FROM THE GROUND UP!

The BIG CHALLENGE: Build a Table-Top Universe!

Can you learn enough about size and scale to build an exhibit display with an astronomical model of some part of the universe?

Student mission (for teams of 3-5 students): the local science museum needs your help to create an exhibit gallery on size and scale in the universe. Your mission is to design and construct a table-top exhibit that includes a 3-dimensional model of some part of the universe [not the whole thing!!]. The model should be accompanied by a graphic panel (poster) with text and images explaining the three dimensional model. Your team also needs to produce an exhibit manual documenting your exhibit design and how you came up with it.

Criteria for a successful exhibit design: You will use the skills, images, data, and knowledge that you gain using the MicroObservatory telescopes to create your design. Your final product should reflect the following:
• an accurate use of scale and measurement, where appropriate, as well as an indication of where your model is NOT to scale
• images taken with the MO telescope should be part of the graphic explanation, as well as part of the exhibit manual
• the exhibit manual should demonstrate how measurements made using the MO telescopes are reflected in the exhibit.

What's going on in this image?

Isn't Saturn really much bigger than the moon?

Is the image real, or has it been "doctored"?

Can you visualize a 3-D model of what's going on?

In Search of Infinity: Size and Scale in the Cosmos

Background for Students: Setting the Context for your Table Top Universe

How big is the universe? How do we fit in to the cosmic scheme of things? If you've ever gazed at the moon and stars and wondered about these things, or have seen a new image from the Hubble Space Telescope and marveled at the beauty of the cosmos, you're not alone. The patterns of stars and motions in the night sky have inspired human awe and curiosity for thousands of years. And ever since Galileo trained his telescope on the heavens 400 years ago, women and men who use telescopes to study the sky have discovered a universe far richer, more varied, (and bigger!) than people's eyes alone had ever led them to imagine.

How is it possible to find out about stars and galaxies that are trillions and trillions of miles away? Unlike scientists who investigate earthly events, astronomers usually are unable to visit or set up experiments with the things they are interested in. They have to be experts in studying objects from a distance, experts at *observation.*

We may not be able to travel to the stars, but the light of the stars travels to us. The night sky (and the day sky, for that matter, but that's another story) is full of starlight. Light generated in the cores of stars and galaxies shines all over the cosmos. It bounces and reflects off of asteroids and planets. It energizes clouds of interstellar gas ("nebulae") and makes them glow like neon bulbs. It is soaked up and dimmed by interstellar dust, and is swallowed up by massive black holes. And sometimes, some of this celestial light passes by our tiny planet called Earth in the Milky Way Galaxy. By collecting, measuring, and making sense of patterns of incoming starlight, we earthlings have begun to understand the story of the universe.

You are about to become a starlight collector. Over the next several days, you will be controlling telescopes over the Internet to learn about some of the cosmic cast members of our universe, and to make some measurements of the scale of the cosmos. Your mission is to share some of your newfound understanding with others in an exhibit display.

Science Concepts included in module:
- Size and scale of astronomical systems
- Earth's place in the solar system, galaxy and universe
- Understanding Models
- Apparent size/distance ratios
- Inverse-Square law (if activities How Far Are the Stars and Galaxies are included)
- Scientific notation

Science Inquiry Skills:
- Creating models
- Analyzing strengths and weaknesses of models
- Analyzing visual information
- Planning observations
- Controlling an on-line telescope
- Collecting and recording data
- Making measurements from visual data
- Image processing

Activity Sequence:
What's Your Model of the Universe?
Cosmic Survey
Surveying the Universe with Online Telescopes
Image Processing for Better Contrast
Size/Scale Image Analysis (1 class period)
Getting Quantitative: Measuring Size from Images
Additional Quantitative Size/Scale Investigations:
    Moon Illusion/ How Far is the Moon?
    How Far are the Stars?
    How Far are the Galaxies?
Final Challenge: Planning and Building Your Table Top Exhibit

TEACHER'S GUIDE

Here is a draft sequence of activities to help students build skills to be able to complete the Table Top Universe project:

Exploring students' preliminary ideas and questions.

Before you begin using the telescopes, you may want to spend a class period on the activity, **"What's your Model of the Universe?"** (See Modeling the Universe PDF file.)

This activity starts a discussion of what IS the universe and what's in it -- a prerequisite for students to start thinking about matters of size and scale in the universe. Lots of questions are guaranteed to be generated through this activity—questions that can lead to many independent student research projects, as well as questions that can help students begin to focus on their future task of designing a table-top museum exhibit.

Alternatively, you can try the **"Cosmic Survey" activity** (see Cosmic Survey PDF file), in which students physically manipulate pictures of objects in space, thereby representing their own mental models of size and distance in space. (Note: Only the first 2 parts of this activity, which ask How Big and How Far the objects are, directly relate to this module. The third part, How Old, can be optional, although it is a great conversation generator and relates ideas about change over time to ideas about size and scale.)

Surveying the Universe with Online Telescopes.

1 to 2 Class Periods
Materials

- Cosmic Cast of Characters Chart (PDF file)
- User's guide (PDF file)
- Observers' Log Sheets (PDF file)
- Access to internet-connected computers
- When and Where to Look (PDF file)
- One to several days to get back good images.

Now is the time to get students obtaining their own images of objects in space. You may wish to divide students into observing teams. Have students look over the Cosmic Cast of Characters Chart and the guide "When and Where to Look" in order to choose a category of objects to take images. Each team should plan on obtaining images of 4 objects. (You may choose either to have each team pick 4 objects from one of the categories— solar system objects, stars, nebulae or galaxies — or 1 object from each of the 4 categories.) The goal is for the class as a whole to come back with a variety of images of celestial objects from all categories.

Each student (or student team) should use the Users' Guide and the MO Observers' Log Sheet to plan their observations. (If you have limited access to computers or need to minimize student time spent at the computer, be sure to have them fill out their Observer's Log <u>before</u> going to the computer.) **Important: for this activity, all students should be sure to choose Main Camera, Zoom Out when controlling the telescope.**

For their first few times using the on-line telescopes, students may need extra time to explore the MicroObservatory web site. After students have gained some experience, however, the actual process of making an on-line image request should take no more than a few minutes, especially if students refer to the "Suggested Settings" page in the User's Guide, and then use the Log Sheet to plan their observation.

Note: Getting good images can take longer than you think! The weather might not cooperate, other observers may take up your time slots, it takes some time to get exposures, filters right. Let students know that, in lieu of coming back with their own images, if they are unable to get good ones they should print out images from the image archive (and their information pages).

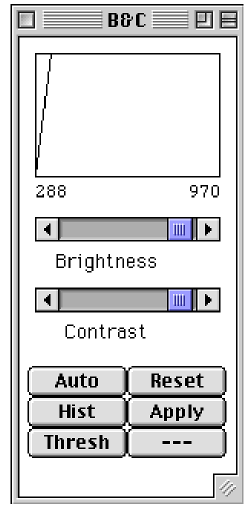
After Students have gotten back images they will need to “image process” their images to improve contrast:

Image Processing for Better Contrast.
1 Class Period
Materials

- Downloaded FITS images (see Users' Guide for instructions)
- Computers with Image Processing Software (either SIP or Image J — see Image Processing Manual for download instructions)
- Printer for printing out hard copies of processed images.

Before using their images for an analysis of size and scale of cosmic objects, students will need to do some image processing. Often the image that comes back as a GIF file on the web site may look like there's not much there (especially for images of dim nebula and galaxies), but the FITS file often has much more information that can be enhanced with image processing.

The simplest way to see if there's more to an image than first appears, is to open it in Image J and do the following commands:



- Image: Adjust - Brightness/Contrast
- Drag the B&C window to the side of the image
- Select "auto"
- If "auto" still doesn't show much, move both the "Brightness" and the "Contrast" sliders way over to the right (but not all the way). You may now have to tweak the B & C sliders a bit to get the best display of your image. (This usually will bring out faint details in nebulae and galaxies)

(instructions for this activity still under construction)

Reflection questions for students after processing their images:

1. Describe the appearance of your planet, star cluster, nebula, or galaxy:

2. Did you find anything unexpected in your image? Does it look like you thought it would?

3. What is a possible explanation for the appearance of your image?

4. An image is of course a 2-dimensional model of the real object out in space. Can you make any hypotheses about the 3 dimensional shape of your object?

5. Is there an image or object that seems particularly aesthetically pleasing to you? Why do you think that one appeals to you? Write a list of descriptive adjectives that convey your reaction to this image.

Size/Scale Image Analysis
1 Class Period
Materials

- Printouts of MicroObservatory images of objects of all sorts: planets, stars, nebula, galaxies (Each team should bring 2 copies of each of its 4 best celestial object images) Each image should be accompanied by a printout of its "Image Info" page.

This activity parallels the Cosmic Survey activity except that this time students have the benefit of knowing that all their images have the same angular field of view, and are at the same magnification (as long as all were taken through the main camera, zoom out, and printed at 100% scale).

Procedure:

1. Each team should label their 2 sets of 4 images with the name of the object, the category (solar system, stars, nebula, or galaxy), and the exposure time.
2. Distribute images among teams so that each team has 8 images (not necessarily all their own) representing objects from all 4 categories.
3. Have each team try to agree on the order of their images according to the arrangements below. They should write down the order for each question, and keep track of any questions or disagreements that come up.

Discussion question: How do the sizes of the objects in these images compare to the size of the Moon's image? Are any of them larger than the Moon's image? Recall that MicroObservatory telescopes take images at the same magnification (when zoomed out). If some of these celestial objects are roughly the size of the Moon, then why don't we see them in the sky? If we COULD see them, what would the night sky look like? (Students might draw a typical night sky scene based on their images.)

Apparently, the reason we don't see many celestial objects with our naked eye is NOT that they're too small… it's that they are too faint. Telescopes are NOT primarily used to magnify (though they do, somewhat). They are used to INTENSIFY light: They have a larger light-collecting area than our eye, and they collect light for a longer period of time. (What is the "shutter speed" of the eye?)

Now try this:

- Arrange the celestial objects by their apparent size in the image, from smallest to largest (this should be very straight-forward, it's just looking at each image and noting the size)

- Arrange, from smallest to largest, by what you think is the actual size of object in nature. For some of the objects, students may have no idea of the actual size. Have them rate their confidence (high, medium or low) in the placement of each image.

Discussion question: Why doesn't the actual size match the apparent size in these pictures? For example, why does the giant planet Jupiter appear so much smaller than the moon?

- Arrange by what you think is the distance from earth (where the telescopes are). Again, students should rate their confidence level in their placement of images.

Discussion question: How does knowing that all the images are at the same magnification help in answering this question? If you assume all galaxies are about the same size (a reasonable, but not perfect assumption), can you make some estimates about the distance of different galaxies? Can you say anything about the distance to an object if you don't know its size? Or its size, if you don't know its distance?

- Arrange by exposure time.

Discussion question: What relationship, if any, does exposure time have to the distance of a celestial object?

Determining Sizes and Distances to Celestial Objects

You can determine the distance to the Moon, to the stars, and to different galaxies for yourself, using the telescope. (See the corresponding activity PDF files under "Size and Scale".) These activities involve two ways to distance to an object: By measuring <u>brightness</u> (objects become dimmer as they get further away) or by measuring <u>angular size</u> (objects look smaller as they get further away).

Students may be able to estimate distances or sizes to objects in their images. For details on how to measure angular size, see the PDF file**, "Determining Size From Images."**

1 Class Period
Materials

- Determining Size From Images guide and Data Sheet (PDF file)
- Rulers and Printed images
    - or computers with Image Processing software and image files

This activity guides students through the math of measuring an angular apparent size from a MicroObservatory telescope image, and from that calculating a distance/size ratio. If the actual size of an object is known independently, the distance can be easily calculated, and vice versa.

Planning and Building your Table Top Model.

Now that students have completed the activities in this module, they can plan and build their exhibit display as a final assessment. You may wish to have the whole class mount a "Cosmic Size and Scale" exhibit fair, for other classes to attend.

Have students answer these questions before they work on their model and display. Review the criteria for a successful display with students.

Planning Questions:

1. What is the celestial object (or system of objects) you want to model?

2. Why did you pick that object? What appealed to you about it?
3. Show how you measured the size of your object. Use telescope images to explain the dimensions of your object.
4. What scale will you use to fit your model on a table top?
5. Where did you find additional information for your object?
6. How does the size and scale of your cosmic object compare to some other reference (to the size of the earth, solar system, or something else, for example)
7. Where in the Universe is your object related to earth?
8. What's something cool you found out about your object?
9. What problems might you have in trying to make a model of your object?