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SMR.1580 - 30

CONFERENCE ON FUNDAMENTAL SYMMETRIES AND FUNDAMENTAL CONSTANTS

15 - 18 September 2004

BARYON-ANTIBARYON ASYMMETRY AND LORENTZ INVARIANCE VIOLATION (or a tiny PCT violation?)

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Baryon - AntiBaryon Asymmetry and Lorentz invariance Violation (or a tiny PCT violation?)

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Plan of the Talk

- Motivation
- An example of QFT with explicit PCT violation
  (particles ≠ antiparticles)
- Thermal equilibrium
- Conclusions and outlook

- In the universe observed presently there are an asymmetry between matter and antimatter.

- Up to now there is no a definitive solution to this problem

In the $B\bar{B}$ problem (1967)

+ Sakharov outlined three ingredients in order to explain this phenomenon

  - Violation of baryonic number
  - C and CP violation
  - departure of the thermal equilibrium

However, alternatively one could consider directly CPT violation as a consequence of matter-antimatter asymmetry.

CPT is a consequence of well established principles (Lorentz invariance, locality, causality)

Thus, CPT is a fundamental stone for our understanding of the fundamental interactions!

However, if CPT is violated this effect should be very small, typically

$\Delta m = m - \bar{m}$ = could be a relic of this fact.

This difference of mass must yield to a tiny Lorentz invariance violation.

The consequences between LIV and CPT have been extensively studied, e.g

+ Mavromatos
+ Kostelecky et al
+ Liberati,
+ Berger
+ ...

Our Approach

One start considering a charged scalar field

$$H = \frac{1}{2}\sum_{i=1}^{2}\int d^3x \left[\pi_{\phi_i}^2 + (\nabla\phi_i)^2 + m^2\phi_i^2\right]$$

with deformed commutators

$$[\pi_i(\vec{x}), \pi_j(\vec{x}')] = i\epsilon_{ij}\,\beta\,\delta(x-x')$$

$$[\phi_i(\vec{x}), \phi_j(\vec{x}')] = \epsilon_{ij}\,\theta\,\delta(x-x')$$

$$[\phi_i(\vec{x}), \pi_j(\vec{x}')] = i\delta_{ij}\,\delta(x-x')$$

where B and θ are very small parameters and

$$\theta B = \text{dimensionless}$$

θ → Cut-off (ultraviolet) (l_p?)

B → improved cut-off (Λ^{NC} ?)

Quantization

(Cortes, Gamboa, Mendez, JG, PLB '93, JHEP' 200

$$H = \int \frac{d^3\vec{p}}{(2\pi)^3}\left[E_1(\vec{p})\left(a_p^\dagger a_p + \frac{1}{2}\right) + E_2(\vec{p})\left(b_p^\dagger b_p + \frac{1}{2}\right)\right]$$

Where E_1 and E_2 are the energies of the particle and antiparticle respectively,

$$E_1(p) = \omega(p)\left[\sqrt{1 + \frac{1}{4}\left(\frac{B}{\omega(p)} - \theta\omega(p)\right)^2} + \frac{1}{2}\left(\frac{B}{\omega(p)} + \theta\omega(p)\right)\right]$$

$$E_2(p) = \omega(p)\left[\sqrt{1 + \frac{1}{4}\left(\frac{B}{\omega(p)} - \theta\omega(p)\right)^2} - \frac{1}{2}\left(\frac{B}{\omega(p)} + \theta\omega(p)\right)\right]$$

$\therefore$ Lorentz invariance is broken if θ and B are $\neq 0$

In the infrared sector $\theta \simeq 0$, and

$$E_1 - E_2 = B \quad - \quad (\sqrt{\Lambda}\,?)$$

$\therefore$ B could be considered as a measure of the matter - antimatter asymmetry.

For $T \sim 10^{2}k$, the universe was in Thermal equilibrium and one could use statistical mechanics.

$$N = 4\pi V \int_0^{\infty} \frac{p^2 dp}{e^{\beta\left(\sqrt{p^2+m^2+\frac{B^2}{4}} - \frac{B}{2}\right)} + 1}$$

$\frac{1}{\beta T}$

$$\bar{N} = 4\pi \int_0^{\infty} \frac{p^2 dp}{e^{\beta\left(\sqrt{p^2+m^2+\frac{B^2}{4}} + \frac{B}{2}\right)} + 1}$$

One could note that $\pm\frac{B}{2}$ play the role of chemical potential.

The ratio $\bar{N}/N$ can be computed numerically, however as B^2 is small, in the $|p| \gg m$ region, one find that

$$\frac{\bar{N}}{N} = \frac{Li_3\left(-e^{-\beta\frac{B}{2}}\right)}{Li_3\left(-e^{\beta\frac{B}{2}}\right)} \simeq 1 + \frac{2\pi^2}{\zeta(3)}\left(e^{-\beta B} - 1\right)$$

$$\beta B = -\ln\left[1 - \frac{9\zeta(3)}{\pi^2}\left(\frac{\bar{N}}{N} - 1\right)\right] + \cdots$$

This formula allow to compute B is the ratio $\bar{N}/N$ is known a viceversa.

In other words, if the CPT is violated one could explain the baryon–antibaryon asymmetry.

In conclusion could be possible explain the asymmetry only assuming a tiny CPT violation in the first instants of the universe $\sim 10^{-?}$ sec without a departure of thermal equilibrium.

Still a more careful phenomenological analysis is necessary.