$t = 0$?

Size (Sphere of CMB emission)

$\hbar, c, G$

$t_p = 5.4 \cdot 10^{-44}\,s$ ($l_p = 1.6 \cdot 10^{-35}\,m$)

T

Λ-dominated expansion ↓

$t = 10^{-37}\,s$ INFLATION $R \approx 10^{-30}\,m$ $\gtrsim 10^{30}\,K$

$t = 10^{-35}\,s$ INFLATONS decay: $R \simeq 1\,cm$

Symmetry breaking

$e^-, \mu^-, \tau^-, (\nu_e, \nu_\mu, \nu_\tau), (u, d), c, s, t, b, W, Z, H, (\gamma), (g)$; ? DM

↓ DM, (DE)

Rad. dom. expansion $a \propto \sqrt{t}$

$t \simeq 10^{-4}\,s$ p, n

$t \simeq 10^{2}\,s$ $p + n \rightarrow d, {}^4He, ({}^{6,7}Li)$ ...

$n \rightarrow e^- + p + \bar{\nu}_e$ 20%

$t \simeq 10{,}000\,yr$ → dark matter starts clumping

380,000 yr → atoms, γ

Matter dom. universe

$T \simeq 3000\,K$

$t \simeq n \cdot 100\,Myr$ stars, galaxies, quasars, filaments + nuclear reactions

SMBH

– n Byr

4 Byr Milky Way

9 Byr Solar forms → Λ dom.

50 Blyr

2.7 K

QM

Field ⟷ Particle

$h\nu = \Delta E$

atoms have quantized energy levels

GR

$$R_S = \frac{2GM}{c^2}$$

$$E^2 = ((mc)^2 + p^2)c^2$$

$E \sim mc^2 \rightarrow pc$

matter Radiation

Heisenberg

$$\Delta t \cdot \Delta E \gtrsim \frac{\hbar}{2}$$

$$\Delta p \cdot \Delta x \geq \frac{\hbar}{2}$$

Pauli (Fermi/Dirac)

13.7 Byr Sun

18.7 Byr → red giant

→ ${}^4He + {}^4He + {}^4He \rightarrow {}^{12}C$

→ core C, N, O

envelope blows off ($L_{eddington}$)

→ electron degeneracy stabilizes → White Dwarf

→ planetary nebula

heavier → Supernova Ia → neutron star

ignition:

$p + p \rightarrow d + e^+ + \nu_e$ (d = pn)

further reactions → ${}^4He + \gamma$

energy flux $\sim \sigma T^4$

$$\lambda_{max} \sim \frac{1}{T}$$