Cosmic Survey: *What are Your Ideas About the Universe*

Goals:

- To have fun!
- To introduce the concepts of the contents, structure and evolution of the universe

Materials:

For each student
- 1 set of 7 different images cut from a copy of the Cosmic Survey Master
- scissors
- 1 copy each of the 3 "What are your ideas about the Universe" survey data sheets
  How Big? How Far? How Old?

Background:

We could live in an infinite universe. No one yet knows the true size of our universe. Our view is limited not by a physical edge to space, but by how far light has traveled since the time our universe was born. The observable universe is just a portion of the whole.

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 because 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. 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.

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

When you lead discussions with 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 assessment activity for you to find out how your students think about the universe, and a good introduction to other, related activities about space science.

Suggestions for Introducing the Activity:

This is an introductory activity that guides students as they begin to think about where we fit in the universe. Students should be familiar with the objects in our solar system and the terms for celestial objects beyond our solar system. Ask students to name some objects in the universe. What might we want to know about objects in the universe? What kind of information could we gather about objects in the universe?

Procedure:

- Make enough copies of the Cosmic Survey Master images for each student to have a set of seven images. You do not need to cut these images from the book; a separate set of both large and small images is found in the pocket at the back.

Part 1. What are your ideas?

- Hand out copies of the three data sheets and the sets of seven images. Have students cut the images apart so they can physically manipulate them as they fill out their data sheets. They should 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.
- Organize the class into discussion groups of three to five students. 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 record questions that arise as they order the images.
- 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

- 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.") See the discussion notes for "correct" answers and frequent student ideas.
- 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.
- After getting a class consensus on all three questions, let students know the correct answers and observations of astronomers.
- Try this activity again with your students after a visit to the *Cosmic Questions* exhibit or as a post-astronomy unit assessment, to see if their ideas and understanding have changed.

Discussion Notes:

Question 1: How Big?

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

Telescope	40 feet long	(12 meters)
Moon	2 thousand miles diameter	(3,200 kilometers)
Saturn	75 thousand miles diameter	(121,000 kilometers)
Sun	875 thousand miles diameter	(1,408,000 kilometers)
Pleiades	60 trillion miles across the cluster	(1×10^{14} kilometers)
Galaxy	600 thousand trillion miles across	(1×10^{18} kilometers)
Hubble galaxies	600 million trillion miles across the cluster	(1×10^{21} kilometers)

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. They collapse under their own weight and grow fiercely hot as their nuclear fires are kindled.

Students 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:

Telescope	350 miles above surface of Earth	(560 kilometers)
Moon	250 thousand miles	(402,000 kilometers)
Sun	93 million miles	(1.5×10^{8} kilometers)
Saturn	120 million miles (at its closest)	(1.3×10^{9} kilometers)
Pleiades	2400 trillion miles	(4×10^{15} kilometers)
Galaxy	200 million trillion miles	(3×10^{20} kilometers)
Hubble galaxies	30 billion trillion miles	(5×10^{22} kilometers)

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 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.

Students 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.

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 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 seven images is actually somewhat ambiguous, and the subject of much current astronomical research! 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! A best response, one that most astronomers—but not all—might give, is:

Telescope	a few years (1990)
Pleiades	80 million years
Moon	4.5 billion years
Saturn	4.5 billion years
Sun	4.5 billion years
Galaxy	10 billion years
Hubble 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.