ington, D. C., meeting of the American Physical Society, 27-30 April 1964. Such resonances should have extremely interesting consequences.

[3]In the well-known octet and decuplet supermultiplet there is no transition which is forbidden by SU(3) and can be used to test symmetry breaking. The forbidden decay of a unitary-singlet vector meson into two pseudoscalars is obscured experimentally by the φ-ω mixing.

[4]The 28-dimensional representation suggested by M. Hogaasen [Nuovo Cimento 32, 1129 (1964)] is ruled out, as it does not appear in the product of three octets.

[5]S. Gasiorowicz, Phys. Rev. 131, 2808 (1963), has considered octet-decuplet resonances in the 35.

[6]S. Okubo, Progr. Theoret. Phys. (Kyoto) 27, 949 (1962).

[7]S. Meshkov, C. A. Levinson, and H. J. Lipkin, Phys. Rev. Letters 10, 100 (1963).

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 dissymetry 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 ($\approx 6\times10^{22}$ cm), and H the galactic hypercharge ($\approx 2\times10^{68}$). This potential modifies the free-space Klein-Gordon equation by the substitutions $(i\partial/\partial t)\to(i\partial/\partial t-g\varphi)$ for K_0 and $(i\partial/\partial t)\to(i\partial/\partial t+g\varphi)$ for $\overline{K}_0$. Decoupling the equations one finds that the amplitude for the "wrong" CP state in each eigenstate is

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

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 $|\epsilon|\approx 2.3\times10^{-3}$, with $(E/m)\approx 2$, and taking[3] $\delta m\approx\delta\Gamma\approx 10^{10}$ 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,

$$GM^2\hbar c\approx 6\times10^{-39}. \tag{4}$$

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[7,8] 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.

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†On leave of absence from CERN, Geneva, Switzerland.

‡On leave of absence from Atomic Energy Research Establishment, Harwell, England.

[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 reference 4.

[3]See, for example, the report of W. F. Fry, in Proceedings of the International Conference on the Fundamental Aspects of Weak Interactions (Brookhaven National Laboratory, Upton, New York, 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

$$g^2/\hbar c\approx 5\times10^{-48}, \tag{5}$$

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

$$g^2/\hbar c \approx 7\times10^{-47}. \qquad (6)$$

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.

[8]Related considerations have been made by M. L. Good [Phys. Rev. 121, 311 (1961)] in showing that the behavior of $K_0{}^2$ is strong evidence against "antigravity."

MESON EXCHANGE EFFECTS IN ELASTIC e-d SCATTERING*

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This Letter reports a calculation of an effect of the three-pion-exchange current on the electromagnetic interaction of the deuteron.

Since the deuteron has isotopic spin $I=0$, only the isotopic scalar part of the electromagnetic current contributes to elastic scattering. In the language of dispersion theory, this selection rule removes all even pion states, and in particular the simple pion-exchange current illustrated by Fig. 1(a). The least massive state is then that with three pions. Its contribution, via the three-pion resonance (the ω or φ), as in Fig. 1(b), has been studied extensively, most recently by Jones[1] and Gourdin.[2] In addition it gives rise to an exchange-current contribution which we study here in the approximation that the 3π state may be approximated by a two-particle (ρ,π) system, with the ρ and π landing on different nucleons and thus constituting an exchange current as illustrated in Fig. 1(c).

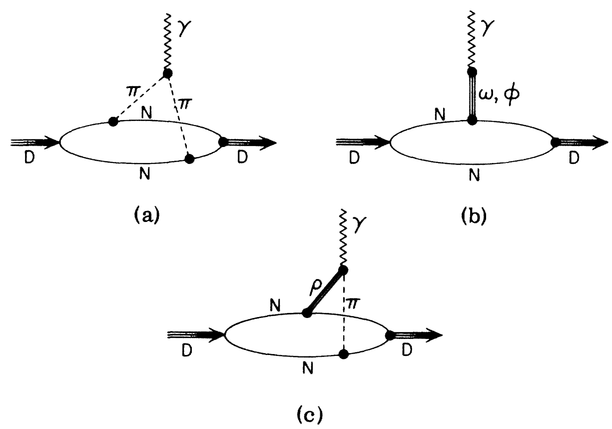

FIG. 1. Diagrams for elastic interaction of a deuteron with an electromagnetic field.

In reporting this calculation we wish especially to emphasize the importance of a measurement of the $\rho\pi\gamma$ coupling strength. On the basis of a polology interpretation of the cross section for ρ photoproduction in terms of one-pion exchange, this coupling strength has already been estimated, although rather crudely.[3] Using this estimate we have calculated the contribution of Fig. 1(c) to the deuteron magnetic moment, obtaining $\sim\pm(1\text{-}2)\times10^{-2}$ nuclear magneton. This result is proportional to the $\rho\pi\gamma$ and ρ-N coupling strengths[4] and is comparable in magnitude with the existing discrepancy of $+1.7\times10^{-2}$ nuclear magneton between the observed moment $\mu_d=0.857$ nm and the value calculated using a 7% D-state probability for the deuteron as indicated by other experiments[5]:

$$(\mu_d)_{\rm th}=(\mu_n+\mu_p)-\tfrac{3}{2}P_D(\mu_p+\mu_n-\tfrac{1}{2})$$
$$=0.840 \text{ with } P_D=0.07. \qquad (1)$$

To reconcile Eq. (1) with experiment in the absence of an exchange current requires $P_D=0.039$; i.e., the small difference between 0.857 nm and 0.840 nm in μ_d corresponds to a large difference, 0.039 versus 0.07, in P_D.