

The velocity of recession of galaxy can be regarded as its escape velocity from the rest of the universe.

The escape velocity is: $v = \sqrt{\frac{2GM}{R}}$

[$M = \text{mass of the rest universe}$]

or, $v^2 = \frac{2GM}{R}$

[$R = \text{distance of galaxy from rest universe}$]

or, $v^2 = \frac{2G}{R} \times \frac{4}{3} \pi R^3 \rho$

or, $\rho = \frac{v^2}{R^2} \times \frac{3}{8\pi G}$

[$v = H_0 R$] Hubble's law

or, $\rho = \frac{3H_0^2}{8\pi G}$

NOTE

CRITICAL DENSITY & FUTURE OF THE UNIVERSE:

The minimum density which is required just to stop the expansion of universe is called critical density of the universe. This is the maximum limit expansion of the universe.

The critical density for the Universe is

$$\rho_c = \frac{3H_0^2}{8\pi G}$$

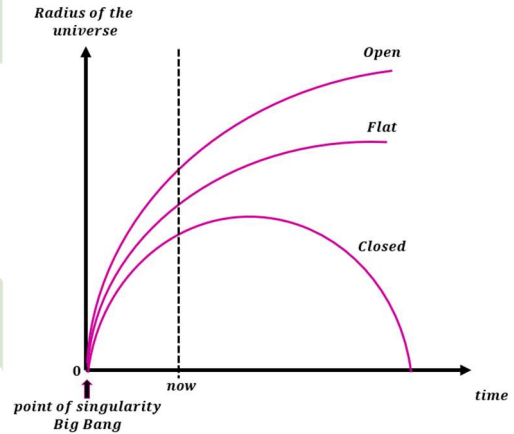
So, the critical density of the universe depends only on Hubble's constant $H_0 = 2.3 \times 10^{-18} \text{sec}^{-1}$.

$$\rho_c = 10^{-27} \text{Kgm}^{-3}$$

The density of the universe affects the Future of the Universe.

There are three future possibilities of the Universe:

- When $\rho > \rho_c$, then universe is **closed** & there would be sufficient mass that gravity will stop expansion.
- When $\rho = \rho_c$, then universe will be **flat** & open.
- When $\rho < \rho_c$, then universe will be **open** & expansion will never stop.



The future of our universe depends upon the balance between **gravitational energy** and **dark energy**.

BIG-BANG THEORY:

This model states that the universe began as an incredibly hot, dense point roughly 14 billion years ago. At this time all matter was compacted into a very small ball with infinite density and intense heat called **singularity**.

The universe as we know is the result of expanding and cooling of the singularity.

Big bang theory is the most widely accepted and popular theory. It explains not only the origin of all known matter, the laws of physics and large-scale structure of the universe, it also accounts for the expansion of universe.

Singularity:

A zero-volume point with infinite density which includes space, energy, time etc. is called as singularity.

DARK MATTER & DARK ENERGY:

Dark matter is the non-luminous material distributed throughout the universe that cannot be directly detected by observing any form of electromagnetic radiation.

- ✓ **Dark matter is hypothetical matter that is undetectable by its emitted radiation but whose presence can be inferred from gravitational effects on visible matter.**
- ✓ The dark matter constitutes approximately **25%** of the universe's mass-energy composition.
- ✓ The dark matter does not interact with electromagnetic radiations (light) and hence it is invisible.

Unlike ordinary matter (which includes protons, neutrons, and electrons), dark matter doesn't emit or absorb light. It remains completely invisible to our current instruments. However, scientists infer its existence due to its gravitational effects on galaxies and galaxy clusters. For instance, stars at the edges of spinning spiral galaxies move at similar speeds to those near the galactic center, suggesting the influence of unseen mass (dark matter) in a halo around the galaxy.