CMB: Surface of Last Scattering

Uniform!

\[ T = 2.73 \text{ K} \]

\[ = 3000 \text{ K} / 1100 \]

\[ \Delta T/T \sim 10^{-5} \]

\[ z = 1100 \]
The Current Theory of Space and Time

Einstein’s Theory of General Relativity

- The Modern Theory of Gravity
- The Modern Theory of Space and Time
  - A dynamical entity
The Theory of the Universe

- Einstein’s Equation

\[ G_{\mu\nu} = 8\pi G T_{\mu\nu} \]

- In a homogeneous and isotropic universe, it is especially simple -- a scale factor \( a(t) \).
The Dynamic of the Scale Factor

- **Speed**

\[
\left( \frac{\dot{a}}{a} \right)^2 = \frac{8G}{3} \frac{k}{a^2}
\]

- Implies two domain -- no stop and stop

- **Acceleration**

\[
\frac{\ddot{a}}{a} = \frac{4G}{3} \left( \frac{1}{\dot{a}} + 3p \right)
\]

- Always negative
Standard Big Bang

- Not adequate
  - Four plus Problems
    - Missing mass
    - New Standard Candle
    - Horizon
      - Exotic particles
    - Age
Missing Mass

- Goes back to Einstein
  - He wanted a collapsing universe
- Luminous matter $\left[ Lum \right] = 0.01$
- Galaxies $\left[ Gal \right] = 0.1$
- Clusters of galaxies $\left[ clus \right] = 0.2$
M33 rotation curve

- observed
- expected from luminous disk

- galaxy & cluster dynamics
- gravitational lensing
- structure formation
- CMB observations
New Standard Candle

- Recalibration of Type 1a Supernovas
Horizon Problem

The Horizon Problem

BIG BANG
Uniform!
$\Delta T/T \sim 10^{-5}$

horizon size = 1°