Cosmology 1

2023/2024
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Proposed problem, lecture 21
Topic: Big Bang nucleosynthesis (see exercise 3.2 of Vittorio).

Try to estimate the temperature of the CMB under the assumption that He is produced during the first minutes of life of the universe. Follow this path, you can neglect order-of-1 factors, but assume that CMB has not been observed:

(a) assume that primordial nucleosynthesis starts at $T \sim 100$ keV,

(b) compute the age of a radiative universe t_u for that temperature,

(c) assume that the cross section for deuterium formation is $\sigma \sim 10^{-29}$ cm^{-2},

(d) work out the thermal speed of baryons at that temperature,

(e) the timescale for deuterium formation is $t_d = 1/n\sigma v$, where n is the baryon number density at nucleosynthesis time,

(f) deuterium production starts when the age of the universe is $t_u \sim t_d$,

(g) the baryon number density today is $n_b \sim 10^{-7}$ cm^{-3},

(h) CMB temperature evolves like $T = T_0\, a^{-1}$,

(i) baryon density evolves like $n = n_0\, a^{-3}$.

What do you obtain, solving for T_0? This argument was proposed by Gamow, Alpher and Hermann in the 1940s. Can you give on this basis a justification of why nucleosynthesis should start at $T \sim 100$ keV?