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ON THE 2π DECAY OF THE K_2^0 MESON*

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Evidence has been presented[1] for a small departure from CP invariance in the decay of neutral kaons. Before a more mundane explanation is found, it is amusing to speculate that it might be a local effect due to the dissymmetry of the environment, namely the local preponderance of matter over antimatter.

To construct a simple model of such a mechanism suppose that there is a vector field analogous to the electromagnetic, but coupled to hypercharge rather than charge. The galaxy[2] will give rise to a corresponding potential

$$\varphi \approx gH/R \tag{1}$$

where g is a coupling constant, R the galactic radius ($\approx 6 \times 10^{22}$ cm), and H the galactic hypercharge ($\approx 2 \times 10^{68}$). This potential modifies the free space Klein-Gordon equation by the substitutions $(i\partial/\partial t) \rightarrow (i\partial/\partial t - g\varphi)$ for K_o and $(i\partial/\partial t) \rightarrow (i\partial/\partial t + g\varphi)$ for $\overline{K}_o$. Decoupling the equations one finds that the amplitude for the "wrong" CP state in each eigenstate is

$$\left|\epsilon\right| = \left|(Eg\varphi/m)(\delta m - \tfrac{1}{2}\, i\delta\Gamma)^{-1}\right| \tag{2}$$

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where m is the kaon mass, δm the (K_1^0, K_2^0) mass difference, and $\delta\Gamma$ the difference of widths ($\hbar = C = 1$). Using the quoted[1] value $|\epsilon| \approx 2.3 \times 10^{-3}$, with $(E/m) \approx 2$, and taking[3] $\delta m \approx \delta\Gamma \approx 10^{10}\ \mathrm{sec}^{-1}$, we find

$$g^2/\hbar C \approx 10^{-49} \tag{3}$$

This is very weak compared with the gravitational coupling, where M is the proton mass,

$$GM^2/\hbar C \approx 6 \times 10^{-39} \tag{4}$$

In fact (3) is too small by between three and four orders of magnitude to show up in the recent version[4] of the Eötvös experiment. If the quantum of the proposed field did not have zero mass,[5] the potential would have a finite range. If this were less than the radius of the galaxy larger values of g^2 would be required, and the Eötvös experiment limits the extent to which this would be acceptable.[6]

Clearly this theory[7] has a very slender basis. However it suggests a refinement of the experiment. Our field provides not only a weak local violation of CP invariance, but also of Lorentz invariance. Thus from (2) the branching ratio for anomalous decay varies with the square of the particle energy.

REFERENCES

1. J. H. Christenson, J. W. Cronin, V. L. Fitch, and R. Turlay, Phys. Rev. Letters 13, 138 (1964).

2. In fact, it might be necessary to identify the local preponderance of matter with a still larger unit than the galaxy; see Ref. 4.

3. See, for example, the report of W. F. Fry in the proceedings of the International Conference on the Fundamental Aspects of Weak Interactions, Brookhaven National Laboratory, September 1963.

4. R. H. Dicke, Phys. Rev. 126, 1580 (1962).

5. There is a technical difficulty with vector particles of zero bare mass in quantum field theory when the source (hypercharge in this case) is not accurately conserved. See G. Feinberg, to be published.

6. For example, if the sun is the dominant object within range, with hypercharge about 1.2×10^{57} at a distance of 1.5×10^{13} cm, (3) is replaced by

$$g^2/\hbar c \approx 5 \times 10^{-48} \tag{5}$$

which is still two orders of magnitude beyond the limit of the Eötvös experiment. If the earth is the effective source, with hypercharge about 3.6×10^{51} and radius 6×10^{8} cm, we need

$$g^2/\hbar c \approx 7 \times 10^{-47} \tag{6}$$

Here only the original terrestrial Eötvös experiment is relevant, 50 times less accurate than the "solar" experiment of Dicke *et al*. So (6) would be nearly three orders of magnitude beyond detection in that way. Going to

still smaller interaction ranges, when the potential $g\varphi$ is held constant the force $g\nabla\varphi$ increases very roughly inversely with the range. So the range could not be less than the diameter of the earth by more than some three orders of magnitude without the effect having been observed in the Eötvös experiment.

7. Note that in this theory time reversibility still holds, even locally, so that particles at rest could not have electric dipole moments.