The Early Universe

- At the first moment of time the universe was nothing more, or less, than extremely hot, dense soup of sub-atomic particles.
The Surface of Last Scatter

- If we look far enough away, we should be able to observe the birth of the universe. When we do so, we see this wall of fog 1/3 million years after the universe formed - the surface of last scatter.
And the light separated from the darkness...

- Attempts to look farther (earlier) are frustrated by the very high opacity of the universe at times earlier than 380,000 years after its birth.
  - At that time the temperature was 3000 degrees K
  - Doppler shifted to 2.73 degrees K today - the dark night sky

- The seeds for the structure that we see today began to form
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**
  
  \[
  \left( \frac{\dot{a}}{a} \right)^2 = \frac{8\pi G}{3} \rho - \frac{k}{a^2}
  \]

  - Implies two domain -- no stop and stop

- **Acceleration**
  
  \[
  \frac{\ddot{a}}{a} = -\frac{4\pi G}{3} (\rho + 3p)
  \]

  - Always negative