Introductory Astronomy

Week 8: Cosmology

Clip 11: Problems of LCDM Cosmology

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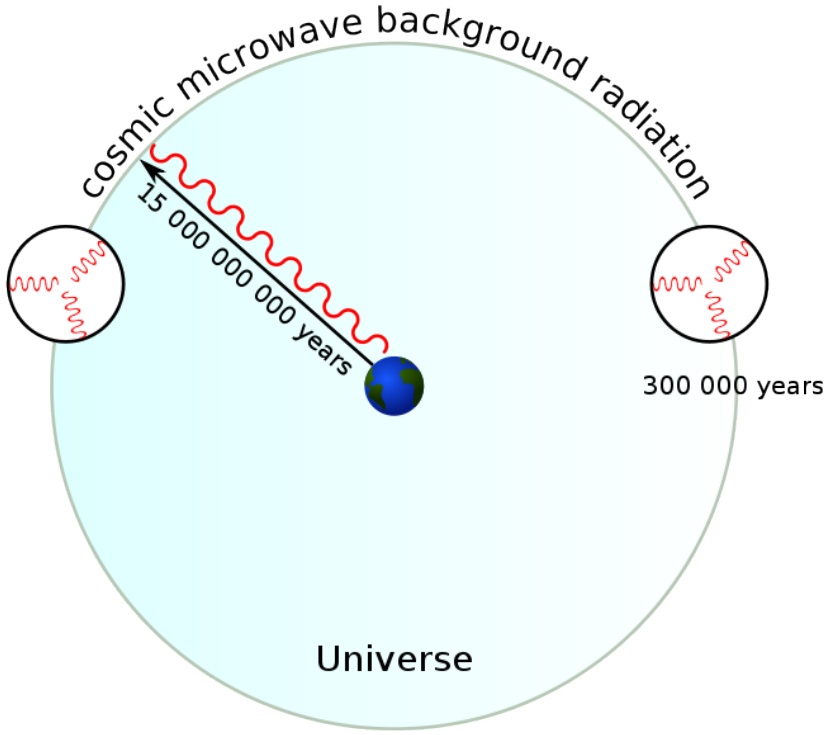
Early Universe

- At times $t < 5 \times 10^{-44}\,\mathrm{s};\ k_B T > 10^{19}\,\mathrm{GeV}$ quantum gravitational effects determine physics near singularity
- For $t > 10^{-34}\,\mathrm{s};\ k_B T < 10^{15}\,\mathrm{GeV}$ Standard Model determines physics (electroweak strong)
- Above $10^{15}\,\mathrm{GeV}$ various GUT extensions
- Typically predict Λ about 10^{60} too large.

Horizon Problem

- CMB is highly isotropic
- Directions more than 3° apart were outside particle horizon at last scattering
- How did it get so uniform?



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Flatness Problem

- We measure $\Omega_0 = 1$
- This requires fine tuning at early times
- In a dust universe

$$H^2\Omega = \frac{8\pi G}{3}\rho$$

$$H^2(\Omega - 1) = \frac{kR_0c^2}{a^2}$$

$$\Omega - 1 = \frac{a(\Omega_0 - 1)}{\Omega_0 - a(\Omega_0 - 1)}$$

- At early times $a \ll 1$ need extreme fine tuning to end up with flat universe we observe

Relic Problem

- Extensions of standard model (GUTs) predict the formation of stable magnetic monopoles and other defects
- Searches discover no monopoles.
- Where are they?

Matter-Antimatter Asymmetry

- Laws of Physics almost symmetric under exchange of particles with antiparticles
- Expect them to be created in equal numbers leaving nothing after annihilation
- If anything survives should be symmetric yet cosmic rays show our universe is predominantly baryons
- Sakharov 1967 finds conditions under which this can occur. Models of baryogenesis not conclusive

Credits

- Horizon Problem: Wikimedia Commons/ Theresa knott http://commons.wikimedia.org/wiki/File:Horizon_problem2.PNG