



modeling the universe

The Scale of the Realms of the Universe

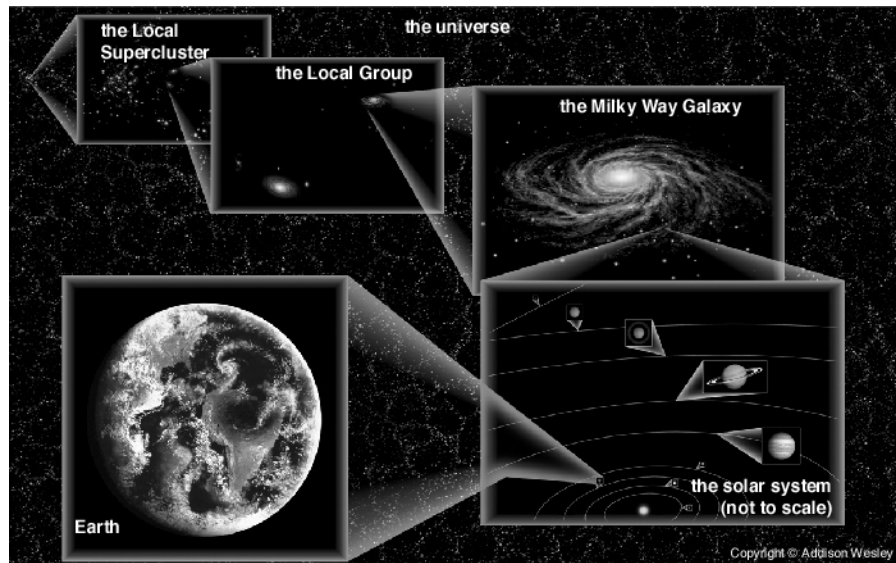


Image courtesy of *The Cosmic Perspective* by Bennet, Donahue, Schneider, & Voit; Addison Wesley; 2002

Goals:

- To gain a sense of relative scales of the various realms of the Universe
- To learn about the structure of the various realms of the Universe

Overview:

The Universe is very, very big. But just how big it is and how we fit into the grand scheme can be quite difficult for a person to grasp. The distances and sizes are so far beyond our everyday experience.

Many activities have been created to help gain a sense of the scale of the Solar System by building scale models of it. Activities for scale models of the entire Universe are lacking, however, because of the sheer size of it. One cannot reasonably create a scale model of the Universe that includes all of its components—from people to superclusters—and simultaneously scales their distances and sizes.

This activity attempts to overcome that difficulty by examining the Universe at different realms. First, we start with Earth and zoom out to the Sun and then the Solar System. We continue zooming out from the Solar System, all the way out to the observable Universe. Each step of the way, we use the room we are in to represent a realm of the Universe and then look for common materials that can represent the astronomical objects within to scale.





What You Need:

- Telescopic images or pictures of various objects and realms with labels for each
- Grapefruit or Wiffle Ball
- Grains of salt
- CD
- Peppercorn
- Large pizza
- Basketball
- Button (1.25 cm diameter)
- BBs
- Cookies
- Globe of Earth
- Anything else that could work...

Getting Ready:

Measure the size of the room where you will be teaching this lesson. Use the table in the discussion notes to calculate what the sizes of the various realms would be for each step and find some materials that are approximately those sizes. The objects don't have to be exact (many of these astronomical sizes are not known with exact precision). We are trying to get a general sense for the sizes with this activity. Gather together the materials and display them for the entire class to see. For the write up of this activity, the room size is taken to be 10 meters across and all objects sizes mentioned are scaled to that.

Procedure:

Begin with a globe, and point out the location of the classroom allowing students to gain some sense of the size of Earth in relation to the places they are familiar with.

Using a large classroom (10 meters square – or 10 meters in diameter):

1. Imagine that the Sun is the size of the classroom. Ask students how large Earth would be.
 - a. Answer: A grapefruit (9.2 cm diameter)
2. Now imagine that the Solar System out to the boundary between the Solar Wind and interstellar space (200 AU diameter) is the size of the classroom. How large would the Sun be? How large would Earth's orbit around it be? How big would Earth be?
 - a. Answer: A grain of salt (0.46 mm diameter)
 - b. Answer: A CD, a bit smaller like half a roll of masking tape (10 cm diameter)
 - c. Answer: Microscopic bacteria (4 microns)
3. Zoom out to make the Sun's Neighborhood (65 light-year diameter) the size of the classroom. How large would the Solar System be?
 - a. Answer: A grain of salt (0.49 mm diameter)





modeling the universe

4. Zoom out to make the Milky Way Galaxy (160,000 light-years diameter) the size of the classroom. How large would the Solar Neighborhood be?
 - a. Answer: A peppercorn (4 mm diameter)
5. Zoom out to make the Local Group of galaxies (6.5 Million light-years diameter) the size of the classroom. How large would the Milky Way be?
 - a. Answer: A Large Pizza (50 cm diameter)
6. Zoom out to make the Local Supercluster of galaxies (130 Million light-years diameter) the size of the classroom. How large is the Local Group? How big is the Milky Way?
 - a. Answer: A basketball (25 cm diameter)
 - b. Answer: A button (1.25 cm diameter)
7. Zoom out to make the entire visible Universe (156 Billion light-years diameter) the size of the classroom. How big is the Local Supercluster? How big would the Local Group be?
 - a. Answer: A small button (8.3 mm diameter)
 - b. Answer: A small grain of salt (0.2 mm diameter)

Discussion Notes:

Notes for Each Realm:

Earth

- Planet where we all live
- Comprised primarily of rock
- Spherical in shape
- 12,700 km in diameter
- It would take 17 days to circumnavigate the globe driving a car at 100 km/hr
- At the speed of light, it would take 0.13 seconds to go all the way around Earth

Sun

- Star that Earth orbits
- Composed primarily of hydrogen and helium gas
- Uses nuclear fusion in its core to generate heat and light to allow itself to resist the crushing weight of its own mass
- Spherical in shape
- 1.39 Million km in diameter
- The Sun's diameter is 109 times greater than that of Earth
- Over 1 million Earths would fit inside the Sun's volume
- Earth orbits the Sun at an average distance of 150 million kilometers. This distance is called an Astronomical Unit (AU)
- It would take 11,780 Earths lined up side to side to bridge the 1 AU between Earth and Sun





modeling the universe

Solar System

- 8.5 planets, thousands and thousands of planetoids and asteroids, billions of comets and meteoroids
- Mostly distributed in a disk about the Sun
- Sun blows a constant wind of charged gas into interplanetary space, called the Solar Wind
- Boundary between Solar Wind and interstellar space at 100 AU from the Sun (200 AU diameter)

Solar Neighborhood

- The region of the Galaxy within about 32.6 light-years of the Sun is considered its neighborhood (65 light-years diameter)
- Here stars move generally with the Sun in its orbit around the center of the Galaxy
- This region is inside a large bubble of hot interstellar gas called the Local Bubble. Here the gas temperature is about 1 million degrees Kelvin, and the density is 1,000 times less than average interstellar space.

Milky Way Galaxy

- The Milky Way Galaxy is a giant disk of stars 160,000 light-years across and 1,000 light-years thick
- The Sun is located at the edge of a spiral arm, 30,000 light-years from the center
- It takes 250 Million years for the Sun to complete one orbit
- There are over 100 Billion stars in the Milky Way
- The Spiral arms are only 5% more dense than average and are the locations of new star formation

Local Group

- Contains 3 large spiral galaxies--Milky Way, Andromeda (M31), and Triangulum (M33)—plus a few dozen dwarf galaxies with elliptical or irregular shapes
- Gravitationally bound together—orbiting about a common center of mass
- Ellipsoidal in shape
- About 6.5 million light-years in diameter

Local Supercluster

- A cluster of many groups and clusters of galaxies
- Largest cluster is the Virgo cluster containing over a thousand galaxies
- Clusters and groups of galaxies are gravitationally bound together; however, the clusters and groups spread away from each other as the Universe expands
- The Local Supercluster gets bigger with time
- It has a flattened shape





modeling the universe

- The Local Group is on the edge of the majority of galaxies
- The Local Supercluster is about 130 Million light-years across

Universe

- Surveys of galaxies reveal a web-like or honeycomb structure to the Universe
- Great walls and filaments of matter surrounding voids containing no galaxies
- Probably 100 Billion galaxies in the Universe
- The observable Universe is 156 Billion light-years in diameter

Note: 1 Astronomical Unit (AU) = $1.4960\text{E}+08$ km

1 parsec (pc) = 206,265 AU = 3.262 light-years = $3.0857\text{E}+13$ km

1 light-year (ly) = $9.460\text{E}+12$ km = 63,230 AU

Parsecs are a unit used by astronomers. It comes from using parallax of nearby stars due to Earth's orbit around the Sun. One parsec is the distance a star would be if it exhibits a parallax angle seen from Earth of 1 arc second (1 arc second = 1/3,600 of a degree).

Realm Sizes for Reference:

<u>Realm</u>	<u>Size (km, diameter)</u>	<u>Size (Light-years, diameter)</u>	<u>X Bigger than Previous Realm</u>
Earth	$1.27\text{E}+04$	$1.4\text{E}-09$ Ly	--
Sun	$1.39\text{E}+06$	$1.5\text{E}-07$ Ly	$1.09\text{E}+02$
Solar System (100 AU radius)	$3.00\text{E}+10$	0.0032 Ly ($3.2\text{E}-03$)	$2.15\text{E}+04$
Solar Neighborhood (10 pc radius)	$6.17\text{E}+14$	65 Ly ($6.5\text{E}+01$)	$2.06\text{E}+04$
Milky Way Galaxy (25 kpc radius)	$1.5\text{E}+18$	160,000 Ly ($1.6\text{E}+05$)	$2.50\text{E}+03$
Local Group (1 Mpc radius)	$3.1\text{E}+19$	6.5 Million Ly ($6.5\text{E}+06$)	$2.01\text{E}+01$
Local Supercluster (20 Mpc radius)	$1.2\text{E}+21$	130 Million Ly ($1.3\text{E}+08$)	$3.98\text{E}+01$
Universe (24 Gpc radius)	$1.5\text{E}+24$	156 Billion Ly ($1.6\text{E}+11$)	$1.20\text{E}+03$

