Session 2 – Cosmic Survey

General Description

Questions on how big, how far, and how old objects in the Universe are might launch students into discussions about where in space the objects are located and when they formed. Students work in teams to physically manipulate paper images of objects in space, allowing them to develop and present their own mental models to address these questions. Students can work in groups of 3 or 4. This activity can also be done in pairs if the overall group is small.

Objectives

- To explore the idea of sorting and categorization in general.
- To explore multiple means of sorting and organizing objects in the Universe.
- To improve students' understanding of the size, structure, and evolution of the Universe.

Concepts Addressed

- Objects found in the Universe
- Size and distance in the Universe
- Structure and evolution of the Universe

Materials

- One set of Cosmic Survey Cards per team (included in Appendix F)
- Scissors
- Access to a laminator (if available) or sturdy paper and glue to mount the images
- One set of three *Cosmic Survey Student Worksheets* per team (included in Appendix E)

Other Requirements

- Enough table or desk space for students to work in small groups

Background

Astronomers believe our Universe began with a Big Bang that occurred over 13 billion years ago, but no one yet knows the true size of the Universe. Our view is limited not by a physical edge to space, but by how far light has travelled since the Universe began (a concept that will be addressed in the next session).

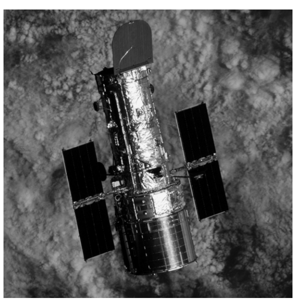
Many people are familiar with the names of objects in space, but most have an incomplete mental model of their relative sizes, distances, and ages, as well as how they fit into the structure of the

Universe as a whole. These concepts are tricky, so patience is required. In our everyday experience, the stars all *seem* the same distance away, and the Moon can *appear* closer or farther 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 from images that are all about the same size and have no indication of scale.

Here is a brief description of the objects pictured in all nine of the Cosmic Survey cards:

New York City is a city of over 8 million people in the Eastern United States.

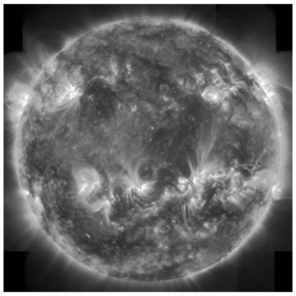
The pyramids were built by the people of ancient Egypt to entomb their emperors.



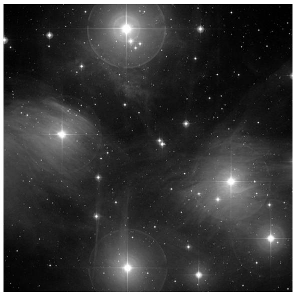
The Hubble telescope is a satellite we have put in space to take images of distant objects.

The Moon is a body that orbits the Earth. This object can be clearly seen in the night sky.

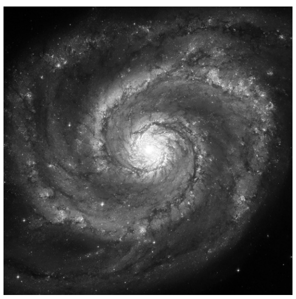
Jupiter is the largest of the planets in our solar system. Depending on the time of year, Jupiter appears as a bright object in the sky.



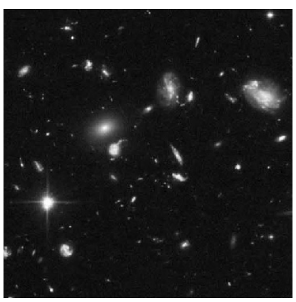
The <u>Sun</u> is the star in our solar system, around which the Earth, Jupiter, and all the other planets orbit.



The <u>Pleiades</u> stars are a star cluster, a grouping of several stars loosely bound together by gravity. It is easily visible to the naked eye in the constellation of Taurus.



Galaxies are large collections of stars held together by gravity. Most galaxies are brighter in the middle because more stars are concentrated there. The <u>Whirlpool Galaxy</u> is the name of a specific galaxy, not a type of galaxy.



The <u>Hubble Galaxies</u> are from the Hubble Ultra Deep Field, an image captured by the Hubble Space Telescope, which took a long exposure of an apparently empty patch of sky. The picture that came back, instead of being empty, contained countless galaxies. This card shows a small portion of that picture.

Session Overview

The session begins with a group discussion of students' ideas and knowledge of objects in the Universe. Working in teams, students then manipulate paper images of objects in space to arrange them in order from smallest to largest, nearest to farthest, and youngest to oldest. In the process, they must consider why they make the decisions they do. The class reassembles to share and discuss results.

Preparation

- Cut cards apart and laminate them if possible — printer paper is too thin for this activity. If you don't have access to a laminator, glue the images to heavy paper to reinforce them.

- Group the cards in sets of 9 for distribution.

- Make 1 copy of the set of student worksheets for each student.
- If you have a transparency projector, make a transparency copy of the sheet with the 9 cards so that you can put it up and discuss it with the full class. Or you can try to make a larger copy of the sheet so that you can hold it up for the whole group to see.
- Make sure that you know what the objects on all of the cards are so that you may describe them and answer questions about them with your students.

Activity

I. Discussion (10 minutes)

Students start by becoming familiar with the concept of categorizing objects according to different characteristics. You can start this discussion by asking students to categorize themselves in some way. Ask the students to line up by height or by age. Once they have done this, ask them to come up with some other criteria that they can then sort themselves by. This shows that the same group of objects (in this case, themselves) can be sorted in more than one way. Alternatively, you can use any objects you think the students will be familiar with.

Once students understand how to categorize items, ask them to name some objects in the Universe. Each time they name an object, ask if they know what it is. Ask what kind of information we could possibly learn about objects in the Universe.

Hand out the sets of cards. If you have a transparency projector, put up a transparency with the images of all the objects on their cards. Or hold up the sheet of paper so all can see it. Ask students to identify the objects on each card. If they are not familiar with the objects, explain briefly what they are using the descriptions from the background section of this session.

If you would like to avoid them sorting by size of the picture rather than size of the actual objects, you may explain this ahead of time, or you may choose to leave this open. This activity is not at all about "correct answers," but is entirely about the process, and about having reasons for the choices they make. There are ambiguities when sorting different objects, and it can be helpful for the kids to see this.

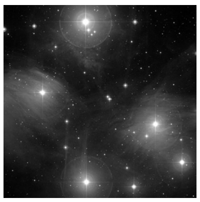
II. Team Activity (20 minutes)

(Adapted with permission from Cosmic Questions Educator's Guide)

1. Form teams of 3 to 4 students. Pairs are also acceptable if your overall group size is small. Hand out the set of *Cosmic Survey Student Worksheets* to each team. Have each team choose a Recorder and a Spokesperson.

2. 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. Each Recorder should record any questions that arise during each set of discussions. Have students answer the survey questions in this order, which represents increasing levels of complexity for most people.

   – How Big?
   – How Far?
   – How Old?



For the Pleiades and Hubble galaxies images, students may wonder if we are talking about the sizes of individual stars or galaxies in an image, or the size of the entire group. In each case they are to work with the relative size of the entire group.

3. Circulate through the class, encouraging them to discuss any disagreements fully and to write down arguments in support of their answers.

4. Pause to discuss each question before moving on to the next one.

III. Discussing and Sharing with the group (15-20 minutes)

Lead the entire class in a discussion about each survey question before the kids move on to the next. Play the role of moderator, requiring each group to explain **why** they chose that order. Start with "How Big?" and ask all groups to share their conclusions. Then go on to "How Far?" and "How Old?" **Do not announce the correct order**; students should be encouraged to think for themselves. Ensure that they are comfortable saying, "I don't know." Getting the "right answer" is not as important as the critical thinking skills developed as their mental models of the Universe develop. In this activity, the reasons they are put in a certain order are much more important than the order itself.

Instead of exact numbers, it may instead be useful to introduce some scale factors when considering the relative size of objects. Some examples are that 100 Earths can span the diameter of the Sun, all the planets of the solar system could fit into the Sun, and a galaxy is a "city" of many billions of stars. Provide other analogies that you feel are relevant.

To further facilitate the discussion you can ask some of the following questions:

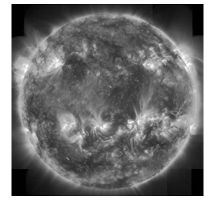
– *What is a planet? What is a star?*
– *What is a galaxy? What is in a galaxy?*
– *Which objects can you see with your naked eye?*

Elicit ideas on what big, far, and old mean on Earth versus in space. Astronomers think about these concepts much differently than we do.

This is a good place to bring in the idea of these images as models, to reinforce session 1.

Question 1: How Big?

In pictures, the objects all look roughly the same size. But the Sun is much larger than Jupiter or any planets — a million Earths would fit inside it. Size counts in nature. Objects that are a bit larger than Saturn or Jupiter will become stars, like our Sun. They collapse under their own weight and grow fiercely hot as their internal fires are kindled — and a star is born! The reason the Moon looks so big is because it is very close to us, relatively speaking.

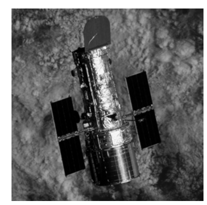


Question 2: How Far?

Figuring out the relative distances to the Sun and Jupiter requires knowledge about the relative orbits of the planets. And depending on how much astronomy background students have, they may think the Pleiades are inside the Solar System, or that they are the farthest objects in space. Most people have a hard time understanding the relative distances of the objects outside our Solar System.

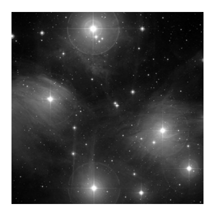
The Hubble Ultra Deep Field image is the most distant view of our Universe, completed in 2004.

Students often struggle with the distance to the Hubble Space Telescope, since it takes images of very distant objects. The telescope itself is actually in orbit around the Earth — high enough for a clear view above the Earth's atmosphere, but low enough for repairs by Space Shuttle astronauts.



Many think the Pleiades star cluster must be further away than the Hubble galaxies, because it looks smaller. But all of the stars we see in the night sky are much closer than even the nearest galaxy. The roughly 5000 stars we can see with our naked eyes (under the darkest conditions) are just the closest of the billions of stars in our own galaxy, the Milky Way Galaxy.

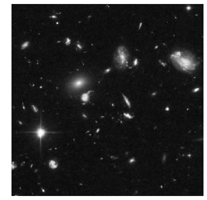
Question 3: How Old?



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

In this activity, it is very valid to consider the Moon, Jupiter, and the Sun all the same age. This is because the Solar System formed at basically the same time. Multiple theories exist as to the exact order of formation, but when we are looking at times in terms of billions of years, these differences are negligible.

Which is older, the Sun or the Hubble galaxies? It depends on what you mean by "age." Although the Hubble "deep field" galaxies images were taken in recent years, they are among the most ancient and distant objects in the sky. The light from them has taken over 10 billion years to reach us, so they were born long before our Sun. (This point is raised again in Session 3.)



On the other hand, *as they appear in these images*, the Hubble galaxies are actually young galaxies! Because of light's travel time, we see them as they were when they formed 10 billion years ago, only a few billion years after the Big Bang. Many of the stars in the galaxies in this image may have been younger than our Sun when the light first left them, so we are looking at the "baby pictures" of objects that are now really quite old.

After the group discussion on all three questions, if you would like to let participants know the correct answers and observations of astronomers, you may do so. We do not consider this to be important for this activity, but the class will likely want to know, so we leave the choice up to you. If you are particularly interested in the numbers, we have done the legwork for you. You can find them in the resources section of our website.

Suggestions for Running this Session

- This activity is not about knowing the actual numbers involved for sizes, distances, and ages. We encourage you to go through the session without any such numbers, and not to give in to demands for "the answers." A lot of the numbers in this activity (especially when you're talking about distances or ages) are very large. Most people don't have a deep understanding of the difference between a million, a billion, and a trillion. They're all "big" numbers with a lot of zeroes at the end, and the differences between them aren't very meaningful. It is more important to understand the relationship between objects (e.g., "the Whirlpool Galaxy is closer to us than the Hubble Galaxies") instead of specific numbers. These relations are more likely to be retained than the numbers themselves. It may also be useful to introduce some scale factors when considering the relative size of objects. Some examples are that 100 Earths can span the diameter of the Sun, all the planets of the solar system could fit into the Sun, and a galaxy is a "city" of many billions of stars. Provide other analogies that you feel are relevant. If you feel that it is important to share the correct answers and observations of astronomers with your group, you may do so after the group discussion on all three questions. You can find this information through internet searches, or compiled together in the resources section of our website

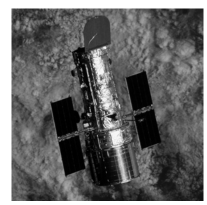
- One of the hardest things about running this session is to answer student questions about objects, and avoid giving away information that answer the questions posed in the activity. This is particularly difficult with the Hubble Deep Field image, as most explanations mention how far away or how old the galaxies are. The descriptions of the different objects as given in the background section can be one possible way to describe each of the cards.

- There are other ways that participants may think of the questions "How big? How far? How old?" besides the literal answers, and these alternate modes of thinking may affect their ordering of the objects. For example, "How big?" could also mean the size of the image in the picture itself (how much of the frame it fills), or the apparent size from the perspective of the viewer. "How far?" will be dependent on the location of the viewer, so if a participant chooses to begin their sort from the Pleiades instead of Earth, it will affect the order of the objects. And "How old?" can also be very interesting - it could be based on the time of the object's discovery, the time the image was captured or created, or even the time of the participant's own discovery of the object! When you have participants share the order of their cards, make sure they explain the basis of their sorting, because this can lead to confusion or the idea that this is "wrong" when it is simply another way of thinking about the objects at hand.

- For the Pleiades and Hubble galaxies images, students may wonder if we are talking about the sizes of individual stars or galaxies in an image, or the size of the entire group. In each case they are to work with the relative size of the entire group.

- In this activity, it is very valid to consider the Moon, Jupiter, and the Sun all the same age. This is because the Solar System formed at basically the same time. Multiple theories exist as to the exact order of formation, but when we are looking at times in terms of billions of years, these differences are negligible.

Misconceptions



- Students have the misconception that space telescopes such as Hubble actually go to the objects and return with images. In reality, these telescopes orbit close to the Earth (like telecommunication satellites do) and only gather the light from distant objects. It is impossible to travel the immense distances to the objects in most of the pictures. See the Cosmic Distance Scale at: http://heasarc.gsfc.nasa.gov/docs/cosmic/cosmic.html

- Students often mistake apparent brightness, size or distance of an object in the sky for the actual qualities. But distance has an effect on how large or bright something looks. The same can be said of a car. It looks small when approaching from a mile away, and its headlights look faint at night; when the car gets closer, we can better observe its real size and the actual brightness of the headlights.

- In answering students' questions about objects, carefully avoid giving away information that answer the questions posed in the activity. This is particularly difficult with the Hubble Ultra Deep Field image, as most explanations mention how far away or how old the galaxies are.

Useful websites for background or activity extension

- **NASA's Universe Education Forum**
  Learn about where we are in the Universe while virtually travelling from Earth to the Hubble Deep Field galaxies, and all the stops in between.
  http://www.cfa.harvard.edu/seuforum/opis_tour_earth.htm

- **Cosmic Distance Scale**
  This feature gives a feeling for how immense our Universe is, starting with an image of the Earth and then zooming out to the furthest visible reaches of our Universe — as in the "Power of 10" films.
  http://heasarc.gsfc.nasa.gov/docs/cosmic/

- **Toilet Paper Solar System**
  This activity explores the distances between the planets, using toilet paper as a measuring tape to determine the placement of the planets.
  http://solar.physics.montana.edu/tslater/plunger/tissue.htm

- **Hubble Ultra Deep Field**
  The Hubble Space Telescope took a million-second-long exposure of an apparently blank patch of sky and saw that it wasn't blank at all — but was filled with galaxies!
  http://hubblesite.org/newscenter/archive/releases/2004/07/text/

- **Wilkinson Microwave Anisotropy Probe (WMAP)**
  NASA's WMAP satellite peered back almost to the very beginning of the Universe!
  http://www.nasa.gov/vision/universe/starsgalaxies/wmap_pol.html

- **Cosmic Questions Educator's Guide**
  http://www.cfa.harvard.edu/seuforum/download/CQEdGuide.pdf