

FORMATION OF THE UNIVERSE

Big Bang Theory

- ▣ The Big Bang Theory was first proposed in the late 1920's.
- ▣ It states that there was an infinitely small, infinitely dense point that contained everything that is the universe.
- ▣ This singularity was incredibly dense and hot.

Big Bang Theory

- ▣ The Big Bang is believed to have occurred between 10 and 15 billion years ago. (Most scientists agree that the universe is 13.7 billion years old.)
- ▣ Two elements, hydrogen and helium were created in the primordial fireball, along with small amounts of lithium and beryllium.

Georges Henri Lemaitre

- ▣ Late 1920's
- ▣ Belgian Astronomer and Jesuit Priest
- ▣ Known as the “Father of the Big Bang”
- ▣ First suggested that the universe formed from a singularity but had no evidence.

Edwin Hubble

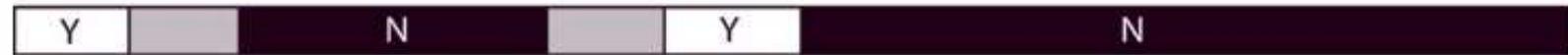
- ▣ 1929
- ▣ Studied light given off by galaxies.
- ▣ Noticed that light from most galaxies was shifted to the red end of the electromagnetic spectrum.
- ▣ Proposed Hubble's Law after studying these galaxies.

Hubble's Law

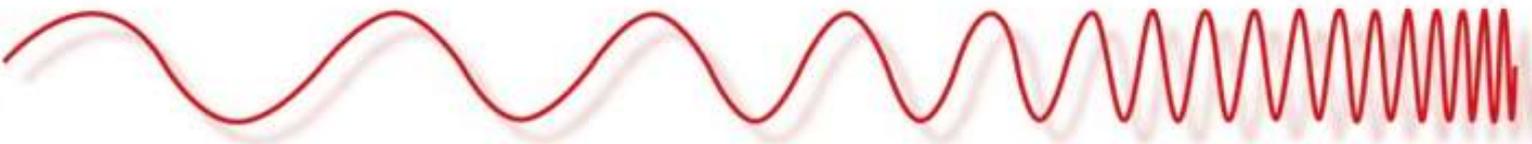
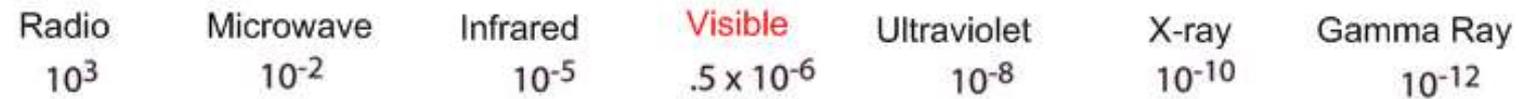
- ▣ The rate at which a galaxy is moving is directly proportional to its distance from us.
- ▣ In other words, the farther away a galaxy is from us, the faster it travels away from us.
- ▣ Thus the universe is expanding.

The Electromagnetic Spectrum

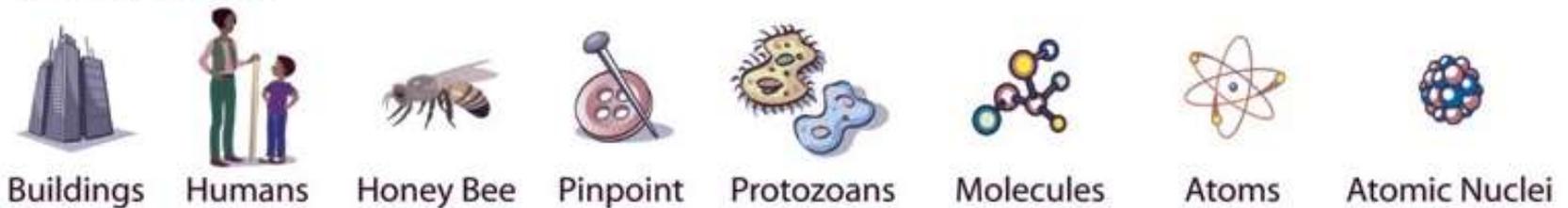
Penetrates Earth Atmosphere?



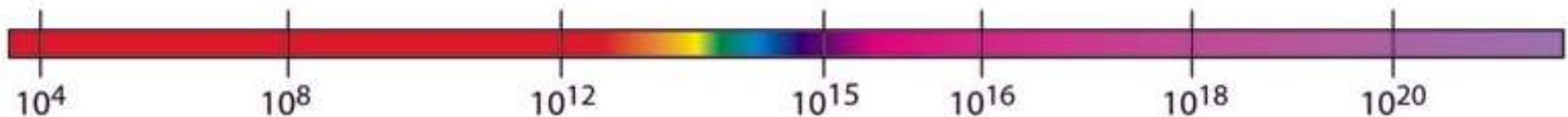
Wavelength (meters)



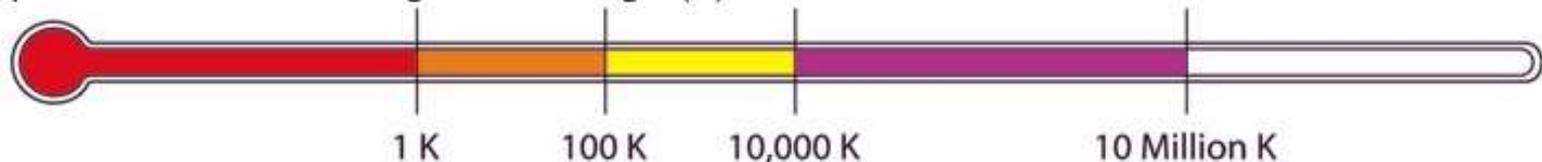
About the size of...



Frequency (Hz)

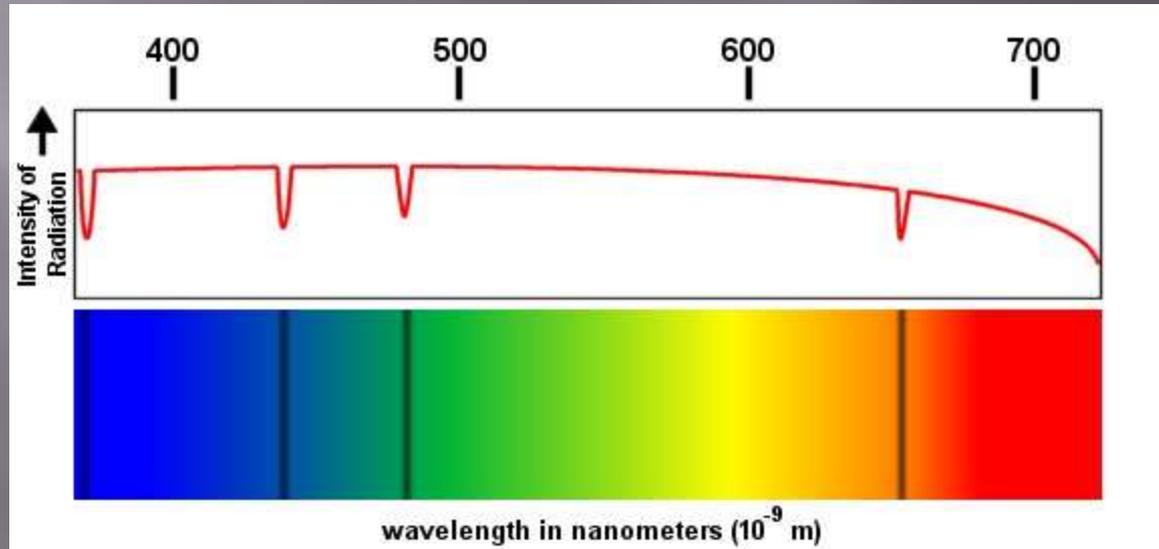
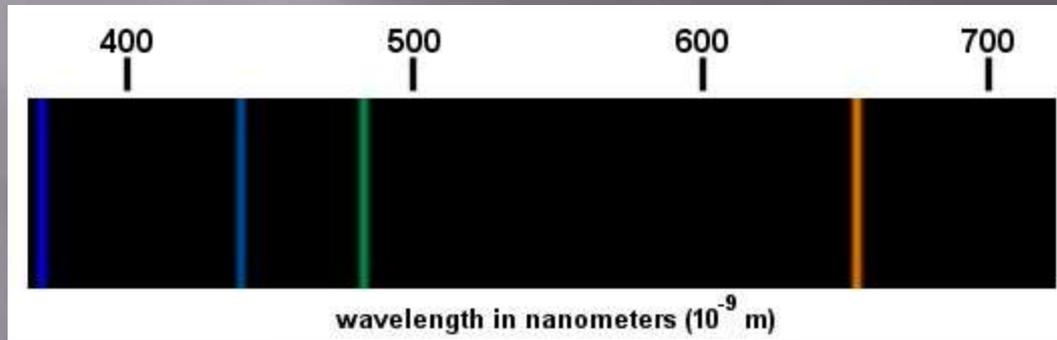
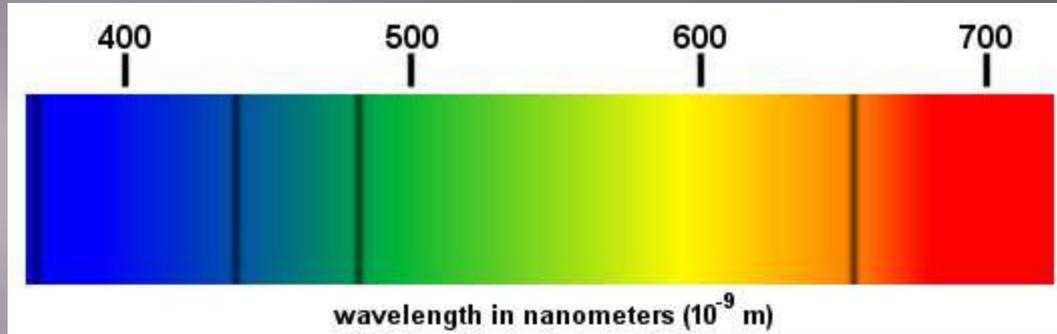


Temperature of bodies emitting the wavelength (K)



[Electromagnetic Spectrum](#)

Emission Lines



Hubble's Law

- ▣ All Galaxies exhibit redshifts of spectral lines.
- ▣ More Distant Galaxies Recede Faster



GALAXIES in



Virgo

REDSHIFTS



1,200 km/s



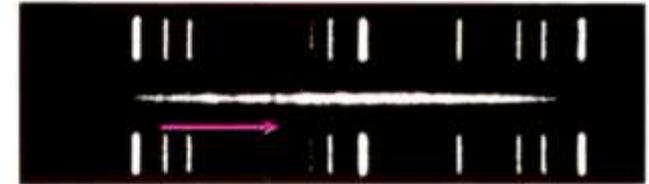
Ursa Major



15,000 km/s



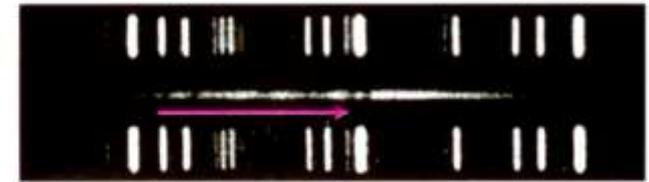
Corona Borealis



22,000 km/s



Boötes



39,000 km/s



Hydra



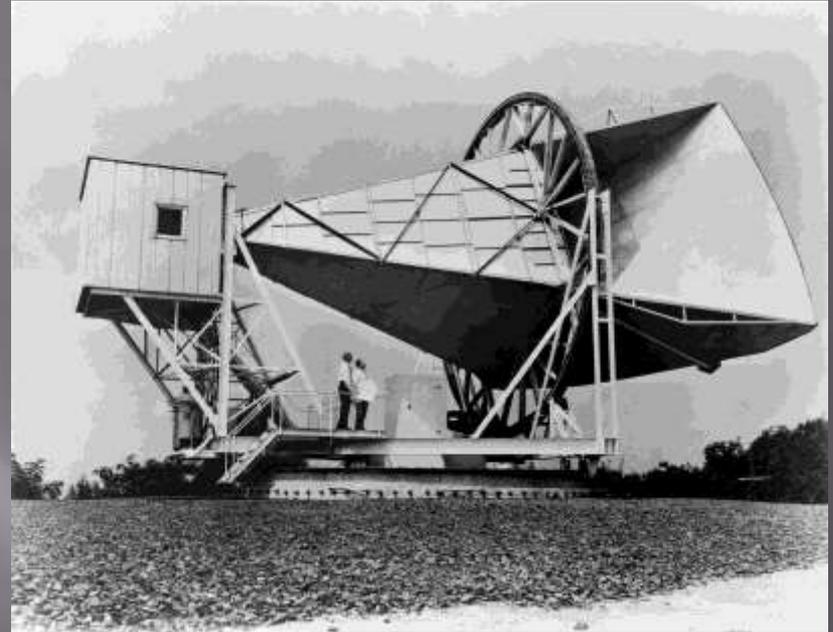
61,000 km/s

Cosmic Microwave Background Radiation

- ▣ Long-wavelength radiation that fills all space.
- ▣ Can be detected using special antenna. (1% of this can be detected in the static on your TV set.)
- ▣ George Gamow (1940's) predicted there should be “echoes” of the Big Bang “explosion.”

Bell Laboratories

- ▣ Penzias and Wilson (1965) were radio astronomers who worked for Bell Telephone Laboratories.
- ▣ Found a mysterious microwave signal causing background noise in their radio telescope.
- ▣ The signal came from everywhere.

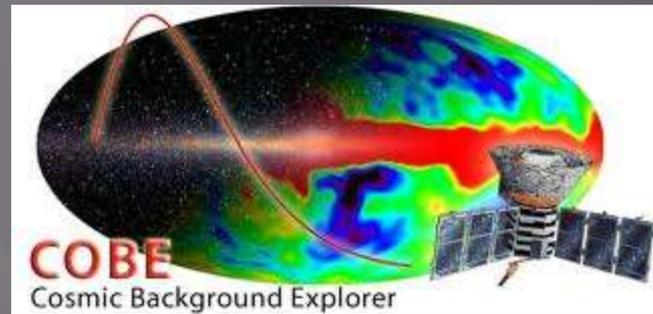


Arno Penzias



Robert Wilson

COBE

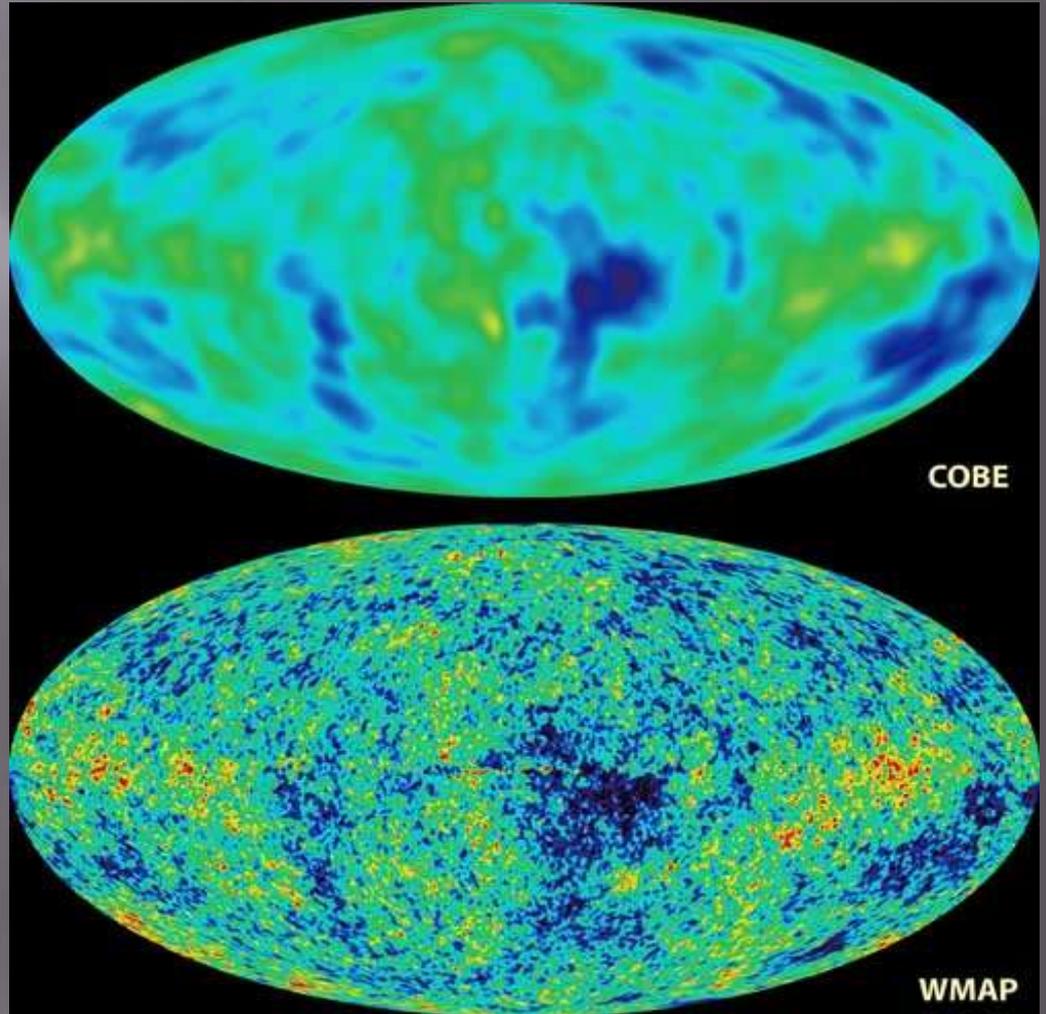


- ▣ Cosmic Background Explorer (1989)
- ▣ Probe that looked 15 billion light years into space to detect tiny temperature changes.
- ▣ These temperature changes were evidence of the heat left over from the Big Bang.

WMAP



- ▣ In June 2001, Wilkinson Microwave Anisotropy Probe (WMAP) captured the “glow” of the Big Bang by detecting temperature changes just like COBE.
- ▣ WMAP was much more precise.

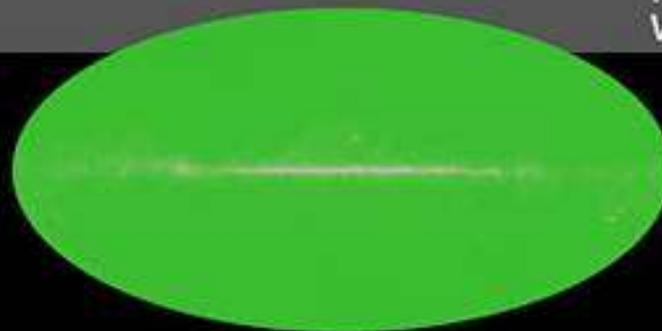


Historical Observations of the CMB and Anisotropy

1965



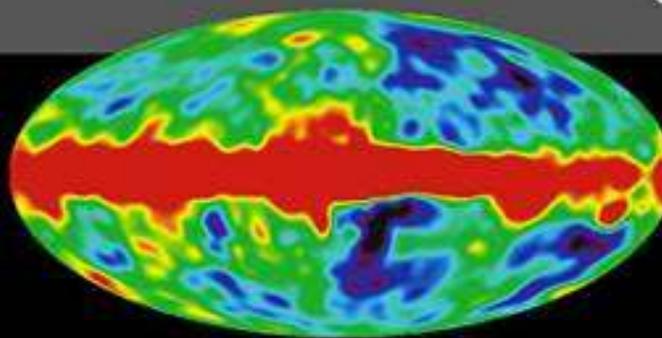
Penzias and Wilson



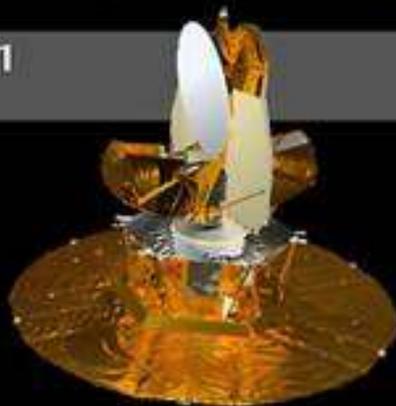
1992



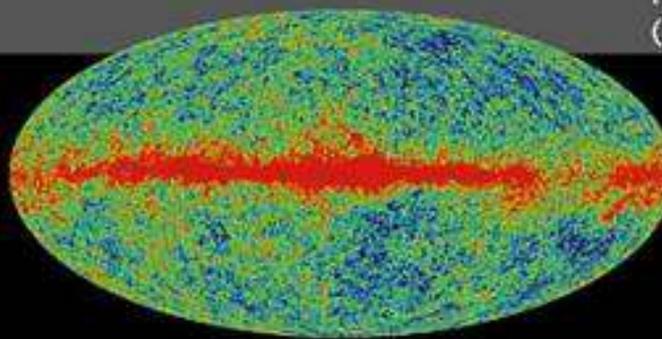
COBE



2001



MAP
(Simulated)



Evidence of the Big Bang

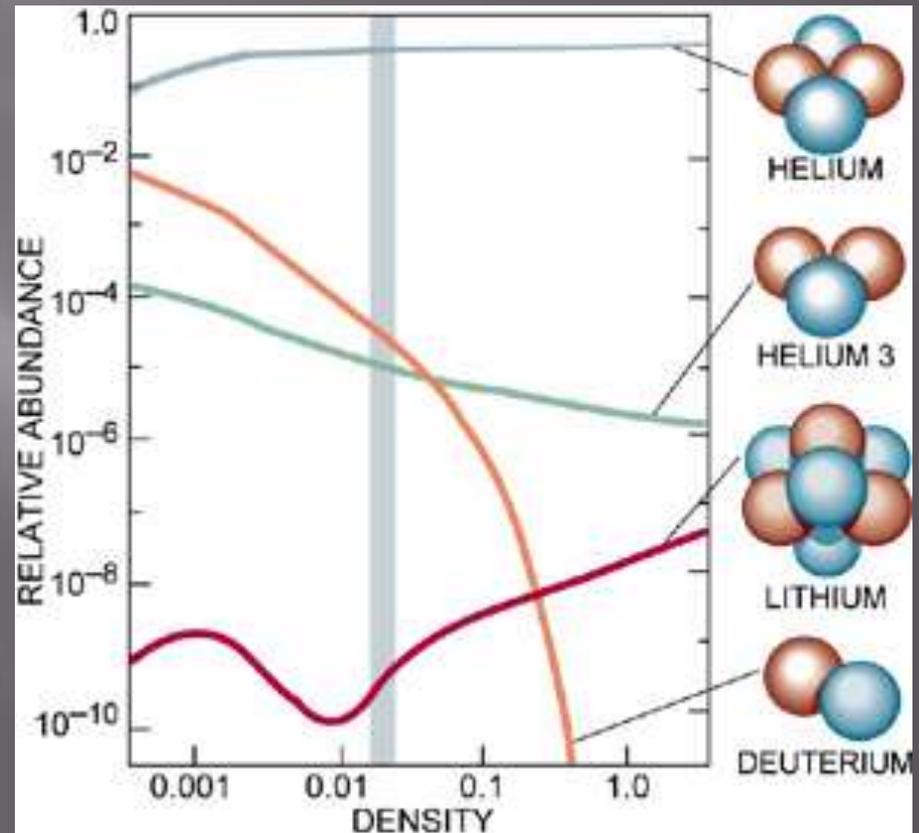
1. The expansion of the universe

Edwin Hubble's 1929 observation that galaxies were generally receding from us provided the first clue that the Big Bang theory might be right.

Evidence of the Big Bang

2. The abundance of the light elements H, He, Li

The Big Bang theory predicts that these light elements should have been fused from protons and neutrons in the first few minutes after the Big Bang.



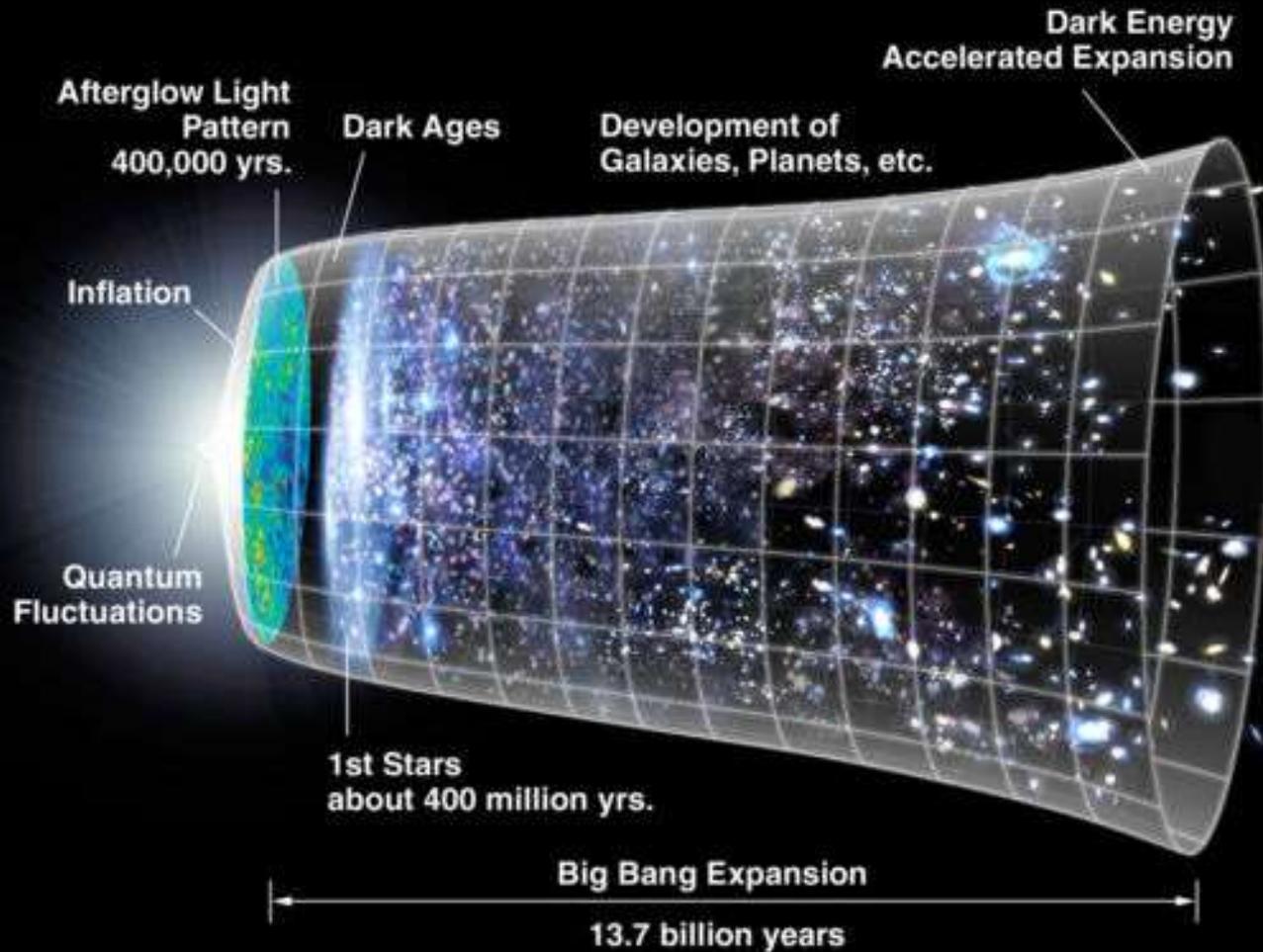
*a function of the density of baryons in the universe
(expressed in terms of the fraction of critical density in
baryons, Ω_B and the Hubble constant)*

Evidence of the Big Bang

3. The cosmic microwave background (CMB) radiation

The early universe should have been very hot. The cosmic microwave background radiation is the remnant heat leftover from the Big Bang.

Big Picture Timeline



Fates of the Universe

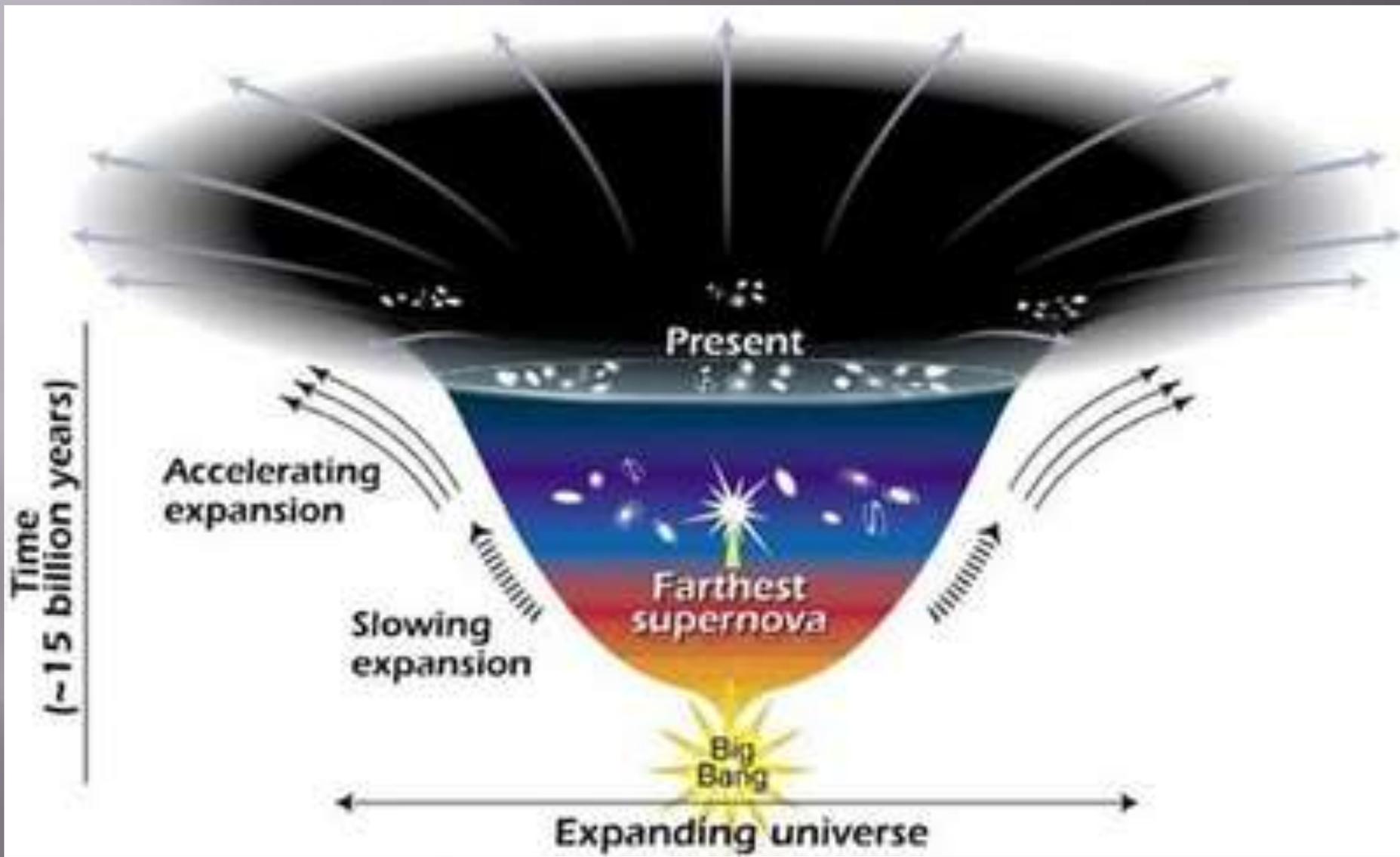
- ▣ Open Universe
- ▣ Closed Universe
- ▣ Flat Universe
- ▣ Accelerating Universe

Fates of the Universe

- ▣ Open Universe – little gravity that outward expansion goes on forever
- ▣ Closed Universe – gravity will eventually halt the expansion and draw everything. Also known as the Big Crunch

Fates of the Universe

- ▣ Flat Universe – expansion slows down but never stops
- ▣ Accelerating Universe - expansion of the universe will speed up. (Most accepted theory because of dark energy.)



Light

- ▣ A light year is defined as the distance that light travels in one earth year.
- ▣ Light travels at
 - 300,000 km/s *or*
 - 186,000 mi/s

Remember...

- ▣ Time and Space are Inseparable...
- ▣ Light travels at a finite speed (3×10^8 m/s)
- ▣ When you look into the night sky, you look into the past...
- ▣ The farther out you look, the farther back in time you see...
- ▣ The sequence of events in the evolution of the universe are “written” in space like an eternal movie...

Into the Past

	Time Required for Light to Travel to the Earth
Moon	1.25 seconds
Sun	8.5 minutes
Centrari	4.5 years
Betelgeuse	1200 years
Milky Way	100,000 years
Andromeda	2.2 million years
Virgo Cluster	60 million years
Hydra Super Cluster	3 billion years
Quasars	13 billion years
Cosmic Microwave Background Radiation (CMB)	13.5 billion years