

$t = 0$  ?

Size (sphere of CMB emission)  $h, c, G$

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

+

$\approx 10^{30} K$

$\Lambda$ -dominated expansion  $t = 10^{-37} s$  INFLATION  $R \approx 10^{-30} m$

$t = 10^{-35} s$  INFLATION ends:  $R \approx 1 cm$

Symmetry breaking

$e^-, \bar{\nu}_e, \tau^-, \nu_e, \nu_\mu, \nu_\tau, u, d, c, s, t, b, W, Z, H, \gamma, g$ ; ? DM

$t = 10^{-4} s$   $p, n, e$

$t = 10^2 s$   $p+n \rightarrow d, {}^4He, ({}^{6,7}Li) \dots$   
 $n \rightarrow e^+ + p + \bar{\nu}_e$  20%

DM, (DE)

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

$t \approx 10,000 yr$   $\rightarrow$  dark matter starts clumping  
 $380,000 yr$   $\rightarrow$  atoms,  $\gamma$

$t \approx n \cdot 100 Myr$  stars, galaxies, quasars, filaments + nuclear reactions  
 $n \cdot 10^8 yr$  SMBH

$T \approx 3000 K$

Matter dom. formation

$4 Byr$   
 $9 Byr$

Milky Way  
Solar forms  $\rightarrow \Lambda$  dom.

50 Byr

2.7 K

QN

GR

Heisenberg

Field  $\leftrightarrow$  Particle

$h\nu = \Delta E$

atoms have quantized energy levels

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

$\Delta t \cdot \Delta E \geq \frac{h}{2}$

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

Pauli (Fermi/Dirac)

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

$E \sim mc^2 \rightarrow pc$   
matter

Radiation

13.7 Byr Sun

ignition:

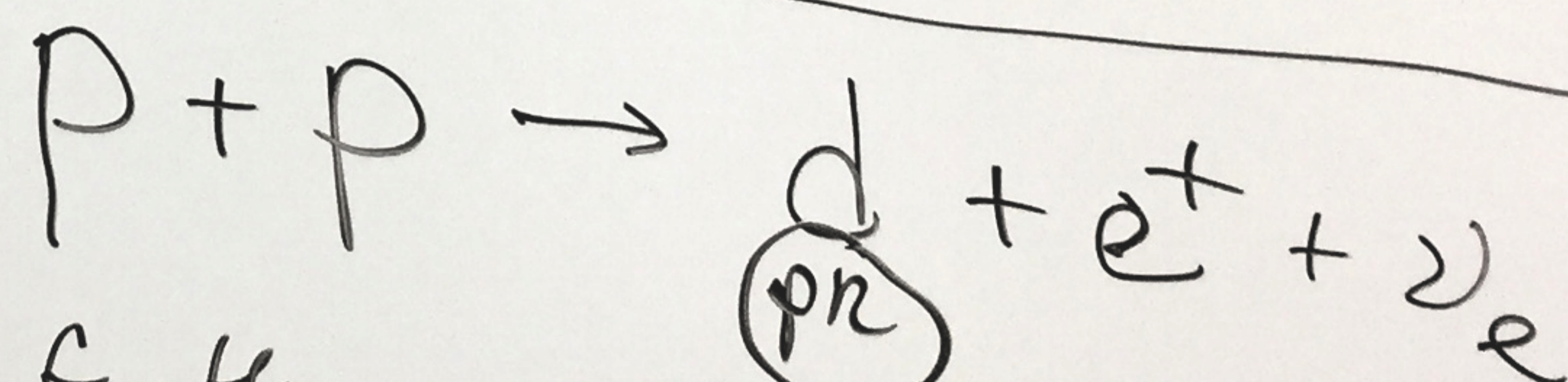
18.7 Byr  $\rightarrow$  red giant

$4He + 4He + 4He \rightarrow {}^{12}C$   
 $\rightarrow$  core  $C, N, O$

envelope blows off (Eddington)  
 $\rightarrow$  electron degeneracy

stabilizes  $\rightarrow$  White Dwarf

heavier  $\rightarrow$  Supernova Ia  $\rightarrow$  neutron star



future reactions  $\rightarrow 4He + \gamma$

energy flux  $\sim \sigma T^4$

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