

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3} \rho + \frac{2U}{r_0^2 a^2}$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2} \frac{U}{c^2} - \frac{Kc^2}{r_0^2 a^2} + \frac{\Lambda}{3}$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2} (U_r + U_m + U_\Lambda) - \frac{Kc^2}{r_0^2 a^2}$$

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→ independent.

$$U_r \propto a^{-4}$$

$$U_m \propto a^{-3}$$

$$U_\Lambda \propto \text{const.}$$

$$U_{\text{crit}} = \frac{3H^2 c^2}{8\pi G}$$

- radiation — most photons today are ^(with) from the CMB
- neutrinos from the early Univ. too (relativistic)

contribute from Tens. $\rightarrow U_r \rightarrow \Omega_r = 8 \times 10^{-5}$

- matter — gravity is clusters $\Omega_m \approx 0.3$ (most is hot gas in between galaxies in galaxy clusters)
but $\Omega_{\text{baryon}} \approx 0.04$

\therefore most matter is dark matter
no interaction w/ light, but
has gravity — not neutrino, no photons

- cosmological constant — repulsive force: counter gravity —

$$\Omega_\Lambda = 0.7 \quad \begin{array}{l} \text{detected by its acceleration} \\ \text{effect on the cosmic expansion} \end{array}$$