Cosmic time dependence of fundamental constants?

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→ CERN-Courier March 03

Keck telescope (Australia, England, US).

"many multiplet method" (Webb, Wolfe...)

fine-structure of Fe, Ni, Mg, Sn, A

~150 quasars (→ 11 bn years in time)

$$\frac{\Delta\alpha}{\alpha} = (-0.72 \pm 0.18) \cdot 10^{-5}$$

α = 1/137,03599976 (today)

early: $\alpha \approx$ 1/137,037 (not: 036)

Time Dependence of constants:

long history

30's: Dirac, Milne ($\rightarrow G$)

P. Jordan (other constants)

L. Landau (α: in conn. to renorm.)

$$\alpha = \frac{e^2}{\hbar c}$$

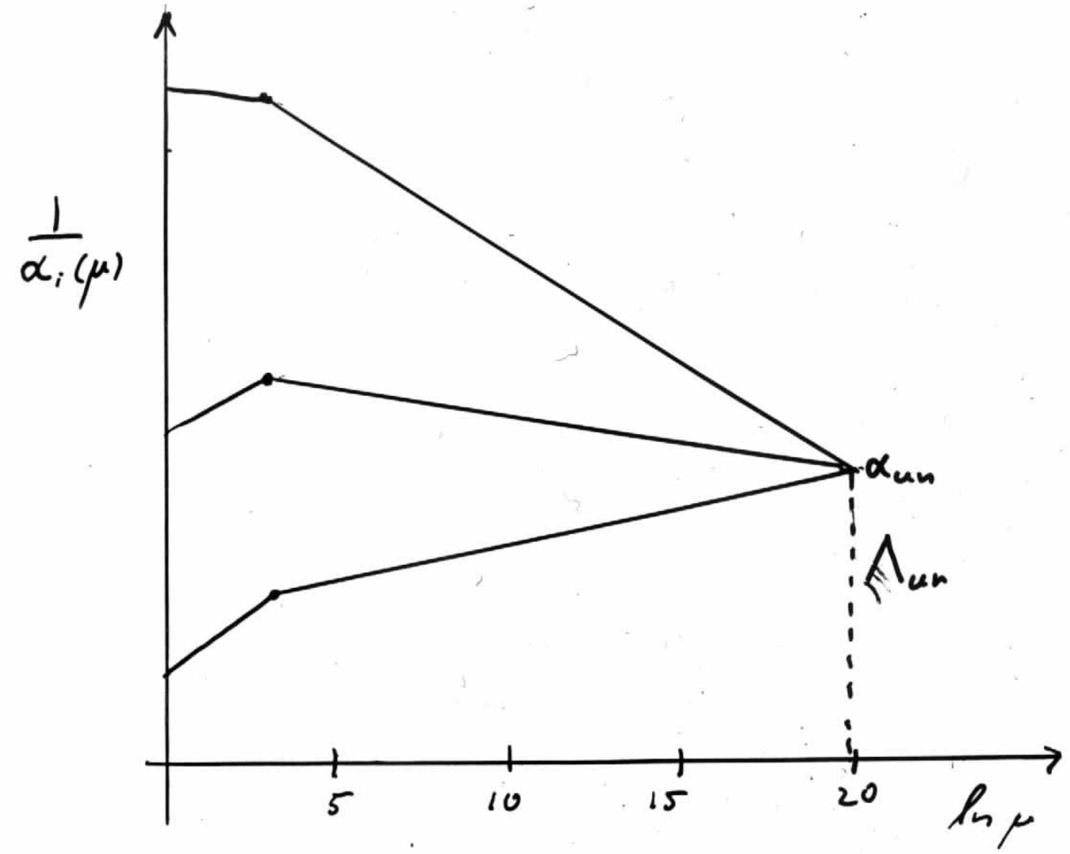
$\hbar, c \rightarrow 1$ in suitable systems

→ unlikely, that $\hbar$ or c depend on time

→ time-dependence of e

Grand unification:

$$SU(3)^c \times SU(2) \times U(1) \subset \begin{matrix} SU(5) \\ SO(10) \end{matrix}$$



Example SU(5) with supersymmetry at $\mu > 1$ TeV

(different, but possible pattern for SO(10) without supersymmetry)

Cosmic Time Dependence of α:

a) time dependence of α_{un}

b) time dependence of Λ_{un}

In general:

$$\frac{1}{\alpha}\frac{\dot{\alpha}}{\alpha} = \frac{8}{3}\frac{1}{\alpha_s}\frac{\dot{\alpha}_s}{\alpha_s} - \frac{1}{2\pi}\left(b_2^s + \frac{5}{3}b_1^s - \frac{8}{3}b_3^s\right)\frac{\dot{\Lambda}_{Gut}}{\Lambda_{Gut}}$$

$$\dot{\Lambda}_{Gut} = 0$$

$$\frac{1}{\alpha}\frac{\dot{\alpha}}{\alpha} = \frac{8}{3}\frac{1}{\alpha_s}\frac{\dot{\alpha}_s}{\alpha_s}$$

$$\frac{\dot{\Lambda}}{\Lambda} \approx -30{,}8\,\frac{\dot{\alpha}}{\alpha}$$

→ Magnetic Moments of Nuclei:

$$\frac{\dot{\mu}_p}{\mu_p} = \frac{\dot{\mu}_N}{\mu_N} \approx 30{,}8\,\frac{\dot{\alpha}}{\alpha} \sim 3.1\cdot 10^{-14}/\text{year}$$

Quantum Optics

(MPQ ~ Haensch, Walther)

Suppose: $\dot{\alpha}/\alpha \cong -1.2 \cdot 10^{-15}$

$\dot{\Lambda}/\Lambda \cong 2.4 \cdot 10^{-14}$

Cesium clock: 1 s =: 6 192 631 770 cycles of microwave light ~ hf-transition of cesium-133

$\nu_{hf} \sim \frac{m_e}{\Lambda} \alpha^4$

→ Cesium clock ≠ H-clock (no dep. of Λ)

(~ 3 cesium cycles / day)

1. Step: Cesium ⇝ H

Effect ~ 3σ, if $\frac{\dot{\Lambda}}{\Lambda} \approx 10^{-14}\ yr^{-1}$

2. Step: Indium (trapped) ~ AG (trapped)

→ sensitiv to $\frac{\dot{\Lambda}}{\Lambda} \approx 10^{-17}\ yr^{-1}$ (~ 3 yrs)

e.g.: $\dot{\Lambda}/\Lambda = (2.13 \pm 0.01) \cdot 10^{-14}$

Conclude

S. M.: 18 constants P_i

Particle Physics: one should

prepare for

$$\frac{\Delta P_i}{P_i} \sim 10^{-15}\ yr^{-1} \sim 10^{-5} \text{ / Hubble Time}$$

$$\sim \left(\frac{\alpha_u}{\pi}\right)^2 \text{ / Hubble Time}$$

$$\frac{\Delta \alpha}{\alpha} \sim -0.6 \cdot 10^{-5} \qquad \frac{\Delta \Lambda}{\Lambda} \sim 18 \cdot 10^{-5}$$

Tests in Quantum Optics –

Results soon. (before summer)