The Early Universe

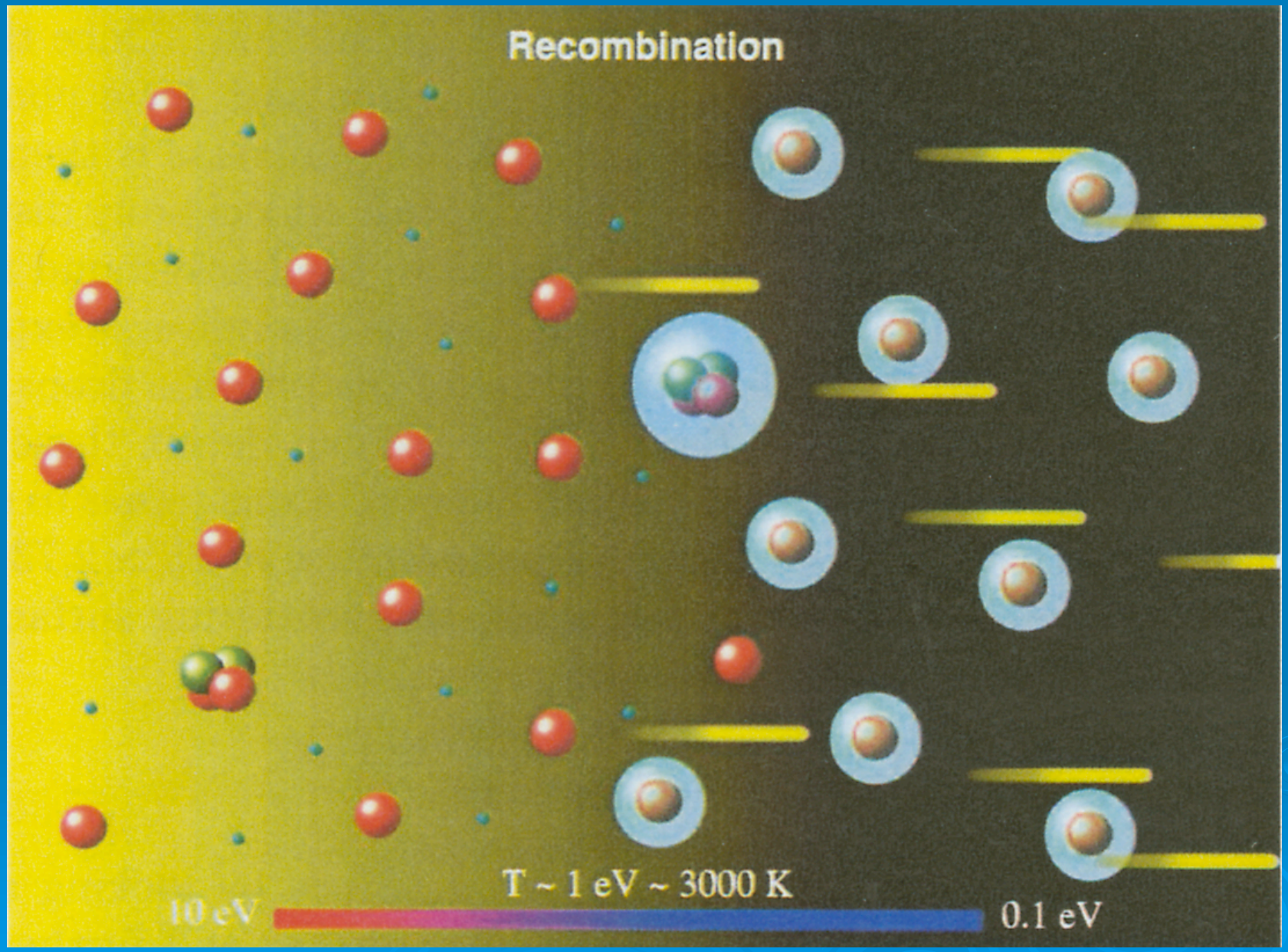
- At the first moment of time the universe was nothing more, or less, then extremely hot, dense soup of sub-atomic particles.

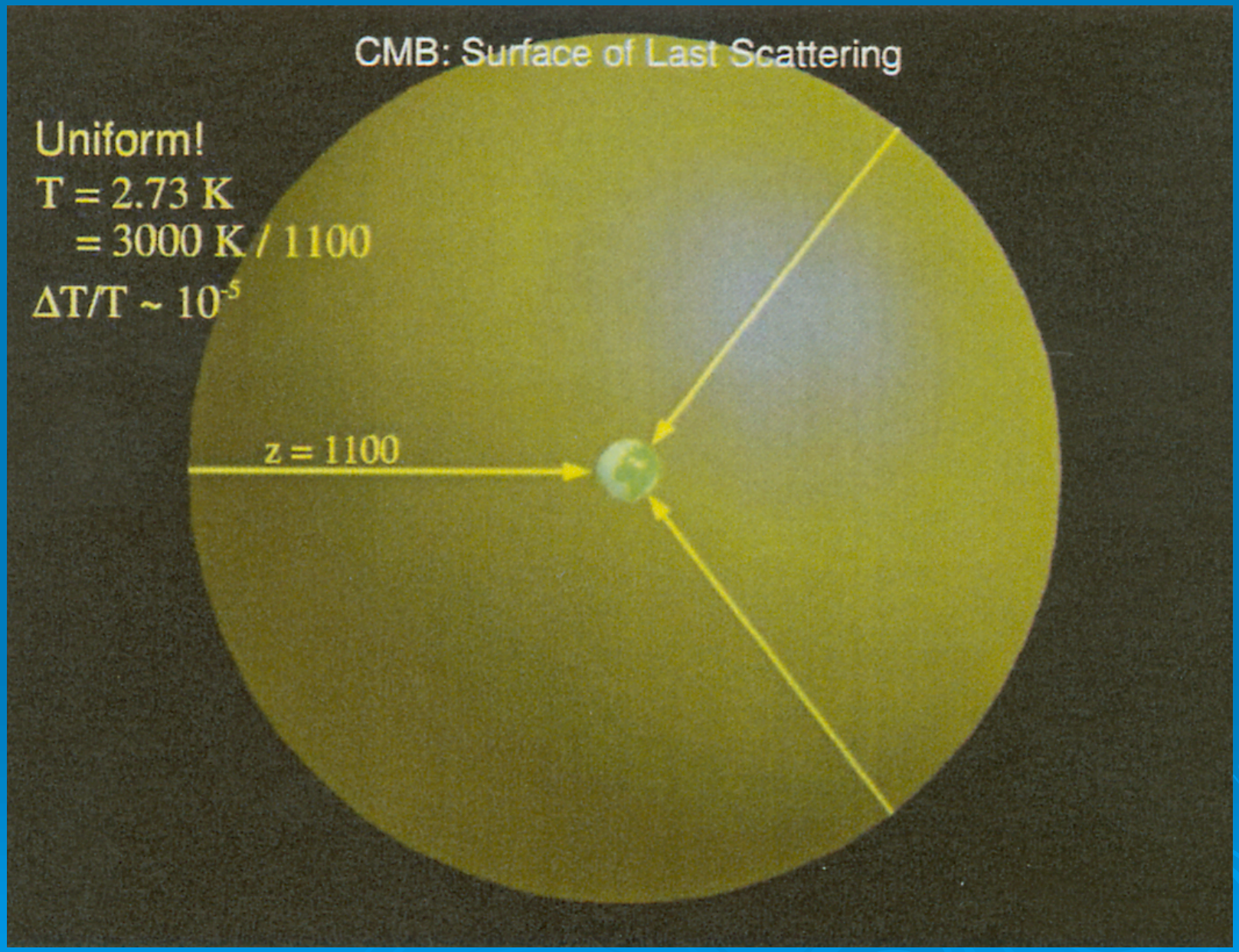
The Surface of Last Scatter

- 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


Recombination
T ~ 1 eV ~ 3000 K
10 eV
0.1 eV


CMB: Surface of Last Scattering
Uniform!
T = 2.73 K
= 3000 K / 1100
ΔT/T ~ 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 $$(\frac{\dot{a}}{a})^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2}$$
  - Implies two domain -- no stop and stop
- Acceleration $$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p)$$
  - Always negative