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# ON A NEW TYPE OF LONG-RANGE FORCES

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1.At the present time, the problems of the existence of the new (fifth) force [1], are widely discussed [2];there are some preliminary results of observations of new long–range forces in laboratory conditions too [3]. The general origin can exist for these problems and results.

Below we consider an interesting theoretical possibility to introduce quite a new, unknown until now, specifically quantum type of long-range forces acting between systems which consist of several elementary particles, each having no this property. It is just composite systems that generate these forces inasmuch as every particle that composes these systems has not this property. It is important to emphasize that the new type of interaction is generated only by objects with nonfixed spins only.

2.As it is known, a Lorentz 4-vector field $A_i$ has four polarizations and can describe states with spin $s = 0$ and $s = 1$. To fix spin, one should introduce some auxiliary conditions . Specifically, in electrodynamics it is the Lorentz condition tightly connected with the group of gauge transformations

$$A_i \Rightarrow \quad A_i' = A_i + \partial_i \varphi. \tag{1}$$

However, when spin is not fixed, we can act on a 4-vector with transformations of the form

$$A_i' = L_i^j A_j, \tag{2}$$

where the matrix $L^i_j$ is a second rank tensor field with Det $(L^i_j) \neq 0$. Under this condition the transformations (2) form a group. It is important to note that transformations (1) and (2) do not commute.

We should clarify the meaning of the new group of transformations that "mix" the states with spin one and zero. Now we need an additional constraint on this group

$$g_{kl} L_i^k L_j^l = g_{ij}, \tag{3}$$

that follows from the invariance of the scalar product $(A, A) = A_i A_j g^{ij}$ under the transformations (2), where $g^{ij}$ is the Minkowski metric tensor $g^{ij} = g_{ij} = \text{diag}(1, -1, -1, -1)$.

Let us investigate the well known Lagrangian

$$L = -\frac{1}{2}\partial_i A_j \partial^i A^j \tag{4}$$

its being invariant with respect to the transformations (2). To this end we shall redefine the operator of partial differentiation so that

$$D'_i A'_j = L^l_j (D_i A_l). \tag{5}$$

It follows from (5) that

$$D_i A_j = \partial_i A_j + H_{ijk} g^{kl} A_l, \tag{6}$$

where $H_{ijk}$ is a tensor field of the third rank antisymmetric in two indices ($H_{ijk} = -H_{ikj}$), with the law of transformation

$$H'_{ijk} = H_{ilm} L^l_j L^m_k + g_{lm} L^l_j \partial_i L^m_k. \tag{7}$$

The simplest way to proof this expression is to consider the infinitesimal transformation $L^i_j = \delta^i_j + U^i_j\, dt$, where in accordance with (3) $U^{ij} = -U^{ji}$, and to insert (6) and (7)into (5). It is not difficult to verify that

$$[D_i, D_j] A_k = G_{ijkl} g^{lm} A_m, \tag{8}$$

where

$$G_{ijkl} = \partial_i H_{jkl} - \partial_j H_{ikl} + H_{ikm} H_{jnl} g^{mn} - H_{jkm} H_{inl} g^{mn}. \tag{9}$$

is the strength tensor of the gauge field $H_{ijk}$. From (6), (8), (9) it follows that the Lagrangian invariant with respect to the transformations (2) has the form

$$L = -\frac{1}{2} D_i A_j D^i A^j - \frac{1}{4} G_{ijkl} G^{ijkl}. \tag{10}$$

By making use of the variational principle with the Lagrangian (10) it is not difficult to derive invariant equations of motion. It is clear that all expressions including the operator $D_i$ are covariant under the transformations (2), but this is not true for transformations (1).



As it is seen, the vector field $A_i$ in one case plays the role of a gauge field carrying interactions between charged particles but in other cases it generates a new long-range field, which would be called the torsion field. The most important conclusion that follows from the above consideration is that particles with a fixed spin cannot generate a torsion field. The name "torsion field" is used for the following reason. As it is known, in General Relativity with Riemann geometry as a geometrical framework, a metric tensor is connected with gravitational forces. In a more general Riemann–Cartan geometry [4] there is an additional tensor quantity called the torsion. Since this tensor is of the same type as the tensor of spin angular momentum [5], the suggestion has been put forward that particle spins play the role of torsion field sources.

Indeed, in a set of parameters characterizing properties of elementary particles, only the mass and spin are fundamental and can be interpreted as " charges " which are connected with the geometrical properties of space–time . However, there is a principal difference between these two notions. A stress -tensor of matter is intimately connected with a diffeomorfisms group [6] which is a group of space–time symmetry General Relativity and determines the form of gravitational interactions [7], but for the tensor of spin angular momentum the analogous group of symmetry cannot be shown. Hence one can doubt a possibility to construct a theory of "torsion forces "on a simply formal level. The example considered above of the vector field, shows that physical systems with fixed spin cannot generate the torsion field. In other words, the spin in contrast to the energy–momentum is not the " charge " that generates some field. It is not accidentally that our experience does not indicate any traces of " torsion forces", when we deal with systems whose spin is fixed.

**3.** To develop a consistent theory of long–range "torsion forces" we should have systems with indefinite spin . It might be expected that such systems will be really connected by forces absent for elementary particles.

Let us consider the simplest and probably most realistic system of that kind. Two charged particles with spin $\hbar/2$ in the general case compose an object the total spin of which runs over two values, $s = 0$

and $s = 1$. The object, as a whole, can be described by a complex vector field $\psi_i$, and, as whole again, generates the "torsion field" $H_{ijk}$. The total Lagrangian

$$L = -D_i\overset{*}{\psi}_j\, D^i\psi^j - \frac{m^2c^2}{\hbar^2}\,\overset{*}{\psi}_i\,\psi^i - \frac{1}{8}G_{ijkl}G^{ijkl}. \tag{11}$$

is invariant not only under Lorentz transformations $\bar{x}^i = a^i_j x^j$ but also under transformations (2). The corresponding equation of motion can be written in the form

$$\partial_i\partial^i\psi_j + \psi^k\partial^i H_{ijk} + 2H_{ijk}\partial^i\psi^k - H_{ikj}H^{ikl}{}_{.}\psi_l = 0, \tag{12}$$

$$\partial_i G^{ijkl} - H_{i\,.\,m}^{\,k} G^{ijlm} + H_{i\,.\,m}^{\,l} G_{ijkm} = S^{jkl}, \tag{13}$$

where

$$S^{jkl} = \overset{*}{\psi}{}^k(\partial^j\psi^l + H^{jlm}\psi_m) - \overset{*}{\psi}{}^l(\partial^j\psi^k + H^{jkm}\psi_m) + c.c. \tag{14}$$

is the tensor of spin angular momentum of the considered system.

Using the well known rules one can get from (11) the gauge invariant expressions for the energy-momentum tensor and current 4-vector

$$T_{ij} = D_i\,\overset{*}{\psi}_k\; D_j\psi^k + c.c. + G_{iklm}G_{j\dots}^{\;klm} + g_{ij}L, \tag{15}$$

$$j_i = i(\overset{*}{\psi}{}^j D_i\psi_j - \psi^j D_i\,\overset{*}{\psi}_j), \tag{16}$$

where $L$ is the Lagrangian (11).

Thus, we have shown that a system of two particles with spin $\hbar/2$ can generate a new type of forces which disappear upon decay of the system.

It is necessary to substantiate now why we have not introduced the special constant of interaction $\epsilon$ into the (6) and second term of action (11) as one does usually. Consider the infinitesimal transformations of the diffeomorphisms group $\bar{x}^i = x^i + K^i(x)dt$, mentioned above. If under these transformations the gravitational potentials $g_{ij}$ do not vary, i. e. the vector field $K^i(x)$ satisfies the Killing equations [8]

$$K^i\partial_i\, g_{jl} + g_{il}\,\partial_j K^i + g_{ji}\,\partial_l K^i = K_{j;l} + K_{l;j} = 0,$$



then the vector field $V^i = T^{ij}K_j$ will satisfy the equation $\partial_i(\sqrt{-g}V^i) = 0$. Integrating this equation we obtain the conservation law. However, the Killing equations imposes severe constraints on the gravitational potentials. Thus, we see that in general case the Killing equations have no solutions at all and there are no conservation laws. This result allows us to understand why there is no constant of interaction of matter fields with the gravitational one similar to the electric charge e and why the Newton gravitational constant $G$ does not enter into the equations of matter fields: it is impossible to "switch on" or "switch off" the gravitational field. The latter does not admit the existence of the gravitational screen.

Now consider infinitesimal gauge transformations $L^i_j = \delta^i_j + U^i_j dt$. If the field $H_{ijk}$ does not vary under these transformations, then the tensor field $U^i_j$ satisfies the equations

$$\partial_i U_{jk} + H_{ijl}U^l_{.k} - H_{ikl}U^l_{.j} = 0. \tag{17}$$

From (12),(13),(17) it follows that the vector field $Q^i = S^{ijk}U_{jk}$ ($S_{ijk}$ is the tensor of spin angular momentum (14)) has to satisfy the equation $\partial_i Q^i = 0$. Integrating this equation we get the conservation law, as usual. Equation (17) imposes severe constraints on the field $H_{ijk}$. For example, equation (17) is quite integrable, if the strength tensor $G_{ijkl}$ satisfies the equation $G_{ijkl} = 0$. So, in the considered case, generally speaking, there is no conservation law. Therefore it is natural to conclude that there is no special coupling constant (like the electric charge) of the fields $\psi_i$ and $H_{ijk}$ and the action for the gauge field $H_{ijk}$ has the form

$$S = -\frac{f\hbar}{8}\int G_{ijkl}\,G^{ijkl}\,d^4x$$

analogous to the case of the gravitational action

$$S = -\frac{c^3}{G}\int R\sqrt{-g}d^4x.$$

Here $f$ is a dimensionless constant.

**4.** In conclusion we present some remarks about the physical meaning of the field $H_{ijk}$. It can induce relativistic effects in solids. For example, the theory of superconductivity considers a Cooper pair as a single particle with the mass $m \simeq 2m_0$ and charge $q = 2e$, where $m_0$ and $e$ are the electron mass and charge. Here it is assumed that spin of such particles equals zero. However, the pairing in a triplet state is also possible [9]. So, if we consider the electron pair as a system with nonfixed spin, then one can expect new quantum relativistic effects. They can appear not only in superconducters but also in ferromagnetics and chemical phenomena. We cannot reject this possibility beforehand.

At the same time, if the gauge field $H_{ijk}$ does not exist, we have to look for an exclusion principle.

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