing Project #3.

Goals

- Develop a question or topic to be the basis for the third observing project
- Develop a data collection plan and learn how to make sense of observational data
- Understand that professional science is driven by asking well-defined questions that are based on observations
- Build upon data analysis skills by examining MicroObservatory FITS images and their FITS header files

Activity Overview

This is an introductory activity for the third observing project. In this activity, participants develop a research question to be the focus of their project. This question could come from any of the following:

- A new question that the youth have come to as a consequence of engaging in past activities. (Make sure this question is a 'good' question. Review background of "Observing Project #1: Sharing & Publishing" for information about what makes a 'good' question for scientific investigations).
- A question from the suggested list of questions that is interesting to the youth and answerable given the tools at hand (see suggested list under "Gathering of materials" section).

Note: If as a facilitator you are not experienced with leading inquiry-based activities, coaching the youth through the process of developing their own project may be exceedingly difficult. It is recommended that the list of questions be used if this is the case.

Participants should write down in their journals any information that they already know about their chosen topic, especially findings from past activities. Second, review the observing skills from "Observing Project #2" regarding keeping a journal. The journal entries should all be dated and log the participant's daily activity, observations, and findings. Bring back out their conclusions related to what worked well or did not work well from their second observing project reminding the youth to take their own advice for improving this project.

Ask the participants where and how they will obtain their data. Go over some potential sources of data such as the FITS header if they do not mention it as a source. Finally, participants develop their plans for collecting their data and record it in their journals. For example, a participant with the question: Do all galaxies look the same? They might decide that, over the course of the next couple sessions, they will take images of many galaxies, and compare their data with images from the MicroObservatory Image Archive.

Background

When doing science asking good questions is often just as important as finding the answers. To be able to do either of these however, we must collect data, make observations, and analyze the data to make meaning of it. In addition to visual observations made by looking at an object in the sky, or from images, a wealth of information is available from the **FITS header** of an image. This file provides important information about when and how this image was taken and who took it. Some of the information in this file may still be unfamiliar to you. Continue to focus on the following vital pieces of information:

FILE = name of the file
DATE = when the image was taken
EXPTIME = exposure time
START-OBS and OBS-END = Starting and ending time of the exposure
FILTER = filter used when taking this image
TELESCOP = name of the telescope used to take this image
OBSERVER = who took the image
OBJECT = name of the object in the image

To access this information, find your image on the **Latest Image Archive** page on the MicroObservatory website and click on **Image Info**. Also, opening the FITS image with the MO Image software and clicking on the menu bar under **Window**, then clicking on **FITS Header** pulls up the information.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants. At certain points, use of computers will be needed – the best scenario is one computer per participant.

Materials:

- ❑ Small notebooks, which participants should have already.
- ❑ Word processing document—digital journal
- ❑ Computer lab

Preparation time: 🕖

Activity time: 30 minutes

Gathering of materials and final preparations:

The following list of potential projects should be written on a whiteboard or chart paper. For their third project many of the youth might have a question they posed at the conclusion of their second observing project. In this way this third observing project could be a continuation of the second project. Encourage the youth that do not have a lingering question that would make a good research question to select a new project concept from the list below:

- ❑ Why does the Moon look different night after night?
- ❑ What are the objects surrounding Jupiter and how do they behave?
- ❑ How can we classify galaxies according to their shape?
- ❑ How can we classify nebulae?
- ❑ How can we organize galaxies or nebulae based on their size?
- ❑ Is there color in the Universe? How do we create full color images?
- ❑ How does the image of my favorite astronomical object change when taken with different exposure times?
- ❑ Why are some objects only up in the sky during certain times of year? Compare an object inside our galaxy vs. one outside of our galaxy.

Procedure

Discussion lead-in:

Introduce the third observing project as a continuation of the second, in that the youth will be using the observing and analysis skills honed while working on that project. Also, some may want to now address a question developed then, as the focus of this project. For those unsure about what their topic question could be, they may select one from the provided list of potential questions.

Finally, remind the participants that asking a well-defined question, which will be the focus of their project, is critical to the success of their work. Also, inform the youth that asking questions, making careful observations and then arriving at conclusions is the process that professional scientists go through in their research.

Procedure:

1. Participants first select their research question or topic for their project. Once this is chosen, have the youth write in their journals any knowledge or ideas they have about this topic.

2. Go around the room and see if any of the youth have selected the same or similar topics for their projects; try and pair up participants by topic (some of their project ideas may be more complimentary topics than similar, but explain to them how they may fit together in these cases).

3. Review the skills needed for scientific observing.
   - ❑ Being well-organized (dating journal entries)
   - ❑ Recording detailed observations
   - ❑ Making sure that observations are not actually inferences

4. Review the idea of an image as a piece of data. Use the information in the FITS Header as examples of the data that can be extracted from an image (See the Background section for more on FITS headers).

5. Direct the youth to the MicroObservatory Image Archive and remind them of the extensive collection of data available there.

6. The youth should now be able to develop a plan for their collection of data. This plan should be recorded in their journals.

7. If there is time participants should begin gathering their data and taking the first steps that they outlined in their plans.

Follow up

Most, if not all, of the youth will need to take images as part of their data collection plan. Be sure to allow time at the end of the session for them to schedule these observations.

Observing Project #3: Daily Journal & Project Report

Goals

- ❑ Develop better organizational skills by keeping track of daily progress and findings in a scientific journal
- ❑ Analyze and interpret data to make connections and draw conclusions

Activity Overview

The Daily Journal is an ongoing activity added to during each session. The journal helps the youth keep their work and progress organized while reflecting on their data. This reflection helps the youth make meaning of their data and reach a conclusion. Refer to the "Observing Project #3: Overview" to see what prompts are to be answered in each of the sessions.

During the final session days for this project, participants should open their word processing document containing their daily journaling. Present them with the task of completing each of the 4 parts of the project report, using their answers to the daily prompts as the basis for each part of the report. Have the youth type their answers into a document that does not include the Project Report Prompts (see separate page titled "Observing Project #3: Project Report"). You may want to print out the Project Report Prompts page or transfer them onto a whiteboard or piece of chart paper for the participants to reference. Additionally, it is not expected that the youth complete the entire project in one session, and so splitting up the report prompts is recommended. That way the number of questions does not overwhelm them. Finally, be sure that the youth answer the questions of the report prompts with a series of complete sentences. Make sure that they do not just copy and paste notes from their daily journal.

Follow up

- ❑ The 4 parts of the project report are to be posted online on the MicroObservatory website as part of the published project report. (refer to the previous write-up "Observing Projects: Publishing the Project Report" for detailed instructions).

Daily Prompts

1. What is my research question? How did I come up with it? What information do I already know about my object or topic?

2. Given what I know about my object or topic, what do I expect to find? What is my prediction?

3. What is the title of my project?

4. How can I answer my question? What is my plan for taking data?

5. Describe the process of collecting and analyzing your data? Are there any new developments to report today?

6. Look at your image and describe what you see, list any observations related to the features of the object, for example, size, shape, color, location.

7. Describe any patterns or changes that occur between the images. Compare and contrast the images.

8. What did I learn? What would I like to teach someone else?

9. What questions do I have now? How would I answer them?

10. Summarize and evaluate your process in doing this project? What would you do again, what would you do differently the next time to improve your process?

11. Do you have any personal conclusions that in doing this report you came to realize?

Observing Project#3: Project Report

Part 1- Introduction:

Part 2 - Images and Data:

Part 3 - Explanation of Observations & Data

Part 4 - Conclusions, Questions, Recommendations

Project Report Prompts

Part 1- Introduction:

- ❑ What was the question you investigated in your project? How did you come up with it?
- ❑ Given what you know about your question topic, what was your prediction about what you would find out?
- ❑ How did you try to answer your question? Did you have a plan for taking data? What was it?

Part 2 - Images and Data:

(This is the section in which you will place your saved .GIF images)

Part 3 - Explanation of Observations & Data

- ❑ What were the most important and most interesting observations you made? Describe them.
- ❑ Were there any patterns between your images? What stayed the same between some or all of them? What changed?

Part 4 - Conclusions, Questions, Recommendations

- ❑ What was interesting that you found out from this project? What new ideas did you come up with? Do you think that you could convince someone else of your findings?
- ❑ You underwent a process of planning your images with MicroObservatory and making observations. Was there any part of your method that worked really well? Was there anything that could be improved?
- ❑ How would you revise or improve your process?

Observing Project #3: Creating Posters

Note: This is the write-up of the fifth session of Observing Project #3.

Goals

- ❑ Improve oral and written communication skills by organizing project report into a PowerPoint/poster and presenting project to others

Activity Overview

In this session give participants the time to bring together all the work they have been doing over the last 5 sessions. Participants work with their partner on their posters. The posters are created by printing out PowerPoint slides as full pages and affixing the printouts to poster paper. If desired, and your site has the means to project the PowerPoint slides, you may want to have the youth present their work giving a presentation.

Background

During the previous sessions, participants have gathered data, spent time analyzing the data, and come to a conclusion in their journal. This time should be spent solely on putting everything together on their posters in preparation for sharing with the group. It is important to be able to organize new knowledge and communicate that knowledge to others. Without these skills, the value of any learning becomes much less as this learning may be misunderstood or even lost.

Preparation

Space Required:

You will need a room with enough seating and writing space for all of your participants. At certain points, use of computers will be needed – the best scenario is one computer per participant.

Materials:

- ❑ Colored paper, markers, scissors, glue sticks, tape, etc.
- ❑ Chart paper

- ❑ Computer lab for preparation of PowerPoint presentation

Preparation time: 🕜

Activity time: 60 minutes

Gathering of materials and final preparations:

Make sure to have enough craft supplies so that the youth have the option to decorate their posters. Also, the computers the youth are working on need to have Microsoft PowerPoint loaded onto them.

Procedure

Discussion lead-in:

Introduce this time as the only time they have to put all their information on the posters.

Creating posters:

1. Have youth gather everything they need for their poster (all of the information should have already been typed-up in their journal):
    - ❑ Question - Prediction
    - ❑ Images & Data
    - ❑ Data Analysis & Observations
    - ❑ Conclusion

2. Give participants 30 minutes to prepare the slides for their posters. Instruct them to take their typed up information and summarize each paragraph into a single main idea to be entered into the PowerPoint slide as a separate bullet point. Once they are done entering in the information, print the slides and their typed up reports.

3. After the 30 minutes, announce to the group that there is 15 minutes left to finish putting posters together. Participants should be finished preparing their information and start to glue and tape items to the chart paper.

4. Once their posters are finished, groups that are done can begin to rehearse the oral side of their presentation. They should work out with their partner who is to say which portion of the report, and practice good communication skills (Speaking loudly and clearly, standing up straight, eye contact, and presenting without fidgeting are examples).

5. Gather all the finished posters and keep them in a safe place for the next session, or if there is time, begin presenting the projects right away.

Follow up

Presenting the posters!

Watch out for…

- Participants may attempt to cut and paste entire paragraphs of text on the PowerPoint slides. Explain to them that they may have the print out of this information in front of them as they present, and so they should summarize their paragraphs as bullet points.

Observing Project #3: Presenting Posters

Note: This is the write-up of the sixth session of Observing Project #3.

Goals

- ❑ Improve oral and written communication skills by organizing project reports into a PowerPoint/poster and presenting projects to others

Activity Overview

During this session, participants share their projects to the large group.

Background

This session allows for the youth to practice their communication skills as they present their projects to each other. Explaining their questions, process, data and conclusion clearly to others takes practice. Provide time for the project teams to go through their presentations a couple of times among themselves first to feel more comfortable presenting in front of the group.

Preparation

Space Required:

You will need a room with enough seating space for all of your participants.

Materials:

- ❑ Participants' posters

Preparation time: none

Activity time: 1 hour

Gathering of materials and final preparations:

Arrange room to allow for foot traffic to areas where the posters will be set up. Think about how and where the individual presentations will take place.

Procedure

Discussion lead-in:

Announce that this is the time for the youth to share their work with each other.

Presenting:

1. Bring together 2 pairs to make small groups of 4.

2. In each group, the participants share their projects for 3-5 minutes. Each group member shares one thing that was surprising, interesting or confusing about the other pair's projects. The focus should be on the positive aspects.

3. After 15 minutes or so each group member should have had time to share.

4. Gather everyone for the pairs that volunteer to present their posters/presentations to the entire group.

5. At the end of those presentations break-up the youth back into their initial small groups and elicit comments and feedback. Possible questions to pose:
   - ❑ What was the most surprising thing you found while conducting your observations?
   - ❑ What was something you learned?
   - ❑ Did this project change your views on doing science? If so, how?

Watch out for...

- ❑ Participants may spend time socializing instead of looking at each other's posters.

YOUTH ASTRONOMY APPRENTICESHIP

Glossary

Glossary:

absorb: To retain (radiation or sound, for example) wholly, without reflection or transmission.

angle of incidence: The angle from which a ray of light strikes a reflecting object.

angle of reflection: The angle for which a ray of light is reflected from an object. The angle of reflection is always the opposite of the angle of reflection. For example, a particle of light that hits a mirror at a 45 degree angle will be reflected at -45 degrees.

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.

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. Most asteroids in our solar system orbit in a belt between Mars and Jupiter.

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.

automated telescope: An automated or robotic telescope provides a way for observers to collect data (images) without actually "observing." An automated telescope can be programmed to take a picture (or many pictures) of stars or other objects in the night sky. It can be useful for many types of projects. Examples might be photographing Jupiter every day, or capturing images of objects that are visible only at inconvenient hours, like the third quarter moon.

axis: A straight line about which a body rotates.

billion: The cardinal number equal to 10^9, or a one with nine zeroes after it. The number that is represented as a one followed by 9 zeros: 1,000,000,000.

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.

bookmark: A file within a browser in which an Internet user can save the addresses of interesting or frequently used websites, so that they are readily available for re-use.

browser: A program that allows a user to find, view, hear, and interact with material on the World Wide Web. Netscape Navigator and Microsoft Internet Explorer are examples of popular browsers.

Callisto: The second largest of Jupiter's satellites. Callisto is not geologically active and has a thin atmosphere. This combination means it has a very "old" surface, remaining almost entirely unchanged except for accumulating craters, much like our own Moon. Its diameter is about 2980 miles (4800 km) and takes about 16.7 days to orbit Jupiter.

Cat's Eye Nebula: Three thousand light-years away, the Cat's Eye Nebula is a dying star throwing off shells of glowing gas.

causation: The relationship that results when a change in one variable is not only correlated with but actually produces a change in another variable.

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.

celestial object: A natural object, like a star, planet, comet, galaxy, etc. that is observable in the sky.

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.

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.

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).

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.

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.)

contrast: Contrast is the difference between the darkest and lightest areas in an image. The greater the difference, the higher the contrast.

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

correlation: A measure of how two variables are related.

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

dark frame: A dark frame is an image taken with the CCD's shutter closed. This image records only the electronic noise due to the detector itself. When a picture is taken of the night sky it records both the object in the sky as well as the noise. The dark frame is subtracted from this image to leave only a clear image of the object.

data: A collection of facts or information from which conclusions may be drawn. In computer science, data is used to describe information that is stored and/or processed digitally.

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

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.

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

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.

inference: A conclusion based on observations.

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.

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.

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

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.

electromagnetic spectrum: The full range of frequencies, from radio waves to gamma rays, that characterizes the different "colors" of light. There is a relationship between the amount of energy electromagnetic radiation (light) carries and the frequency. Radio waves are low frequency and low energy radiation while gamma rays at the other end of the spectrum are high frequency and high energy radiation. Visible light, that our eyes can see, is also part of the electromagnetic spectrum.

e-mail (electronic mail): Messages sent through an electronic (computer) network to specific groups or individuals. Though e-mail is generally text, users can attach files that include graphics, sound, and video. E-mailing requires a modem to connect the telephone line to the computer, and an e-mail address. E-mail addresses include the @ symbol.

emit: To give or send out (matter or energy).

Europa: The fourth largest of Jupiter's satellites. Europa is a large, dense, icy moon of Jupiter. Its surface is covered with long, crisscrossing track ways (but few craters) and frozen sulphuric acid. Its diameter is less than 2,000 miles (3,138 km), smaller than the Earth's moon. It takes Europa 3.55 days to orbit Jupiter. Its mean distance from Jupiter is about 420,000 miles (670,900 km). It was discovered by Galileo and Simon Marius (independently) in 1610.

exposure time: The period of time a telescope's light-sensing camera collects light coming from the source one wants to take an image of. The longer the exposure time, the more light that the telescope can gather to make an image. The recommended exposure time varies for various targets: faint targets, such as far away galaxies, require long exposure times; bright targets, such as the Moon, require short exposure times.

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.

favorite: In Internet Explorer, a favorite is a collection of Web addresses selected by the user. Favorites are stored in a folder and are accessed by selecting the Favorites menu. Favorites provide an easy way to organize the Web addresses of interesting sites.

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

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.

FITS-format: FITS stands for Flexible Image Transport System, and is an image file format widely used by the Astronomical community. It's great advantage over more familiar image file formats, is that it can, and often does, contain information about the imaging device used to capture the image, and more importantly, the time, date, and location of the telescope used. Additionally, each pixel of a FITS file will often be linked to the Right Ascension and Declination of the portion of the sky imaged. Moving a cursor across such a calibrated image enables an astronomer to determine the positions and names of the stars in the filed of view.

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.

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.

Ganymede: The largest of Jupiter's satellites, with a diameter slightly larger than Mercury's. It is the only moon known to have a liquid core generating its own tiny "magnetosphere." A compass would probably work on Ganymede. It is 3,270 miles in diameter (5262 km) and takes 7.15 days to orbit Jupiter.

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).

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.

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.

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.

inference: A deduction or conclusion made from facts that are suggested or implied rather than overly stated. Drawing meaning from a combination of clues in a given context without explicit reference to that context.

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

internet: A "network of networks" linking millions of computers worldwide for communications purposes. The Internet was originally developed in 1969 for the U.S. military and gradually grew to include educational and research institutions. Today commercial industries, corporations, and residential users all communicate using the Internet. The World Wide Web is a collection of interactive documents accessible via the Internet.

Io: The third largest of Jupiter's satellites and the closest to the planet. Io is the only body in the Solar System, other than Earth, to currently have active volcanos. Photographs taken by visiting unmanned spacecraft have revealed smoke plumes hundreds of miles high. Unlike Callisto, these volcanos are constantly changing the surface of the 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.

Kepler's relation: Also known as Kepler's third law. Kepler's third law of planetary motion says that the average distance of a planet from the Sun cubed is directly proportional to the orbital period squared. Newton found that his gravity force law could explain Kepler's laws. Since Newton's law of gravity applies to any object with mass, Kepler's laws can be used for any object orbiting another object.

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

link: A word, phrase, or image highlighted in a hypertext document to act as a navigation aid to related information. Links may be indicated with an underline, a color contrast, or a border.

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.

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.
million: The number equal to 10^6, or a one with six zeroes after it.
model: A simplified imitation of something that helps us explain and understand that 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.
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.
nebula: A cloud of gas and/or dust in interstellar space. (The word *nebula* in Latin means "cloud"; its plural is "nebulae.")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.
Neptune: The eighth planet from the sun.
normal: An imaginary line that is drawn perpendicular to a reflecting optical element, like a mirror, regardless of whether or not the surface is curved.
nova: A cataclysmic nuclear explosion caused by the accretion of hydrogen onto the surface of a white dwarf star.
observation: The process of using one's senses to perceive and record information about some aspect of the natural world. Also, the act of making and recording a measurement.
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.

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.

opaque filter: This is not a real filter. When using MicroObservatory you select “Opaque” in the filters selections when you want to take an image with the camera’s shutter closed.

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.

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

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

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.

Period: The amount of time it takes for a planet to complete one revolution, or one orbit about the sun.

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."

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.
planet: A spherical ball of rock and/or gas that orbits a star. The Earth is a planet.
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.
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.
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.
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.
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.
rotate: To turn around a center point, or axis, like a wheel turns on a bicycle.
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.
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.
scale: The ratio between the size of something and a representation of it; "the scale of the map"; "the scale of the model"
silicon chip : A wafer-thin slice of silicon that contains thousands of microscopic electronic circuits.

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.

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

spectrum: The distribution of energy emitted by a radiant source, as by an incandescent body, arranged in order of wavelengths.

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.

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.

starburst: A generic term to describe a region of space with an abnormally high rate of star formation.

The Sun: The star at the center of our solar system.

supernova: A special event at the end of the life of a massive star 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. At peak light output, these supernova explosions can outshine a galaxy.

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.

Subaru: Japanese name for Pleiades, stars in the constellation Taurus.

system: a group of independent but interrelated elements comprising a unified whole.

target: In astronomy the celestial object one takes a picture of is called target.

Taurus (The Bull): This is one of the 13 constellations of the Zodiac.

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

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.

trillion: The number that is represented as a one followed by 12 zeros: 1,000,000,000,000.

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.

Universal Coordinated Time (UTC): Universal Coordinated Time is an adaption of Greenwhich Mean Time, but is maintained by over 300 atomic clocks all over the world and has features such as "leap seconds" to maintain better accuracy. It is commonly used by groups that need to share on a single time standard. Astronomers, pilots, and military organizations are common users of UTC. In the United States, Eastern Time is five hours behind UTC during Standard Time and four hours behind during Daylight Saving Time.

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

upload: Copying or sending files or data from one computer to another. A Web developer, for example, could upload a document to a Web server.

Uranus: The seventh planet from the Sun.

Venus: The second-closest planet to the Sun, orbiting it every 224.7 Earth days.

waning: The act or process of gradually declining or diminishing.

waxing: To increase gradually in size, number, strength, or intensity.

web interface: A window screen that can be access through the Internet. Through this window you can interact or communicate with another device usually located away from you. In our case an observer can communicate with the MicroObservatory telescopes through a web form – the web interface - found on the MicroObservatory web site.

world wide web: A vast collection of files, including text, graphics, and other data linked through the Internet.