Had I been present at the Creation, I would have given some useful hints for a better ordering of the universe.

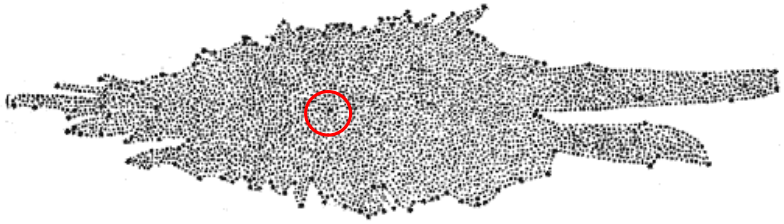
Alfonso the Wise (1221-1284)
King of Castile and Leon

Five questions to ponder ...

- *When did the concept of a universe first occur to scientists?*
- *How old is the universe?*
- *How big is it?*
- *What is the universe made of?*
- *How will it end?*

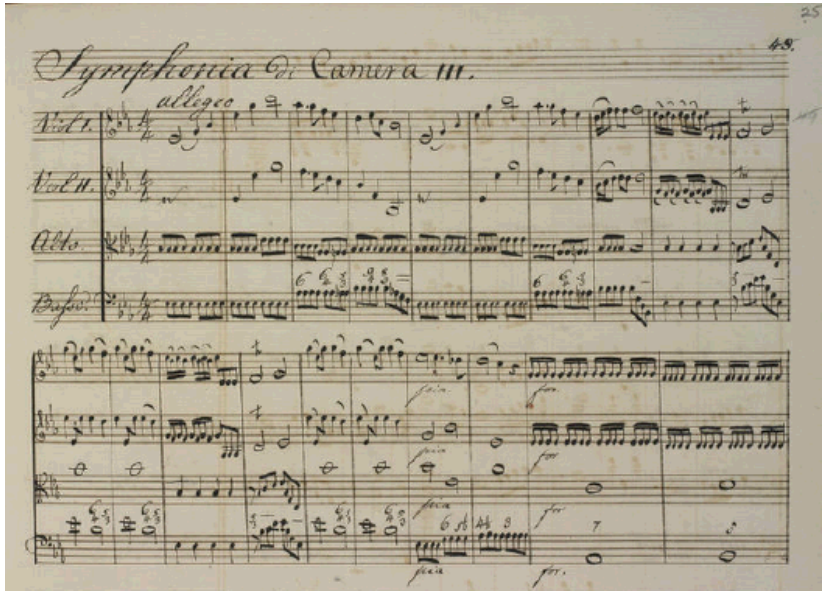
Sir William Herschel (1738-1822), a painting by William Artaud.

Caroline Herschel (1750-1848). She supported her brother in his astronomical researches.



In 1785 William Herschel produced his model of the Milky Way galaxy. It was roughly disk-shaped with the Sun close to the galactic center.

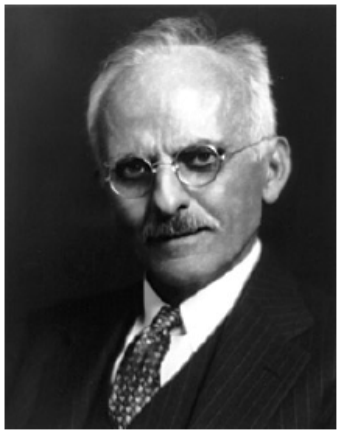
We now know that our solar system is about one-quarter of the distance from the galactic center towards the edge. There are ~ 200 billion stars in the Milky Way galaxy.



Symphony No. 15 in E flat major, by William Herschel, in his own hand (1762).

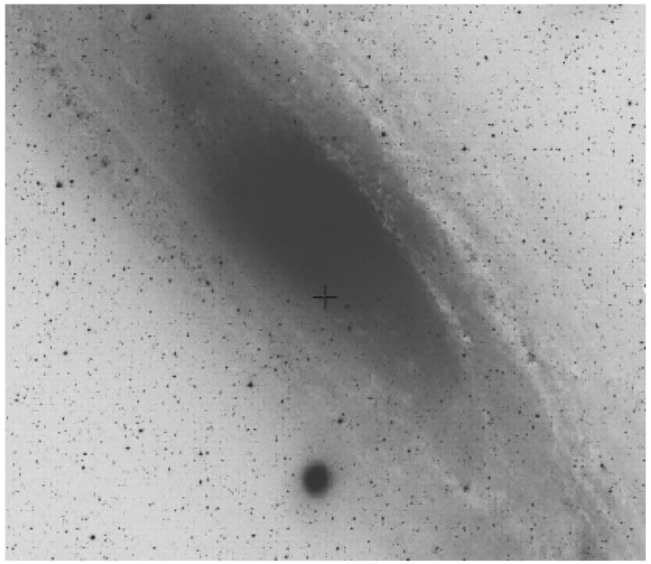
Beiginning of the 1st movement of Symphony No. 12 in D major by William Herschel (1761).

Harlow Shapley
(1885-1972)



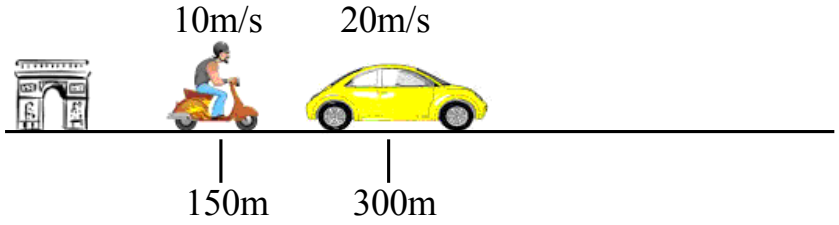
Heber Doust Curtis
(1872-1942)

In 1920 Harlow Shapley and Heber Curtis took part in a discussion over the nature of nebulae. Shapley argued that all nebulae were gaseous formations *within* our galaxy. Curtis maintained that many nebulae were individual galaxies consisting of billions of stars far *outside* our galaxy. Their discussions became known to astronomers as the *Great Debate*.



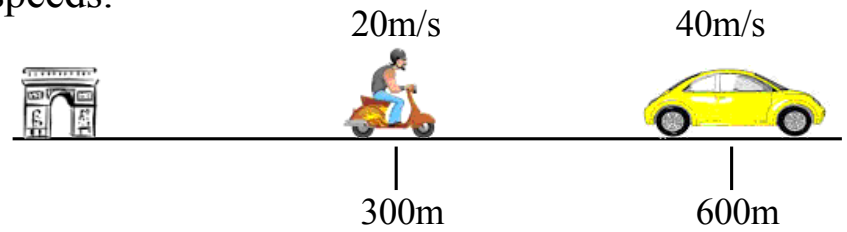
A negative of a photograph of the Andromeda nebula (galaxy) taken by Edwin Hubble in 1923 using the 100 inch Hooker telescope at the Mount Wilson Obervatory. Numerous individual stars are visible. Andromeda is about 2.5 million light years from Earth and so this is what it looked like 2.5 million years ago!

You are standing on top of the Arc de Triomphe watching a scooter and a car traveling down the Champs Elysees away from you. You measure their distance from your position and their speed.

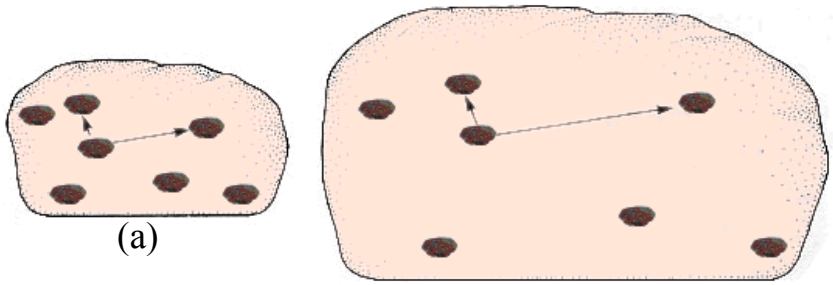


You find their speeds are proportional to distance.

After 10s you again measure their distances and speeds.

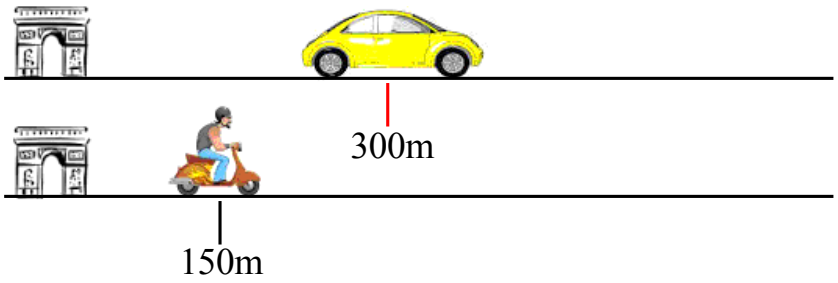


Again their speeds are proportional to distance. But what about the distance *between* them?

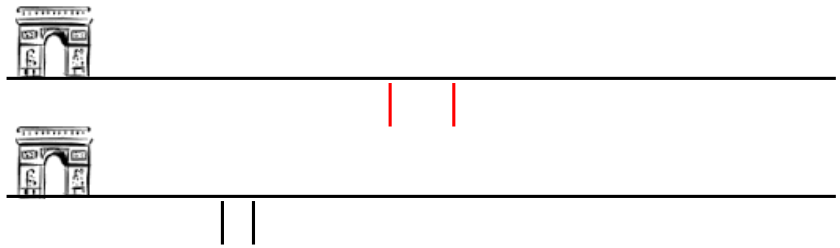


A raisin bread picture of the expanding universe. Imagine a slice cut through the dough for raisin bread as it is left to rise. (a) is the slice before it rises, (b) after it rises. If we identify the raisins with galaxies and the dough between the raisins as space, we see that the raisins (galaxies) do not get larger as the space between them expands. But, the final distance between raisins (b) depends on how far apart they were to start with (a).

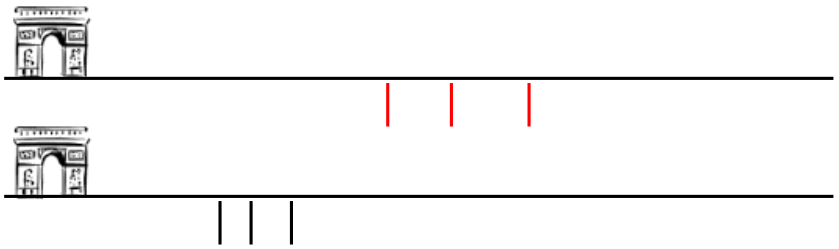
Start your clock:



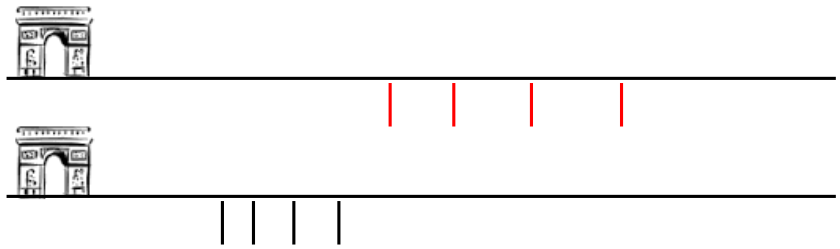
After 2.5 s:



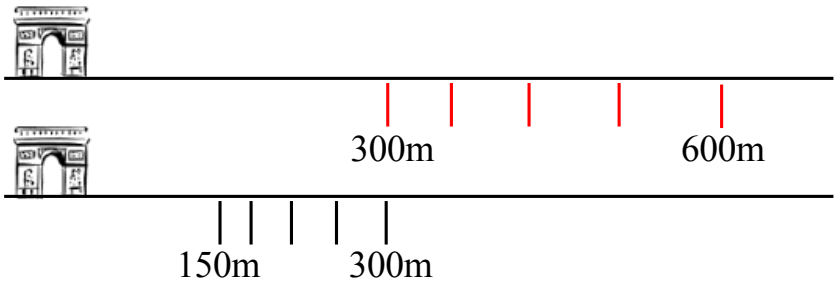
After 5 s:

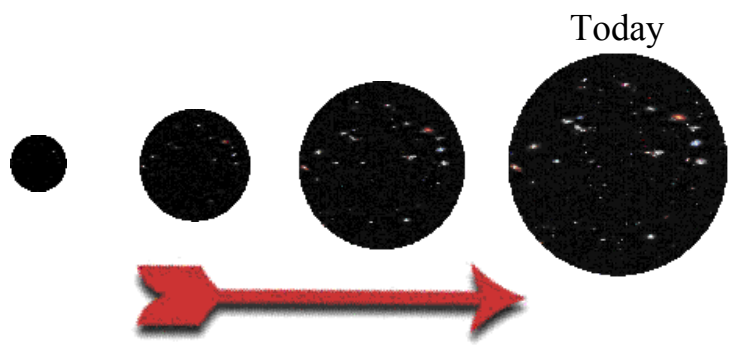


After 7.5 s:

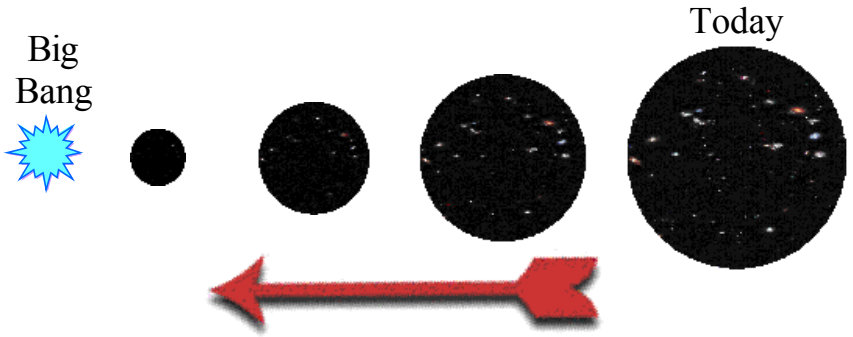


After 10 s:





Expansion of the universe



Run the expansion in reverse

Sir Fred Hoyle (1915 - 2001)

His use of the term "Big Bang", which he introduced in 1949 during a BBC interview, rather overshadowed his pioneeering discoveries in *stellar nucleosynthesis* - the synthesis of chemical element heavier than helium by nuclear reactions in stars. Many believe his often outspoken criticism of the Big Bang resulted in him being overlooked in favor of his co-worker, Alfred Fowler, for the 1983 Nobel Prize.

<u>Commmon misconceptions - addressed</u>!

• The Big Bang was neither big nor was there a bang!

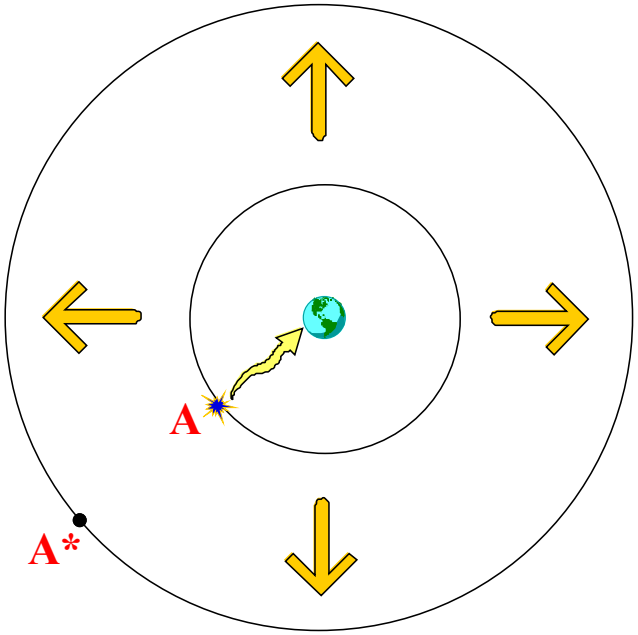
• It didn't occur somewhere in space; it *<u>created</u>* space and time. Therefore, there was no time *<u>before</u>* the Big Bang.

• There is no space outside the universe.

• The universe has no "center".

• The picture of matter flying outwards from a single point is not correct. Matter is stationary with respect to space; it is space that expands dragging the matter with it, as I show in this short demonstration ...

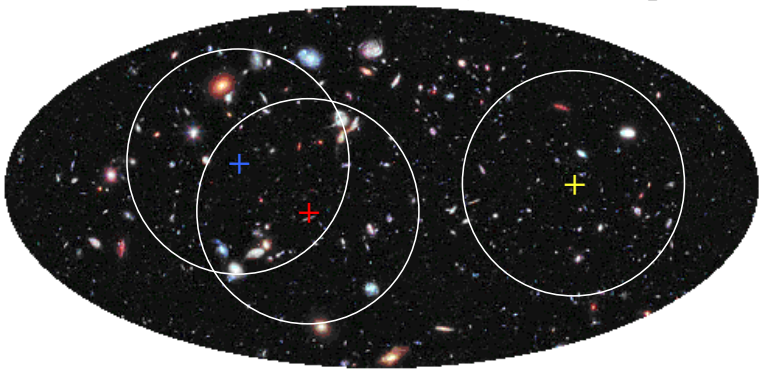
The paperclips do not move on the rubber band, rather, it is the rubber band that is expanding carrying the paperclips along with it.



During the time it takes for light to travel from the edge of the observable universe (at **A**) to Earth (13.8 billion years) the universe will have continued to expand. When the light reaches Earth, that spot will be about 47 billion light-years away (at **A***)!

Observable universe from Earth

'Actual' universe (size and shape unknown)



Observable universe from other locations

The observable universe depends on the location of the observer. What that means is that someone a few billion light years from Earth would have a different view of the universe. Every location in the universe has its own observable universe, which may or may not overlap with the one centered on Earth.

Luminous matter:

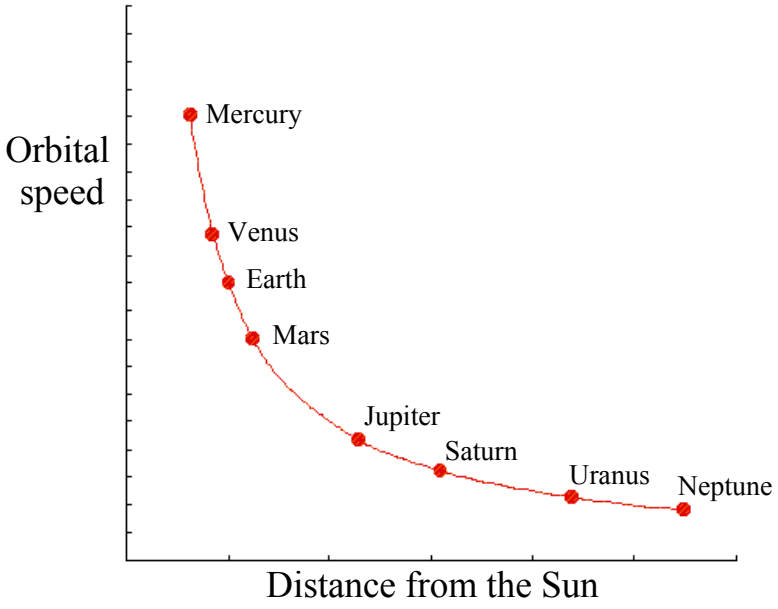
- Stars and luminous gas 0.4%

Non-luminous matter:

- Inter-galactic gas 3.6%
- Neutrinos 0.1%
- Supermassive Black holes 0.04%

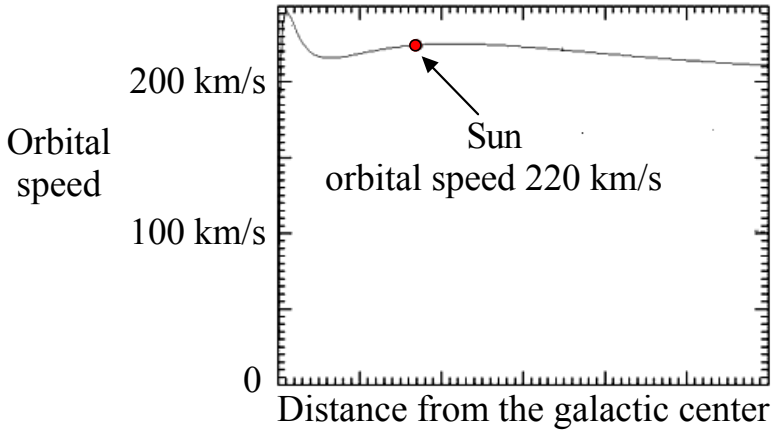
- *Dark matter 23%*
- *Dark energy 72%*

According to Newton's and Kepler's Laws, the speed of planets and stars rotating about a central point under gravity should decrease the farther they are from the central point. For example, the solar system fits the Laws almost exactly.

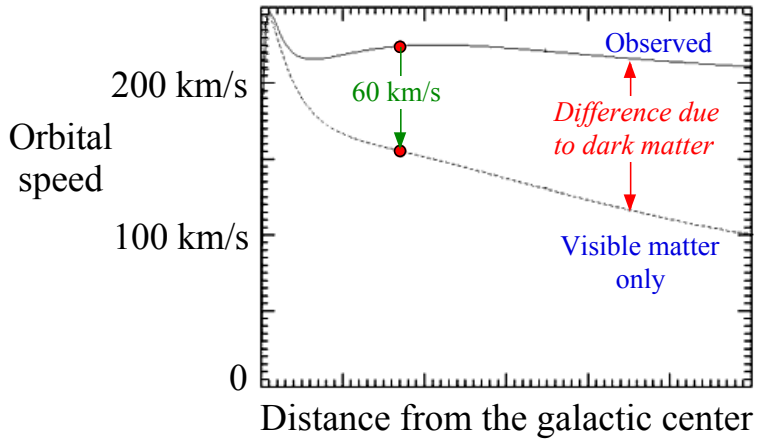


Milky Way galaxy
(an artist's impression)

However, the speeds of stars in our galaxy (and other spiral galaxies) remain roughly constant with increasing radius. According to Newton's Laws, the outer stars should be 'thrown off' because there is not enough gravity.

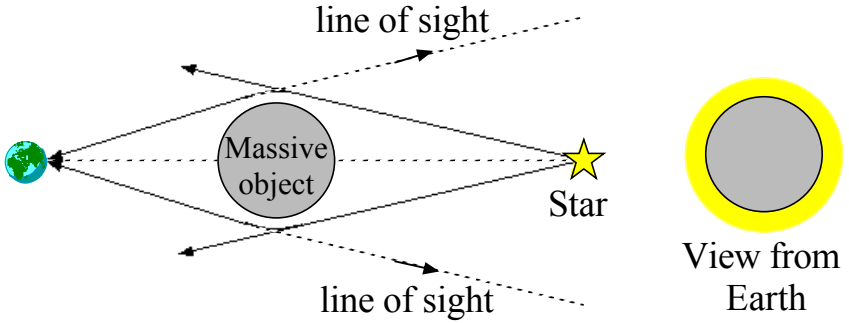


The gravitational force due to visible matter in the galaxy is not enough to explain the high orbital speeds of stars. For example, our Sun is moving about 60 km/s too fast if only visible matter is taken into account!

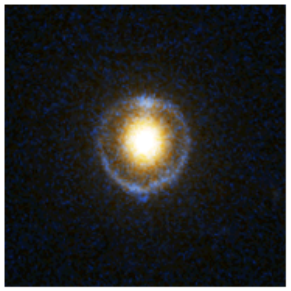


There must be additional mass in the galaxy to produce the extra gravitational force, which we cannot see. The "missing mass" is called ***dark matter***.

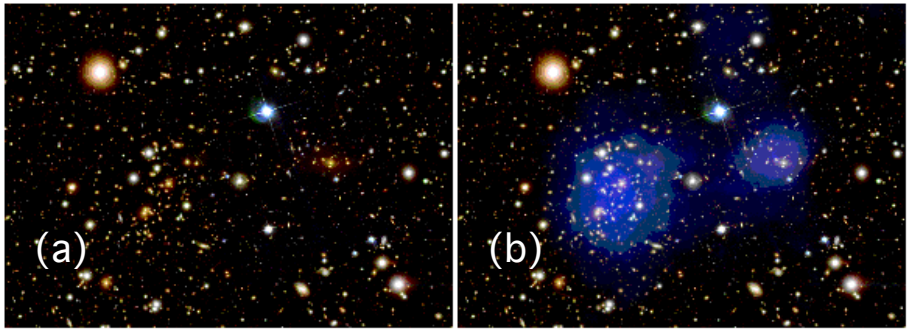
Gravitational lensing occurs when light from a distant source passes near a massive object, like a galaxy between the source and the Earth, and is bent.



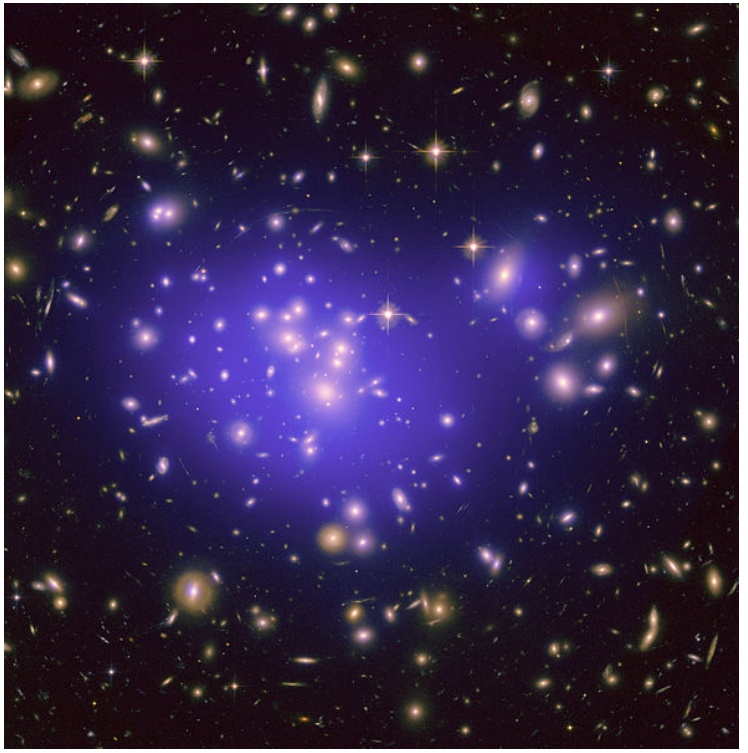
The shape of the image depends on the geometry of the massive object.



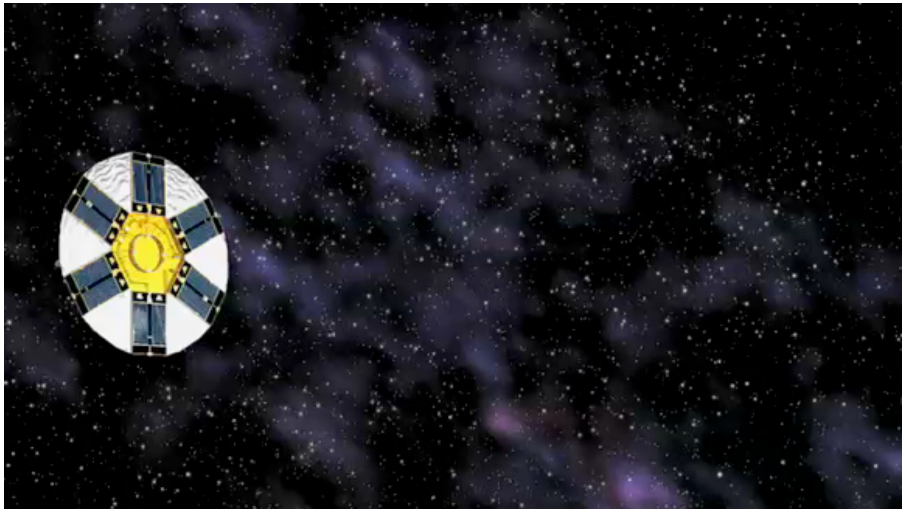
Gravitational lensing. This object (SDSS J162746.44-005357.5) was photographed using the Hubble Space Telescope. The halo is called *Einstein's Ring*.



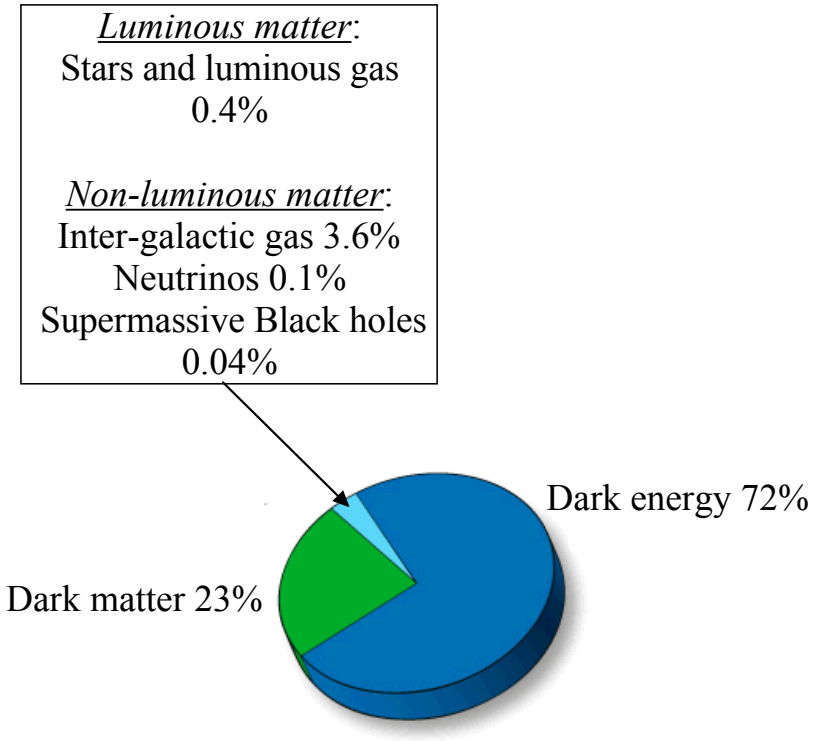
Two images of the so-called Bullet cluster. (a) shows the distribution of ordinary, visible matter. However, gravitational bending of light from behind the cluster indicated there was much more mass associated with the cluster than was visible. The distribution of the missing "mass", i.e., the dark matter shown in blue (b), was deduced from the measurements in 2006. Dark matter forms giant invisible "clouds" in and around galaxies.



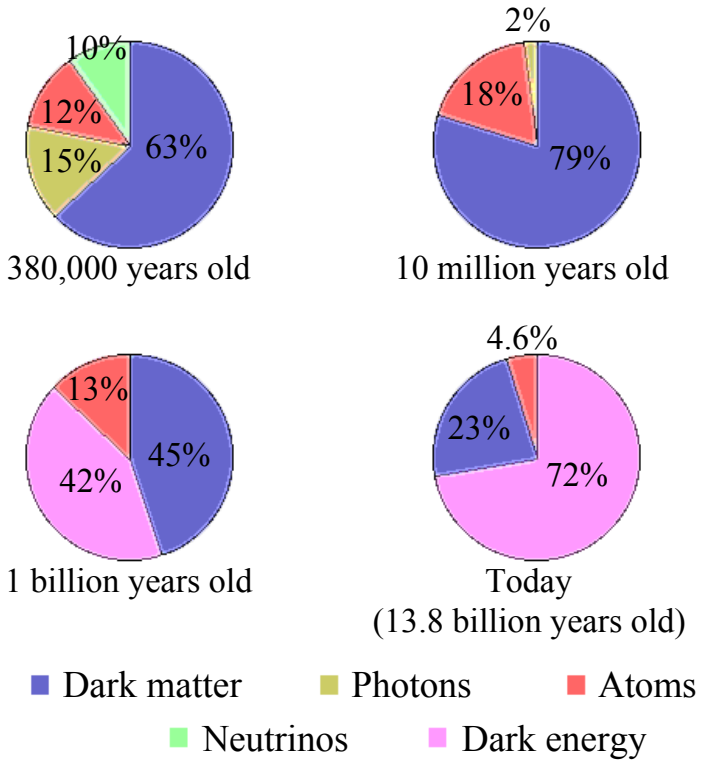
The galaxy cluster Abell 1689, with the mass distribution of the dark matter shown in purple. The mass of this cluster is made up partly of normal (baryonic) matter and partly of dark matter.



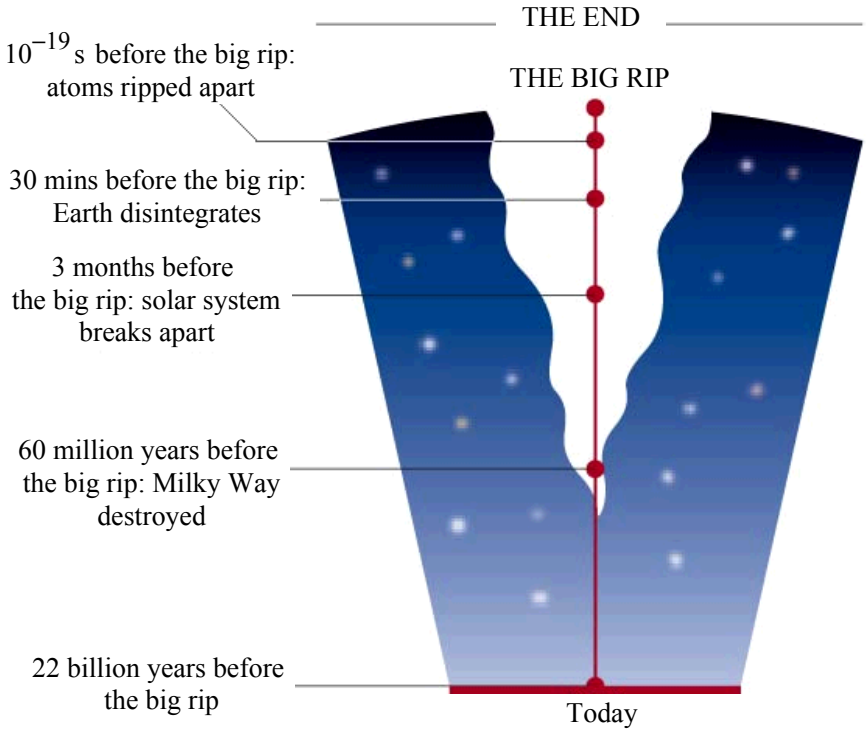
WMAP was launched on June 30, 2001 and orbited Earth at a distance of about one million miles. The Sun shield and solar panels always protect the sensitive measuring equipment from the Sun.



Recent mapping on the universe suggests that less than 0.5% is ordinary visible matter and some 95% is made up of completely unknown matter and energy!

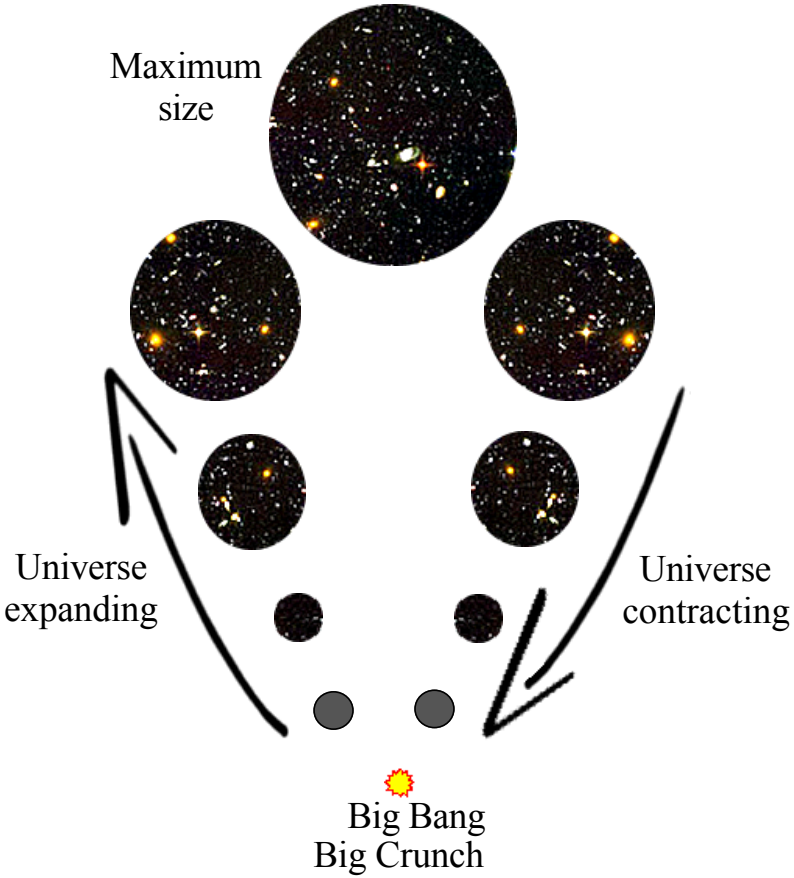


The matter/energy content of the universe during its expansion to the present. Notice that dark energy has now taken over as the most important form of energy in the universe.



Possible timescale for the Big Rip.

The Big Freeze. The universe continues to expand the heat is dispersed throughout space as clusters, galaxies, stars and planets are all pulled apart. It will continue to get colder and colder until the temperature throughout the universe reaches absolute zero. The timescale, howver, is immense.



In the Big Crunch hypothesis, the universe continues to expand until it reaches a maximum size when gravitational forces overcome the dark energy and the universe begins to contract.

Some final words:

There is a theory which states that if ever anyone discovers exactly what the Universe is for and why it is here, it will instantly disappear and be replaced by something even more bizarre and inexplicable.
There is another theory which states that this has already happened.

Douglas Adams
The Restaurant at the End of the Universe

I'm sure the universe is full of intelligent life. It's just been too intelligent to come here.

Arthur Clarke

I don't pretend to understand the universe - it's much bigger than I am.

Albert Einstein