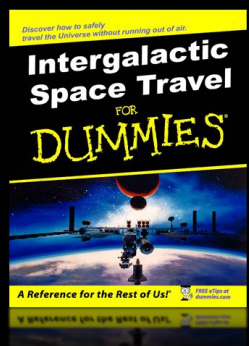


Class 3: Stars, Galaxies and the Universe

How long would it take to travel to the nearest star or nearest galaxy?

Only 4% of the Universe is made of matter astronomers understand. What evidence is there for the other 96% of the Universe?

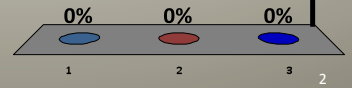


1

Which of the days learning objectives seem most difficult to answer?

1. Order largest to smallest and describe contents of Local Group, Solar System, Milky Way, the Universe.
2. Compare/Contrast Dark Matter & Dark Energy, give evidence for each.
3. Describe Big Bang, what's expanding, 3 pieces of evidence for it.

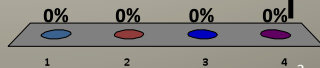
Remember: Ch, 80, Ch



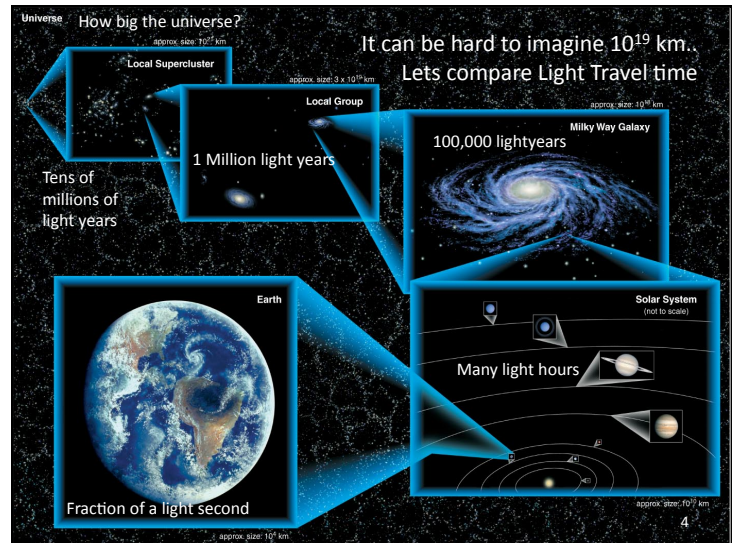
2

Put the following in order of LARGEST scale to the smallest scale:

1. Local Group, Galaxy, Universe, Solar System
2. Universe, Local Group, Galaxy, Solar System.
3. Universe, Galaxy, Local Group, Solar System.
4. Galaxy, Universe, Local Group, Solar System.



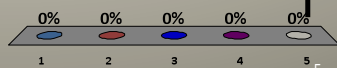
3



4

What is the diameter of the Milky Way Galaxy (light travel time)

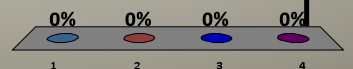
1. 10 light years
2. 100 light years
3. 1,000 light years
4. 10,000 light years
5. 100,000 light years



5

What is the diameter of the Local Group of galaxies

1. 100,000 light years
2. 1 million light years
3. 10s of million light years
4. 100 million light years



6

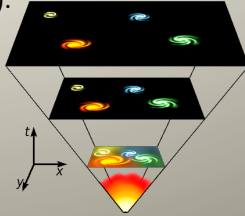
Cosmology: the study of the origin, structure and evolution of our universe

In 1924, Edwin Hubble announced other galaxies were ALL moving away from us (our galaxy).



Big Bang Theory of cosmology:

The scientific theory that the universe emerged from a tremendously dense and hot state.



7

The birth of a scientific theory

1924 -- Edwin Hubble discovers galaxies are all moving away from us.

1927 -- George Lemaitre, uses Einstein's general relativity to put forth a hypothesis: expansion of the universe. Running things backwards, the mass of the Universe was smashed into a primeval atom, when time, space and matter first come into existence.

1940s -- George Gamov derives predictions from Lemaitre's model: the original heat and light should be observable today.

1949 -- Fred Hoyle, a 'steady state' cosmologist (believes the universe has existed for all of eternity), refers to this 'exploding universe' model as **The Big Bang**, in an entirely pejorative manner. The Name Sticks.

1964 -- The light and heat from the Big Bang is detected with radio telescopes at Bell Laboratories in New Jersey. Lemaitre's Big Bang model is elevated to the status of a scientific theory.

2007 -- The sitcom **'The Big Bang Theory'** premieres on CBS.

8



The Observable Universe. What is it?

Working alone: draw a diagram demonstrating why the age of the universe is equal to the radius of the observable universe in light travel time.

Share your answer with others in your group and come up with the group's best answer & diagram.

Is the 'whole' universe smaller or bigger than the observable universe?

10

Is our universe infinite?

Are we the center of the expansion?

Each group gets a balloon and marker. Blow up the balloon to about half its full size. **DO NOT TIE IT.** While one is holding the balloon, another in the group should draw 15 galaxies (somewhat) evenly spaced on the surface.

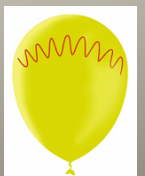
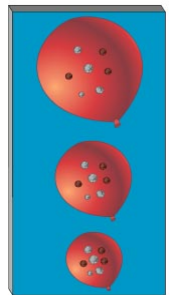
Answer these questions using your 2-Dimensional universe:

- 1) Which galaxy is at the center of the expansion?
- 2) Is the number of galaxies (representing the mass of the universe) increasing as the balloon expands?
- 3) Is the surface space of the balloon infinite at any one moment?
- 4) What 'space' is the balloon expanding into? Where was that space before the expansion?

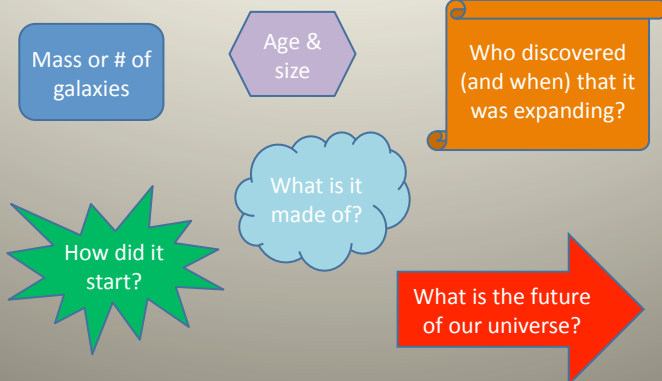
11

Big Bang Theory proposes:
The universe has expanded from a smaller space.

Predictions/Tests:
What evidence should we see today of it having been smaller in the past?



Amongst your **group**, write down as many properties of our Universe as you know:



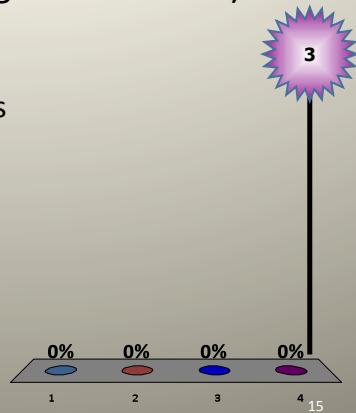
Our Universe

A finite age & observable radius: 13.72 billion (light) years.
 Started very hot & small, and has been expanding ever since.
 It created normal matter in the form of Hydrogen (~75%) and while small fused some of that hydrogen to form Helium (~25%), plus a small, small amount of Lithium.
 It has a finite observable mass: About 10^{55} kg (this is about 100 billion galaxies like the Milky Way)
 Its made up of all matter, but is mostly ENERGY. ($E=mc^2$)
 Our current understanding suggest it will expand for ever.

How do we know this?? Stay tuned..

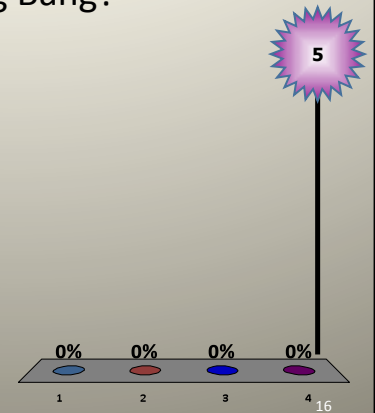
What is the radius of the Observable Universe (in light travel time)

1. ~100 million light years
2. ~Billion light years
3. ~10 billion light years
4. ~100 billion light years



Which of the following is NOT evidence of the Big Bang?

1. Radiation from explosion
2. Discovery of the explosion point
3. Expanding universe
4. Relative abundance of simplest atoms.



In the Big Bang theory, is EVERYTHING in the universe expanding?

1. Yes, everything in the universe expands
2. No, not everything in the universe expands.



In the Big Bang theory:

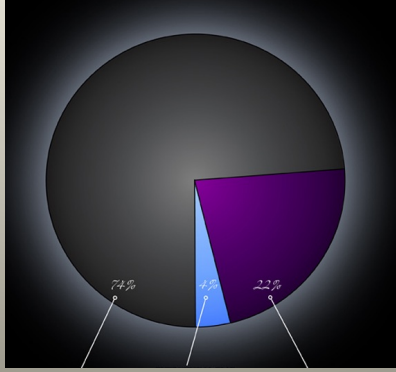
What is expanding and what is **not** expanding?

Examples: Galaxies, stars, planets, atoms, YOU?

What about: Clusters of Galaxies?

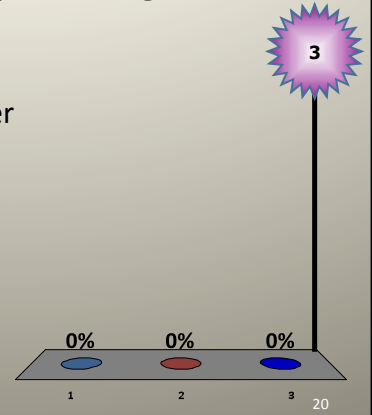
What about: Distances between Galaxy Clusters?

What is our Universe made of?

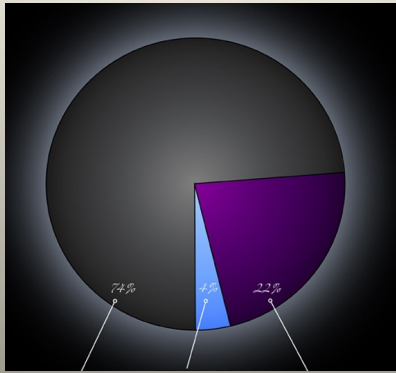


What is the Universe made of, in order of highest percentage..

1. Dark Energy, Dark Matter, Normal Matter
2. Dark Matter, Normal Matter, Dark Energy
3. Dark Energy, Normal Matter, Dark Matter



What is our Universe made of?



Dark Energy Normal Matter Dark Matter