Cosmic Survey: What are your ideas about the Universe?

Introduction

Many people, adults and students alike, are familiar with the names of objects in space, but have an incomplete mental model of WHERE those objects are in space, their relative size and scale, and how they fit into the cosmic scheme of things. Understanding the sizes and distances of celestial objects can be tricky, since in our everyday experience, the stars all seem the same distance away, and the moon can appear close or far away depending on whether you observe it near the horizon or higher in the sky. And of course 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 — 2" x 2 "!

In this activity, a three-part questionnaire launches your students on discussions about where objects in space are located, and when they formed — an introduction to the concepts of structure and evolution of the universe. By physically manipulating images of objects in space, students represent their own mental models of space and time.

When you lead discussions with your students, please 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 that students develop as they confront the questions that arise as they struggle with their mental models of the Universe.

This survey can serve as a great pre-unit assessment activity for you to find out how your students think about the Universe, and you can use it to help design follow-up activities that help students to improve their understanding. The Universe! Education Forum has been using this survey as a research tool to help inform future curricula, and we would love to have your feedback. Email us at: seuforum@cfa.harvard.edu.

Time Frame

Part 1: What are your ideas about the Universe?	30 minutes
Part 2: Discussion	30 minutes

Materials Needed

For each student:
• 1 strip of 7 different images cut from a copy of the Cosmic Survey Classroom Master
• a pair of scissors
• 1 copy each of the 3 "What are your ideas about the Universe" survey data sheets (How Big? How Far? How Old?)

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For the class:
• 8 sets of the 3 "What are your ideas about the Universe" survey data sheets

Getting Ready
- Make enough copies of the Cosmic Survey Classroom Master image sheets to have 1 strip of 7 images for each student. (There are 4 strips on the master).
- Cut individual strips for each student (students will cut their own individual images).

Part 1: What are your ideas?

1. Hand out copies of the 3 survey data sheets and the strips of images. Ask students to cut the strips into 7 separate images; put their names at the top of the 3 survey data sheets; and then have them work to answer the survey questions in the following order: How Big? How Far? How Old? (This order represents increasing levels of conceptual difficulty for most students). Collect the students' papers so you can look over their ideas later.
2. Organize the class into eight discussion groups of three to five students per group. Give each group a set of survey data sheets. Explain that each team is to discuss the three survey questions and come to an agreement, if possible, on the best order of images for each question. One member of each team should write down and keep track of questions that arise as they order the images.
3. Circulate among the groups of students, encouraging them to discuss any disagreements fully and to write down arguments in support of their answers.

Part 2: Discussion

1. Lead the class in a discussion about the 3 different survey questions. Play the role of moderator, requiring each group to explain why they chose that order. (Ensure that students are also comfortable saying, "we really didn't know about these objects…") Look below for a discussion of "correct" answers vs. frequent student ideas.
2. After discussing each question, poll the students on the alternative orders of images suggested. Do not announce the correct order at this time; students should be encouraged to think for themselves.
3. After getting a class consensus on all three questions, let students know the correct answers according to measurements and observations of astronomers.
4. You can try this activity again with your students as a post-astronomy unit assessment, to see if their ideas have changed.

Possible classroom follow-up activities could include:
• researching size and distances, and calculating and making scale models of different objects in the universe
• activities measuring distances using angular diameter
• investigating how astronomers can find out about distant objects: what can you learn from light

Thanks to GEMS Earth, Moon, & Stars for the format of this activity.

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UNIVERSE!

Discussion Notes for Cosmic Survey: Frequent student ideas compared with astronomers' measurements

Question 1: How Big?

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

Telescope	40 feet long
Moon	2 thousand miles diameter
Saturn	75 thousand miles diameter
Sun	875 thousand miles diameter
Pleiades	60 trillion miles across the cluster
Galaxy	600 thousand trillion miles across
Hubble galaxies	600 million trillion miles across the cluster

Students answering this question sometimes wonder whether Saturn is larger than the Sun (since they may know it as a "giant" planet). They also wonder if, in the image of the Pleiades, "are we talking about the sizes of the individual stars, or all the stars in the picture?" You may need to explain that for this picture (and the Hubble galaxies), the challenge of the survey is to figure out the relative size of the "field of view" — all the stars (or galaxies) in the cluster.

Some notes: 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 destined to turn into stars such as our Sun: They collapse under their own weight and grow fiercely hot as their nuclear fires are kindled. At each scale in the Universe, gravity helps shape the structures we see.

Question 2: How Far?

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

Telescope	350 miles above surface of Earth
Moon	250 thousand miles
Sun	93 million miles
Saturn	120 million miles (at its closest)
Pleiades	2400 trillion miles
Galaxy	200 million trillion miles
Hubble view of galaxies	30 billion trillion miles

In this survey question, students often struggle with

1. the distance of the Hubble space telescope (after all, it takes images of very distant objects…and while NASA has sent some spacecraft out deep into the solar system, the space telescope orbits fairly close to earth's surface).
2. The relative distances of the Sun and Saturn -- figuring this out requires knowledge about the relative orbits of the planets
3. Depending on how much astronomy background students have had, the Pleiades may be placed inside the solar system, or as the farthest objects in space. In general, most students (and adults) have a hard time understanding the relative distances of the last 3 objects.

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Some notes: How far away is that 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.

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 our naked eyes (including the Pleiades) are just among 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! A "best response" (one that most astronomers—but not all—might give) is:

Telescope	a few years (1990)
Pleiades	25 million years
Moon	~4.5 billion years
Saturn	~ 4.5 billion years
Sun	~4.5 billion years
Galaxy	10 billion years?
Hubble galaxies	10 billion years?

In confronting this seemingly simple survey question, students are grappling with the big ideas of formation of the solar system, life cycles of stars, and evolution of the universe!

Some notes: 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 generations of stars, like those in the Pleiades, are continually being born.

The Pleiades stars are only about 25 million years old. If the dinosaurs ever gazed at the night sky...they wouldn't have seen the Pleiades, which hadn't been born yet!

What's older, sun or Hubble galaxies? 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 the Sun.

On the other hand, the Hubble deep field galaxies are young! Because light takes time to travel, telescope images of far-away objects let us look back in time. This image shows these galaxies as they were when they formed only a few billion years after the Big Bang...so many of the stars in these galaxies may be younger than our Sun. We're looking at an "old" image of young objects!

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