Origin and Evolution of Universe

Prof. Rohan Munasinghe
Department of Electronic and Telecommunication Engineering
University of Moratuwa

Guiding Questions of Cosmology

1. How large is the Universe?
2. What is its structure?
3. How long has it existed?
4. How has it changed over time?
5. How will it continue to change in the future?

To Find Evidence of Cosmic Evolution

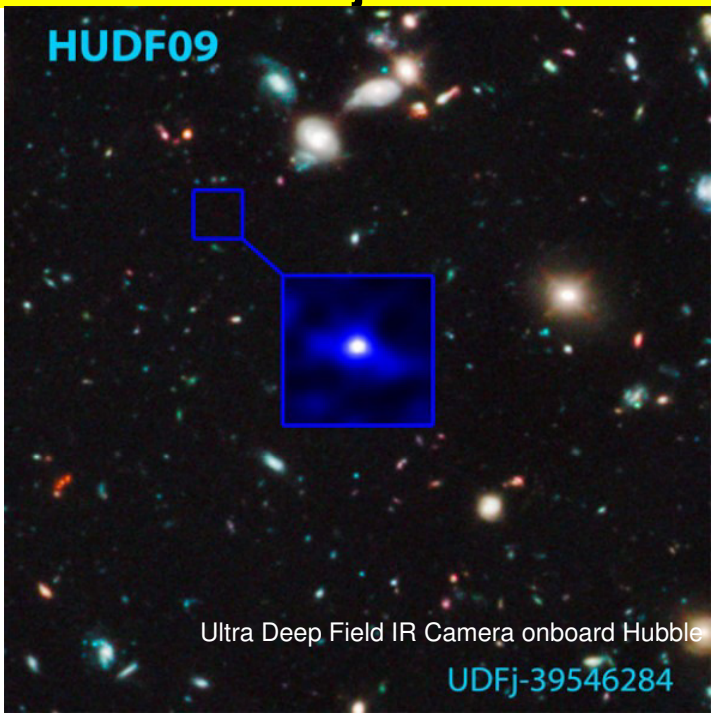
- To reveal how the Universe began and evolve, one has to observe oldest objects.
- UDFj-39546284 Proto-galaxy is 13.37 Billion light years away, farthest (oldest) object.

Ultra Deep Field IR

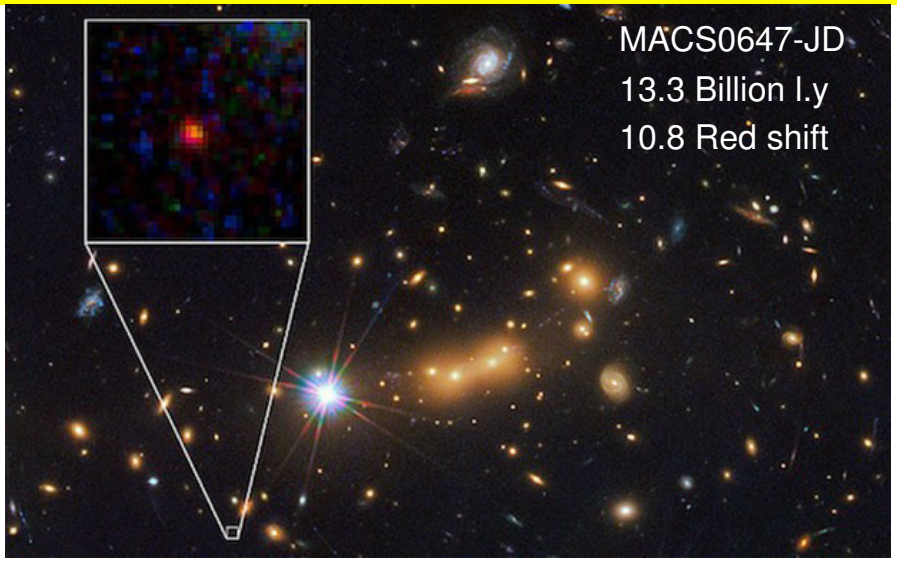
Most Distant Object

UDFj-39546284
Proto-galaxy
13.37 Billion l.y
11.9 Red Shift

Most distant objects are the most oldest objects, they show evidence of how the Universe was like in early stages



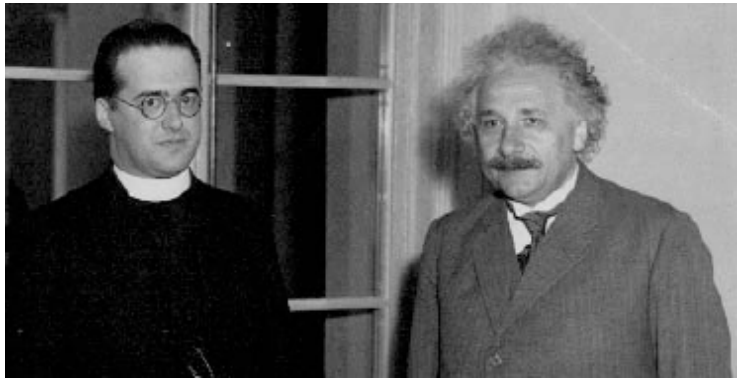
Most Distant Galaxy



CrocRobot.dat

Origin and Evolution of the Universe

- 1916: Relativity (Einstein)
  - Explains how Matter, Space, and Time are inter-related
  - A framework to develop theories of the Universe
- 1922: George Lemaitre and Alexander Freedman
  - EXPANDING UNIVERSE



Einstein's Greatest Blunder

- Around 1915, the prevailing view was a static Universe (as Newton believed). According to GTR, Universe cannot be static
- Einstein believed in steady-state Universe
- In a "senseless" attempt, without any physics base Einstein introduced the cosmological constant Ω

Ω (expansion pressure) = gravitational collapse

just to force GTR to explain static Universe

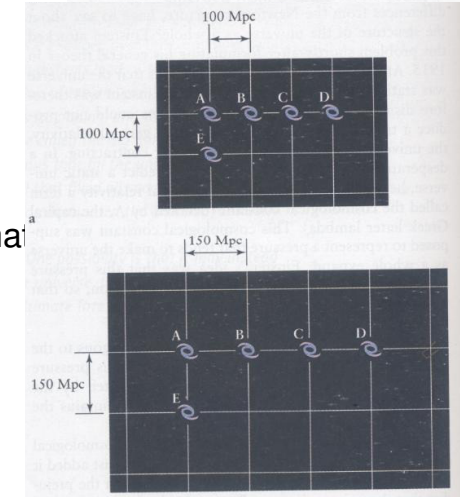
Because he doubted his theory, he missed the golden opportunity of proposing expanding Universe. The actual expansion was observed more than a decade later, by Edwin Hubble

Edwin Hubble

- 1929: Showed expansion by Cepheid variable star observation
- Hubble observed that galaxies (and clusters) recede each other according to

v : receding velocity
d : distance
H_0 *: Hubble constant*

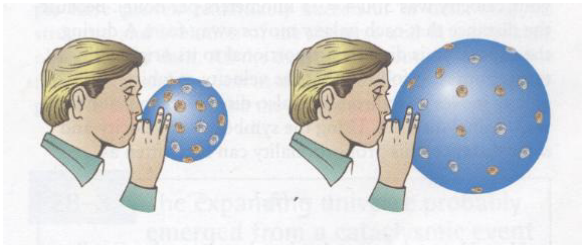
$$v = H_0 d$$



Hubble's observation doesn't say that we are at the centre of the Universe.

Only the distance between widely separated galaxies expand with time.

When Did the Expansion Begin?



$$v = H_0 d$$
$$1/H_0 = d/v$$
$$1/H_0 = T$$

- Hubble estimated H_0=75kms^{-1}/Mpc (Uncertainty in measurements 60<H_0<90)

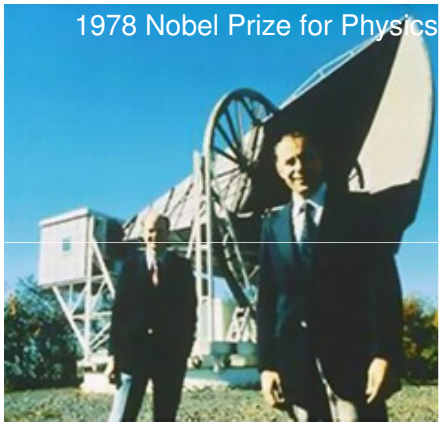
Q: Calculate the age of the Universe

What was at Time Zero

- Universe was a point (singularity)
- Infinitely dense
- Like the singularity of a Black Hole
- Laws of physics don't apply
- "before",or "at the time of" BB are unknowable
- If BB is an explosion, the Universe we see today is the debris of the cosmic explosion

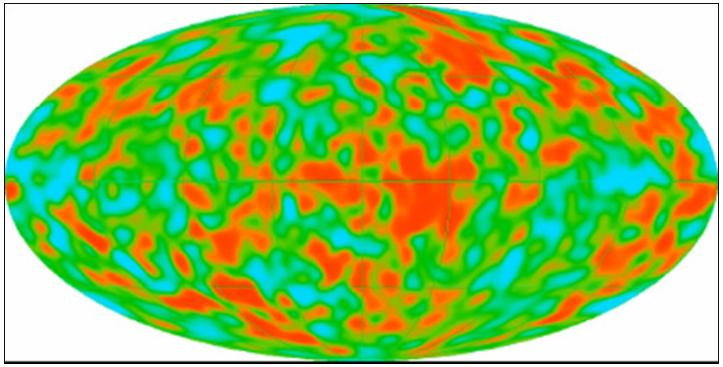
Experimental Proof for Big-Bang

- Early Universe had been at least as hot as the Sun's centre, where Helium is produced (nucleosynthesis). If so, we should see an abundance of He, which was experimentally justified.
- Hot Universe must have filled with high energy photons that might have redshifted to a very low energy state at present (Cosmic microwave background radiation, CMB, 1mm)
  - Worked out by Dick and Peeble (Princeton University)
  - Observed by Penzias and Wilson, (Bell Labs 1964)

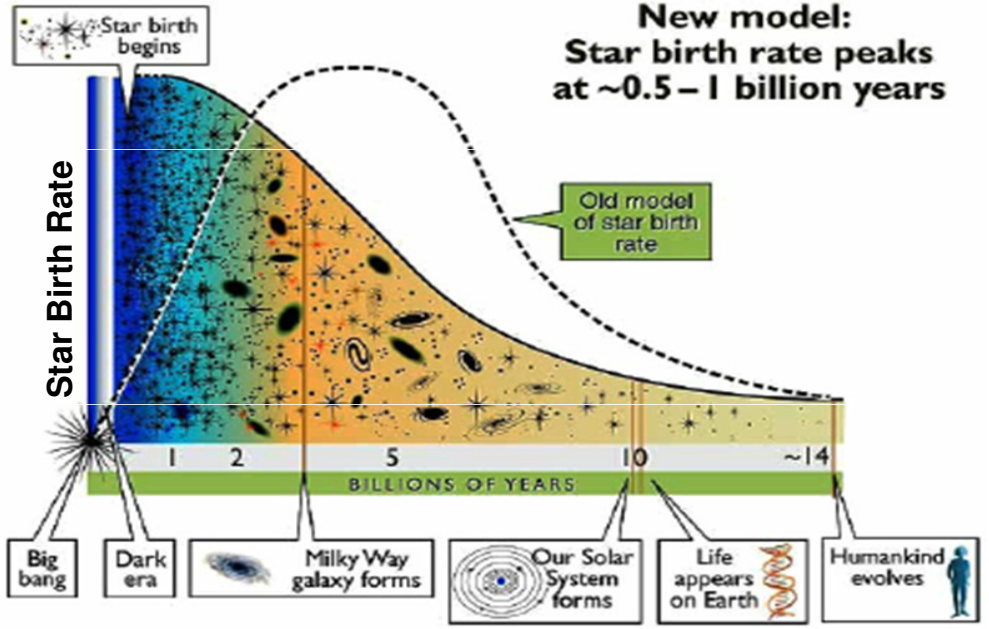


Evidence of Big Bang

- 1989: Cosmic Background Explorer
  - Measured cosmic background radiation. Found perfect match with prediction by BB theory. John Mather received 2006 Nobel Prize for Physics for the finding
  - George Smoot (2006 Nobel Prize for Physics)
    - Slight fluctuations of the background radiation
    - Evolved into clusters of Galaxies and visible matter

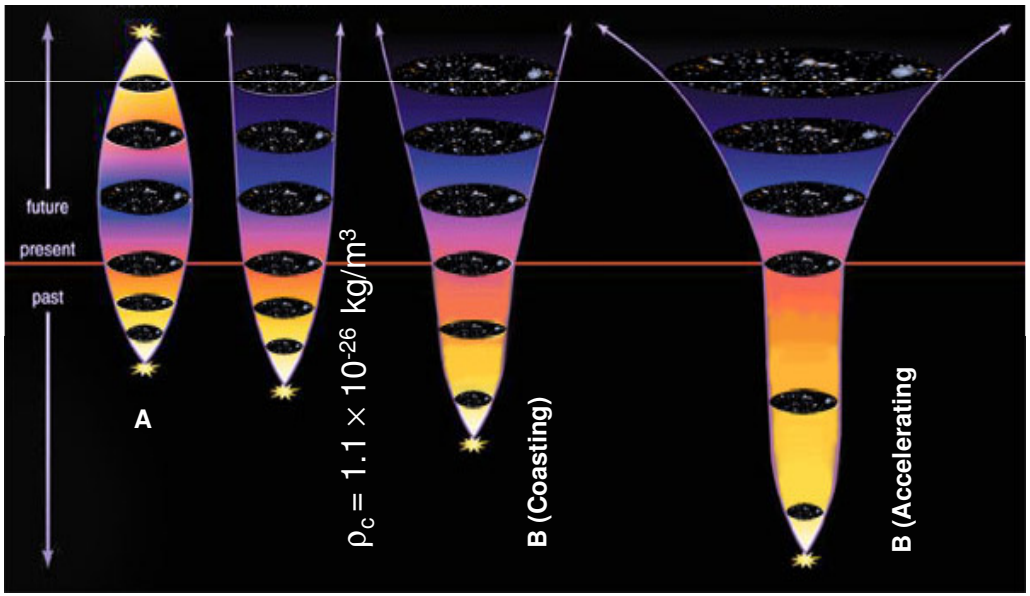


Cosmic Evolution



Fate of the Universe

A. Will the expansion slow down and contract?
B. Will it continue expanding forever (open Universe)?



Matter Density of the Universe

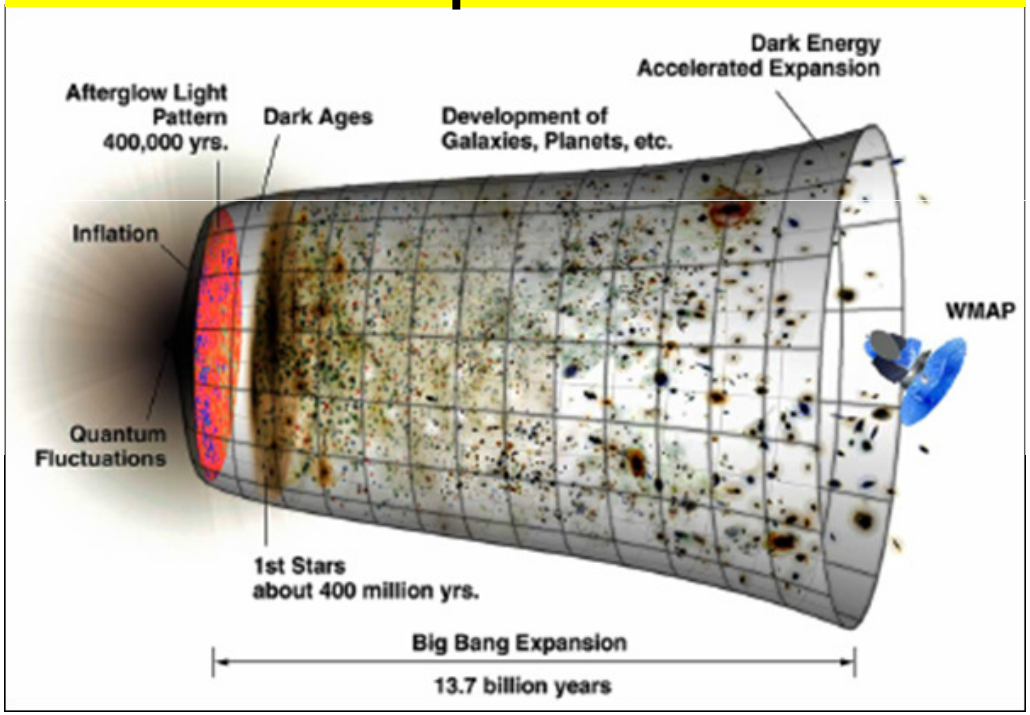
- Matter density (kg/m^3) determines what will happen

	Matter density kg/m^3	Remarks ($\rho_c = 1.1 \times 10^{-26}$ kg/m^3)
Luminous matter	$2\sim4 \times 10^{-29}$	< critical matter density
With Dark matter	2.0×10^{-27}	< critical matter density

Matter Density < Critical matter Density

So, there is no way to stop expansion

Accelerated Expansion Discovered



Our Latest Knowledge about Universe

2003 and 2006: Wilkinson Microwave Anisotropy Probe (WMAP)

- Age: **13.798 ± 0.037** Billion years
- **74%** Dark Energy, **22%** Dark Matter, **4%** Matter
- Reconciled with the Inflation theory, that the infant universe experienced a brief moment of hyper-expansion
- Size: **156**B light years in diameter
- Expand at a rate of **71**km/s/Mpc, and
- Isotropic

Fate of an Open Universe

- H_2 will be burnt out completely (10^{12} yrs)
- No new stars will be formed
  - galaxies will glow dimmer and dimmer
- Dead stars
  - Dwarf stars, Neutron stars, Black Holes
- Rare events will occur eventually
  - Star collisions
  - Black hole formation inside galaxies (10^{27}yrs)
  - Galaxies will collide creating bigger Black holes (10^{31}yrs)
  - Bigger black holes will evaporate (Stephen Hawking)