Density and Fate

Density

Gravity curves space-time

- Matter and energy produce gravity
- The amount of curvature depends on the Combined average mass density of all forms of matter and energy
- \( \rho_0 = \text{average mass density matter} + \text{average mass density of radiation} + \text{average mass density of other forms of energy} \)

Gravity strength depends on the density

Why do we care about the density and overall gravity of the universe?

Curvature

3 Choices

- Flat = zero curvature
  - Parallel lines stay parallel
- Spherical (closed) = positive curvature
  - Parallel lines converge over time (longitude lines)
- Hyperbolic (open) = negative curvature
  - Parallel lines diverge over time (saddle)

Critical density \((\rho_c)\)

- if \( \rho_0 > \rho_c \) the universe is closed
• If $\rho_0 < \rho_c$ the universe is open
• If $\rho_0 = \rho_c$ the universe is flat
• $\Omega_0 = \rho_0/\rho_c$ (this the density parameter)
  - $\Omega_0 : > 1 =$ closed
  - $\Omega_0 :$ between 0 and 1 =$ open
  - $\Omega_0 : = 1 =$ flat
    • See table 26-1 pg. 706 for a summary
• Flatness is a problem
• $\rho_0$ is 24% of $\rho_c$
  - $\rho_0 < \rho_c$ and the universe should be open
  - CMB says it is flat.
• If $\rho_0 = \rho_c$ the universe is flat
• Therefore matter, radiation and dark matter only account for 24% of the density of the universe.
• WMAP & COBE
• We can only “see” up the end of the Era of Nuclei
• WMAP & COBE give us information about this time
• Dark Energy!
• Dark energy accounts for 76% of the density of the universe… whatever it is.
• Fate of the Universe
• We have a couple of choices:
  — Recollapsing- closed
  — Critical- flat
  — Coasting- open
  — Accelerating

• Recollapsing Universe
• Matter density is larger than critical density
• Gravity overwhelms universe expansion
• *Big Crunch!*

• Critical Universe
• Matter density is equal to the critical density
• Gravity matches universe expansion
• Expansion eventually halts

• Coasting Universe
• Matter density is less than critical density
• Gravity doesn’t effect universe expansion
• Expansion continues for ever

• Accelerating
A repulsive force causes expansions to speed up over time

So...

If the density of matter is high enough then gravity is strong enough to change expansion

What density is needed?

> $10^{-29}$ g/cm$^3$

The line between expansion and collapse is called the Critical Density

What kind of universe do we live in?

We live in a flat, accelerating universe

Type 1a supernovae are dimmer than we would expect.

Conclusions

Overall geometry is flat

Matter density is 24%

Flat geometry and matter density is less than critical density and therefore dark energy exists

Age is about 13.7 billion yrs

Temp is 2.73 K