Thetons

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Certain observable corollaries of the hypothesis of the existence of new type of elementary particles whose gauge interaction has a macroscopic confinement radius are examined. The quanta of the corresponding gauge field—thetons—are massless vector particles analogous to gluons.

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The goal of this paper is to examine the hypothesis of the existence of a new non-Abelian gauge field whose quanta are neutral, massless vector paticles (we call them thetons and denote them by the letter θ) have a macroscopic confinement radius. We shall begin by explaining why the hypothesis of the existence of a thetonic interaction seems probable. Then, we shall briefly discuss why to date it has not been observed and how it can be observed experimentally.

As is well known, the gauge theories of electroweak[1] and strong[2,3] interactions, which are based on the $U(1)\times SU(2)_W\times SU(3)_c$ group, assume the existence of W and Z bosons and gluons in addition to photons. Moreover, the Grand Unification models[4] [$SU(5)_G$, $SO(10)_G$, etc.] predict the existence of a large number of other gauge particles. The model of the compound Higgs bosons ("technicolor"[5]) assumes the existence of "technigluons" with the confinement radius of $\approx 10^{-3}$ GeV^{-1}. Thus presently the hypothesis of the existence of several additional gauge bosons does not seem too bold.

As we shall see, the hypothesis of the macroscopic confinement radius also seems probable, since it depends exponentially on the number of gauge fields and on the number of fermions. We remind that for the running interaction constant α_N of the $SU(N)$ gauge group the dependence on the momentum k has the form[3]:

$$\alpha_N(k) = \frac{2\pi}{b_N(k)\ln k/\Lambda}\,. \tag{1}$$

Here k is the momentum and $1/\Lambda$ is the confinement radius,

$$b_N(k) = \frac{11}{3}N - \frac{2}{3}n_f(k), \tag{2}$$

where $n_f(k)$ is the number of different types of fermions with $m_f \ll k$, which interact with the gauge fields. The behavior of the values $1/\alpha_1$, $1/\alpha_2$, $1/\alpha_3$, $1/\alpha_4$, and $1/\alpha_5$ corresponding to the $U(1)$, $SU(2)_W$, $SU(3)_c$, $SU(4)_t$, $SU(5)_G$ groups, respectively, is shown schematically in Fig. 1.

Moreover, Fig. 1 illustrates the possible behavior of the running θ interaction

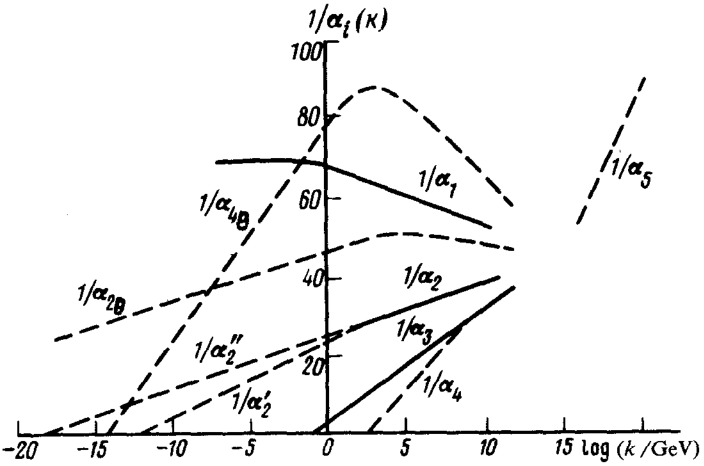

FIG. 1.

constant $1/\alpha_{2\theta}$ and $1/\alpha_{4\theta}$ for the $SU(2)_\theta$ and $SU(4)_\theta$ groups, respectively. It can be seen from the expressions for $\alpha_N(k)$ and $b_N(k)$ and in Fig. 1 that for reasonable values of N and $n_f(k)$, we can easily obtain such behavior of $\alpha_{N\theta}(k)$ for which $\alpha_{N\theta}$ is larger than or of the order of $\alpha (\alpha = 1/137)$ at small distances, and at the same time the confinement radius $1/\Lambda_\theta$ lies in the range of the size of the atomic nucleus and the size of the universe. (We note that if the intermediate bosons would not acquire a Higgs mass in the model of the electroweak interaction,[1] then the confinement radius for them would be of the order of a millimeter, and if all the leptons and quarks would also be massless, then the radius would be of the order of a kilometer; see lines $1/\alpha_2'$ and $1/\alpha_2''$ in Fig. 1.)

The thetons should produce θ neutral systems—thetons comprised of two or three thetons: $\delta_{ik}\theta_i\theta_k$, $f_{ikl}\theta_k\theta_l$, $d_{ikl}\theta_i\theta_k\theta_l$; $i, k, l = 1,2...N^2-1$ in a similar way that the gluons produce gluonium. The lighest levels of these systems should have the quantum numbers $J^P = 0^\pm, 1^- \cdots$. Their masses should be of the order of Λ_θ and their size of the order of $1/\Lambda_\theta$. The cross section for interaction of the thetons should be of the order of Λ_θ^{-2}. The fact that the θ interaction has not yet been observed can be easily explained if we assume that the fermions having thetocharges are heavy fermions, say, heavier than 15 GeV (the threshold attained by colliding e^+e^- beams). The bend in the trajectories $1/\alpha_{2\theta}$ and $1/\alpha_{4\theta}$ on the right-hand side of Fig. 1 is attributed to the fact that there could be many such θ fermions. (The fact that all the particles known today are θ neutral follows from the fact that they have a normal spin-statistics coupling.) We shall denote fermions that interact with θ, W, Z, and (γ) as l_θ thetoleptons and fermions that interact with the g gluons in addition to the above particles as q_θ thetoquarks. Because of the thetoinvariance, the lightest l_θ and q_θ must be stable.

The q_θ loops give an effective interaction of the thetons with the gluons of the type

$$\alpha_\theta \alpha_S m_{q_\theta}^{-4} \theta^i_{\mu\nu} \theta^i_{\mu\nu} G^a_{\rho\sigma} G^a_{\rho\sigma}, \qquad i = 1, 2, \ldots N^2 - 1; \qquad a = 1, 2..\ldots 8,$$

and with the photons:

$$\alpha_\theta \alpha m_{q_\theta}^{-4} \theta^i_{\mu\nu} \theta^i_{\mu\nu} F_{\rho\sigma} F_{\rho\sigma}, \quad \alpha_\theta^{3/2} \alpha^{1/2} m_{q_\theta}^{-4} d_{ikl} \theta^i_{\mu\alpha} \theta^k_{\alpha\beta} \theta^l_{\beta\nu} F_{\mu\nu}.$$

(Here $\theta_{\mu\nu}$, $G_{\mu\nu}$, and $F_{\mu\nu}$ are the intensities of the theton, gluon, and photon fields, respectively.) The l_θ also contribute to the last two interactions; their contribution is proportional to $m_{l_\theta}^{-4}$. It follows from these expressions that the lifetime of thetonium with respect to the decay into photons is practically infinite ($\Gamma \sim \alpha^4 \Lambda_\theta^9 m_{l_\theta}^{-8}$). From the same expressions it follows that so far we are dealing with much smaller energies than the thresholds $2m_{q\theta}$ or $2m_{l\theta}$, and the interaction of the ordinary substance with the thetons is very weak. Thus, the existence of thetonium could have remained unnoticed.

The production of the $l_\theta^+ l_\theta^-$ pair by e^+e^- colliding beams at $\sqrt{s} > 2m_{l\theta}$ should contribute greatly to the total cross section ($\Delta R \to N$). The newly produced l_θ^+ and l_θ^- particles should emit thetons intensively. As they fly apart, they stretch between them a theton string $1/\Lambda_\theta$ in diameter with a specific linear density Λ_θ^2 cm^{-1}, which is produced as a result of spending the remaining part of the kinetic energy of the particles xE_{kin}. As a result, the particles slow down at the distance $L \approx xE_{\text{kin}}/\Lambda_\theta^2$.

The properties of the thetoparticles describes above could change dramatically if thetoneutrinos ν_θ with zero Lagrangian masses would exist. The meson-like states $\nu_\theta \tilde{\nu}_\theta$ would have masses generally of order Λ_θ, but the pseudoscalar ground state $\nu_\theta \tilde{\nu}_\theta$ (we call it π_θ) would have a mass equal to zero (these are goldstones corresponding to spontaneous breaking of chiral invariance). As a result, the thetonium with $J^P = 0^+(0^-)$ would decay into $2\pi_\theta(3\pi_\theta)$. In the experiment described above the θ leptons would produce θ neutral systems $l_\theta^+ \nu_\theta$ and $l_\theta^- \tilde{\nu}_\theta$ by picking up a $\nu_\theta \tilde{\nu}_\theta$ pair from the vacuum and in such neutralized form could fly apart to any distance.

The possible cosmological manifestations of θ interaction are of great interest. The relict thetons, whose burn-up we shall examine separately, may exist today in a nondissociated state only if they are smaller than the wavelength of the relict radiation ($1/\Lambda_\theta < 1$ cm). The data on the abundance of helium exclude the possibility of a large variety of thetons, so that in $SU(N)_\theta N \lesssim 4$ (see Ref. 6). The fact that in practice the permissible concentration of anomalous hydrogen is very small ($\leqslant 10^{-21}$ as compared to normal concentration, see Ref. 7) imposes serious constraints on the properties of l_θ and possibly excludes the existence of q_θ, since estimates of the concentration of the relict l_θ and q_θ give vaues approximately ten orders of magnitude greater than the experimental upper limit. At $\Lambda_\theta \leqslant 10$ eV the theton strings would not be able to pull out the atoms, which include l_θ or q_θ, from the solids that contain them and hence the different solids (including living organisms) would be interconnected by the θ strings. Such theton strings could be observed in the Eötvös-Dicke-Braginski type experiments.

A possible existence of thetons should be borne in mind when interpreting experiments in which a loss of energy or new penetrating particles are observed (in neutrino experiments using accelerators or in underground experiments with cosmic rays).

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