INTERACTIONS OF ELEMENTARY PARTICLES SIMILAR TO GRAVITATIONAL ONE

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It is shown that in the non-relativistic limit the Newtonian gravity law can be derived at the equality of the coupling constants for the electron, proton, neutron interactions with the spin-2 massless particle (quasigraviton). The interactions of the photons and the gluons with quasigraviton in one-loop approximation are studied at the contributions of quarks, leptons, W, and the scalar fields. From the absence of the quadratic divergences it is derived that the sums of the coupling constants of the quasigravitational interactions of all the quarks and all the leptons vanish. Therefore the black holes do not appear.

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INTRODUCTION

As is known the electric charges of the hadrons do not renormalized by the strong interactions. In particular, if the charges of the bare electron and proton are equal then their charges induced by the electromagnetic and the strong interactions are equal also [1 – 4]. However, as the proton and the electron have different masses their gravitational interactions may be different. Therefore we can assume that the gravitotional corrections to the electric charges of the proton and the electron may be different (i. e. the values of these charges may have a small difference. In connection with this it is important to study the problem of the anomaly similar to the axial Adler–Bell–Jackiw anomaly in the electroweak theory. Well-known theory of the gravitation – the general theory of relativity faces with the problems for the elementary particles. For example, how do the vacuum mean and the Dirac sea affect on the gravitation? Progress in the problem of the gravitational interactions of the elementary particles has been achieved in the supergravity models, but this problem is not solved yet. Therefore it takes interest in the investigations in simple models too.

In this paper the interactions of the massive spin–0, ½, 1 particles induced by the spin–2 massless particle exchange are considered in Minkowski space–time. We study the quantities similar to the axial ABJ–anomaly in the electroweak theory.

1. INTERACTIONS OF TENSOR FIELDS

The equation for the massless spin–2 field $G(x)_{\mu\nu}$ we write as

$$G(x)_{\mu\nu} = j(x)_{\mu\nu}\,,$$
$$\partial_\mu G(x)_{\mu\nu} = \partial_\nu G(x)_{\mu\nu} = 0,\; G(x)_{\mu\mu} = 0\,, \qquad (1)$$
$$\partial_\mu j(x)_{\mu\nu} = \partial_\nu j(x)_{\mu\nu} = 0,\; j(x)_{\mu\mu} = 0\,,$$

where $j(x)_{\mu\nu}$ is the tensor of the interaction current. This tensor can be derived from some current tensor $\eta(x)_{\mu\nu}$ as follows

$$j(x)_{\mu\nu} = \Pi(x)_{\mu\nu,\mu_1\nu_1}\,\eta(x)_{\mu_1\nu_1} \qquad (2)$$

where $\Pi(x)_{\mu\nu,\mu_1\nu_1}$ is the projection operator. The Fourier components of this operator are given by

$$\Pi(q)_{\mu_1\nu_1,\mu_2\nu_2} = \frac{1}{2}\left(d_{\mu_1\mu_2}d_{\nu_1\nu_2} + d_{\mu_1\nu_2}d_{\mu_2\nu_1}\right) - \frac{1}{3}d_{\mu_1\nu_1}d_{\mu_2\nu_2}\,, \qquad d_{\mu\nu} = -g_{\mu\nu} + q_\mu q_\nu / q^2\,, \qquad (3)$$

where q is the 4–momentum of the tensor particle.

The interaction Lagrangian may be written in several general forms

$$\mathcal{L}_{int} = G(x)_{\mu\nu}\, j(x)_{\mu\nu} = G(x)_{\mu\nu}\,\eta(x)_{\mu\nu}\,. \qquad (4)$$

In particular, we choose the next interactions Lagrangians:

a) for the scalar particles

$$\mathcal{L}_s = g_s G_{\mu\nu}\,\partial_\mu \varphi^+ \partial_\nu \varphi\,, \qquad (5)$$

b) for the spin – $\frac{1}{2}$ particles

$$\mathcal{L}_F = i g_F G_{\mu\nu}\left(\bar{\psi}\gamma_\mu \partial_\nu \psi - \partial_\nu \bar{\psi}\gamma_\mu \psi\right), \qquad (6)$$

c) for the vector particles

$$\mathcal{L}_v = -g_v G_{\mu\nu}\left(\partial_\mu A_\lambda - \partial_\lambda A_\mu\right)\left(\partial_\nu A_\lambda^+ - \partial_\lambda A_\nu^+\right), \qquad (7)$$

d) for the $S \leftrightarrow V$ – transitions

$$\mathcal{L}_{vs} = g_{vs}\left(\partial_\lambda G_{\mu\nu}\right)\Big[\left(\partial_\lambda A_\mu - \partial_\mu A_\lambda\right)\partial_\nu \varphi^+ + \left(\partial_\lambda A_\mu^+ - \partial_\mu A_\lambda^+\right)\partial_\nu \varphi\Big]\,. \qquad (8)$$

As the Lagrangian (5)–(8) must be hermitian the constants g_s, g_F, g_v, g_{vs} must be real. The interactions (5)–(8) are C–even.

2. NON–RELATIVISTIC LIMIT

Consider the elastic scattering of the particles in the one spin–2 massless particle exchange approximation (Fig. 1).

In the cms the spin–2 particle momentum is $q = p_2 - p_1 = (0,0,0,2p\sin\frac{\theta}{2})$, where p is the value of the 3–momentum of the first particle, θ is the scattering angle. At low energies we derive from (3) that the leading components of the currents are next only

$$j(q)_{00} = 2j(q)_{11} = 2j(q)_{22} = \frac{2}{3}\eta(q)_{00} \qquad (9)$$

For the spin– $1/2$ - particles

$$\eta(q)_{00} = \frac{g_F}{2E}\bar{u}(p_2)\gamma_0 u(p_1)\cdot 2E \approx 2mg_F\chi_2^*\chi_1, \qquad (10)$$

where p_1 and p_2 are the 4–momenta of the particles in the initial and the final states, respectively; E is their energy ($p_1^2 = p_2^2 = m^2$). The matrix element corresponding to the Fig. 1 is given by

$$T_{fi} = j(q)^{(1)}_{\mu\nu}\, j(q)^{(2)}_{\mu\nu}\,\frac{1}{q^2+i\varepsilon} = -\frac{2}{3}\eta(q)^{(1)}_{00}\otimes$$

$$\otimes\,\eta(q)^{(2)}_{00}\frac{1}{\vec{q}^{\,2}-i\varepsilon} = \eta(q)^{(1)}_{00}V^{(2)}(q) = \eta(q)^{(2)}_{00}V^{(1)}(q),$$

$$V^{(1)}(q) = U^{(1)}(q)\chi_2^*\chi_1, \qquad (11)$$

where $V^{(1)}(q)$ is the Fourier component of the gravity potential induced by the first particle. In the coordinate space we derive the gravity potential and the interaction force of two particles

$$U^{(1)}(x) = -\frac{1}{3\pi}g_F\frac{m_1}{r},\ \vec{F} = -2m_2 g_F\, gradU^{(1)}(x) =$$
$$= -\frac{2}{3}g^2{}_F\frac{m_1 m_2}{r^3}\vec{r}, \qquad (12)$$

where $\boldsymbol{r}$ is the distance vector between two particles. This consideration is similar to the derivation of the Coulomb law in the electrodynamics [3]. But in contrast with the electrodynamics the one spin–2 massless particle exchange leads to the attractions.

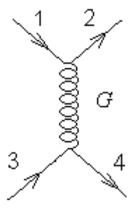

Fig. 1

Now we take into account that the Earth, Moon, Sun and the planets consist of the spin– $\frac{1}{2}$ particles: protons, neutrons, electrons. If we propose that the couplings constants are equal

$$g_{proton} = g_{neutron} = g_{electron} = g_{l^- neutrino} = g_{F_1} \qquad (13)$$

and take into account the linearity of the eq.(1), then we may obtain Newton gravity law. For this we must put

$$g^2_{F_1} = 3\pi G_N/2, \qquad (14)$$

where $G_N = 6{,}707\cdot 10^{-39}\hbar c(GeV/c^2)^{-2}$ is the gravitational constant. If for the coupling constants g_s and g_v in (5), (7) we put

$$g_s = g_v = 4g_{F_1} = 4g_{proton} \qquad (15)$$

then as consequence of the relations (13)–(15) the attractive force will be valid for the interactions of the scalar and vector particles between them and with the protons, neutrons, electrons.

As the one spin–2 massless particle exchange leads to the attractive long–rang force we will call these interactions as quasigravitational and the spin–2 massless particle as the quasigraviton.

The quasigravitational interactions have the next interesting properties. (a) The sources of these interactions are just the elementary particles, but not the masses or the energies of the particles. (b) The intensity of these interactions is determined by the particle coupling constant, which may, be positive, negative and be equal to zero. (c) These interactions are covariant and the consideration is carried out in the flat Minkowski space–time. (d) We may regard that the inertial and gravitational masses are equal. Indeed, for the quasigravitational interactions the origins of the masses in the interaction forces (12) (these masses are just gravitational) are the particles energies, which are related to the masses in the Lagrangian (i.e. inertial masses)

In consequence of the properties (a) –(c) the quasigravitational interactions stay similar to the electromagnetic interactions.

Note that the long–range attractive property of force induced by the spin–2 massless particle exchange was established by Bronstein in 1936.

3. QUANTITIES SIMILAR TO ABJ–ANOMALY

We consider the interactions of the photons and the gluons with the quasigraviton in the one–loop approximation.

In the Weinberg–Salam model there are $\gamma QQ-, \gamma LL-, \gamma WW-, \gamma W\varphi -, \gamma\varphi\varphi, \gamma\gamma WW,-, \gamma\gamma\varphi\varphi$ – verteces of the photon interactions. In Fig. 2 Feynman diagrams are presented for the $\gamma\gamma G$ –interaction, where G is the quasigraviton.

For each diagram with the virtual $W^\pm$ must be diagram with the contribution of the scalar $\varphi^\pm$ field. So besides diagrams B_1 and B_2 there are six diagrams with one φ and two W, six diagrams with two φ and one W, as well as two diagrams with three φ.

The amplitudes corresponding to the diagrams A_1, A_2, B_1, B_2 and others include the quadratically divergent integrals. For the interactions of $\gamma, W, +\varphi$ we use the Feynman rules of refs. [4]. The quadratically divergent part of the amplitudes for the diagrams in Fig. 2 is given by

$$T(\gamma G \to \gamma)_{quadr} = -\frac{2}{3}e^2\varepsilon_\mu(k_1)\varepsilon_\nu^*(k_2)G_{\mu\nu}(q)\cdot \quad (16)$$

$$\left\{4N_c\left[\left(\frac{2}{3}\right)^2+\left(-\frac{1}{3}\right)^2\right]\sum_i g_{Q_i}+\frac{4}{3}\sum_i g_{L_i}+ + 5g_W + g_\varphi\right\}\int\frac{d^4p}{(2\pi)^4p^2}$$

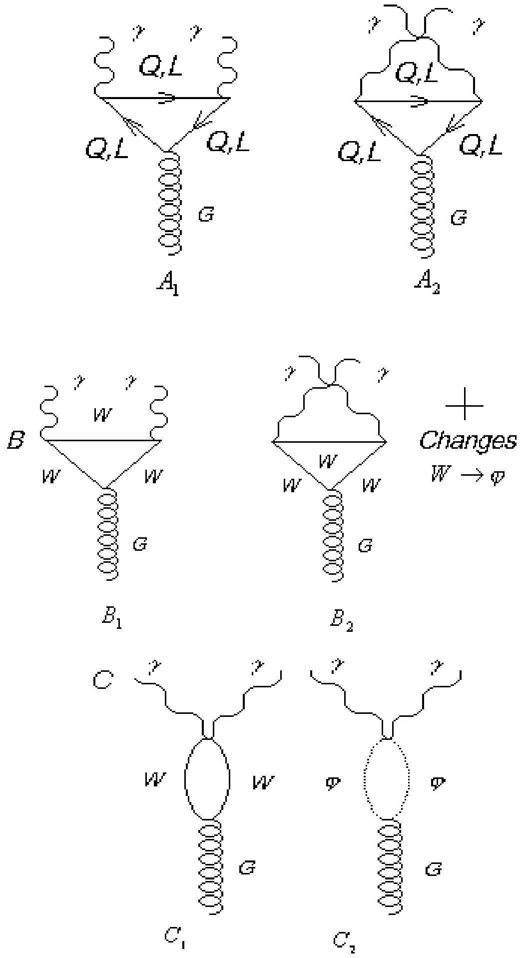

Fig. 2. Feynman diagrams for photon–quasigraviton interaction

where $\varepsilon_\mu(k_1),\varepsilon_\nu^*(k_2)$ are the polarization vectors of the initial and the final photons, respectively, $G_{\mu\nu}(q)$ is the tensor for the quasigraviton, $q = k_2 - k_1$, *e* is the value of the electric charge of the electron and the proton; N_c is the number of the quark colours, In (16) g_{Q_i} and g_{L_i} are coupling constants of the quasigralitational interactions of the quarks and the leptons for i–th generation, respectively. In the additive quark model may be derived

$$g_{Q_1} = g_{proton}. \quad (17)$$

If for each generation to assume

$$g_{Q_i} = g_{L_i}, \quad (18)$$

then between the particles and antiparticles of the i–th generation will be the long–range attractive force of the form (12), (14). The coupling constants g_φ, g_{Q_i} and g_{L_i}, g_W are determined by the Lagrangians (5)–(7) ($g_F = g_{Q_i} = g_{L_i}$; $g_V = g_W$).

Now we study the interaction of the gluon with the quasigraviton. As in QCD the gluons interact with the quarks, gluons g and the Faddev–Popov ghosts the one–loop approximation is determined by the diagrams in Fig. 3.

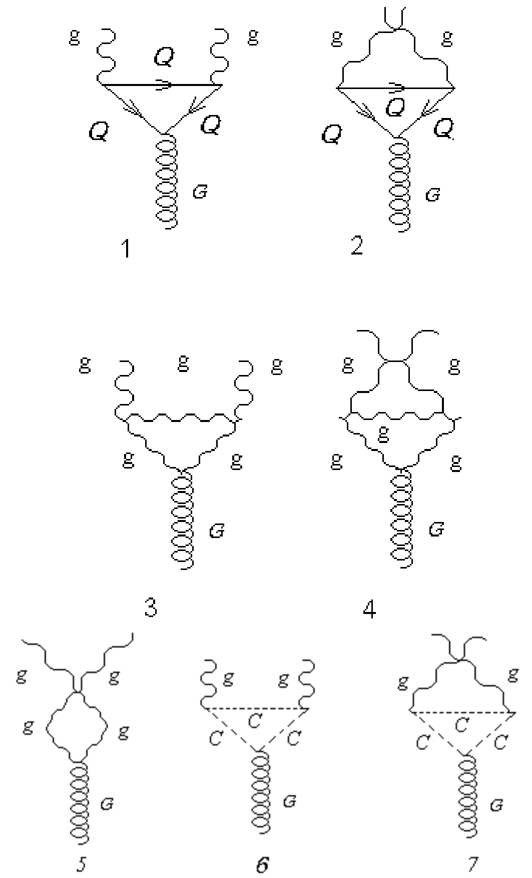

Fig. 3. Feynman diagrams for gluon–quasigraviton interactions $gG\to g$

For the quadratically divergent part of the $gG\to g$ –interaction amplitude we derive

$$T(gG\to g)_{quadr} = -\varepsilon_\mu^a(k_1)\varepsilon_\nu^{*b}(k_2)G_{\mu\nu}(q)g^2_{QCD}$$

$$\otimes\,\delta^{ab}\left[\frac{4}{3}\sum_i g_{Q_i}+5g_{gluon}+\frac{1}{4}g_{F_p}\right]\otimes \quad (19)$$

$$\otimes\int\frac{d^4p}{(2\pi)^4p^2},$$

where $\varepsilon_\mu^a(k_1)$ and $\varepsilon_\nu^{*b}(k_2)$ are the polarization vectors of the initial and the final gluons, respectively, *a* and b are the colour indexes; g_{QCD} is the QCD coupling constant. The interaction coupling constants of the Faddeev–Popov ghosts g_{Fp} and the gluon g_{gluon} with the quasigraviton are determined by the Lagrangians (5)–(7) at $g_\varphi = g_{Fp}$ and $g_v = g_{eluon}$, respectively.

To eliminate the quadratic divergences in the $\gamma G \to \gamma$ and $gG \to g$ –amplitudes we use (18) and put

$$\frac{32}{3}\sum_i g_{Q_i} + 5g_w + g_\varphi = 0, \quad (20.a)$$

$$\frac{2}{3}\sum_i g_{Q_i} + 5g_{gluon} + \frac{1}{4}g_{F_p} = 0. \quad (20.b)$$

By analogy with the photon–gluon and photon–ghost interactions we assume that the quasigravitons do not interact immediately with the gluons and the ghosts (i.e. $g_{gluon} = g_{Fp} = 0$). Then we derive the next relations from (18), (20):

$$\sum_i g_{Q_i} = \sum_i g_{L_i} = 0, \quad (21)$$

$$g_\varphi = -5g_W. \quad (22)$$

In consequence of the relation (21) for the particles and the antiparticles of the second (or the third) generations must repulse the particles (and antiparticles) of the first interaction.

4. RELATED TOPICS

4.1. Black holes. To satisfy (21) assume that the particles of the third generation repulse the particles of the first and the second generations. Consider big body (e.g. the star), which consist of the first generation particles. As consequence of the attractive gravitational force the body dimension can be reduced. According to the Pauli principle the particle energies will increase. At some moment of the time the transitions into the second-generation particles by means of the electroweak interactions became favourable. The second-generation particles will stable at enough quantity of the first generation particles. In further the body reduction the second-generation particles will transit into the third generation particles. The last particles will be pushed from the body. Such a way the body dimension cannot be reduced to very small dimension. The third generation particles will decay outside the body and the body mass will decrease *Therefore the black holes ought not to appear.*

4.2. Red shift. Compare the light emission from big bodies consisting of the particles of the first, second , and third generations (now (21) is not obligatory). In consequence of the small electron mass the light, the ultraviolet, and X-rays are radiated mainly by the electrons. At large the second and the third generation particle concentration the radiation of the electrons is suppresed as: (i) a lot of electrons transited into muons; (ii) The electrons do not radiate to obey the Pauli principle. Therefore with the growth of the second and the third generation particle concentrations the intensities of the light, the ultraviolet, and X-rays radiations will decrease. Besides, in consequence of the increasing of the gravitation field strength the light frequency will be reduced. *Therefore at the reduction of the light radiation intensity the shift to the red side will increase.* Note that such dependence is explained usually by the Hubble law. At very small the electron concentration the body can stay invisible. Possible such bodies can be observed in the investigations of high-energy the γ -quanta and the neutrinos.

4.3. Gravitational waves. The lengths λ of the predicted gravitational waves are rather large: from $3\cdot 10^3$ m to $3\cdot 10^{14}$ m. These waves ought to have the higher modes. We can expect that the ratio of the intensities of the high mode (with the l-wave length) to the ground mode equals $(l/\lambda)^{2n}$, where n is the order of the differential equation for the gravitational waves $(n \geq 2)$. Therefore the receiving antenna of the dimension l about one meter has an insufficient sensitivity to detect the gravitational waves, as such antenna can record effectively only high modes, which intensities decrease (to 10^{-12} for $\lambda = 10^3$ m). To observe Gravitational waves of $\lambda = 10^3 - 10^6$ m we propose to use Earth as the detector. For this the apparatus to record the oscillations or the dislocations must be placed in some points of Earth. This apparatus can be based on the refraction of the laser light. The gravitational waves can be observed by the time delay corresponding to the passage of the wave through different points with the light velocity.

4.4. Motion of Sun in Galaxy and Earth climate. Propose that Sun movs in the orbit at the period about 27 Mil. years and pass through the Galaxy spiral. At the passage through the Galaxy spiral Sun can loss some planets and join another planets. In the Galaxy spiral the planet orbits, the planet angular momenta, and the magnetic fields are changed. Therefore in the spiral the Earth climate, the direction of the axis of the rotation, and the angular velocity, the strength of the magnetic field, the places of North and South magnetic poles of Earth can be changed. In particular, possibly 65 Mil. years ago Earth transited to higher orbit and the Earth climate become more cold. The hypothesis on Sun motion in Galaxy may be considered as true if the times of the mass death of animals coincide with the times of the strong changes of the Earth magnetic field.

REFERENCES

1. A.I. Akhiezer, S.V Peletminskij. *Fields and main interactions.* Kiev: "Naukova Dumka", 1986, 552 p. (in Russian).
2. V. De Alfaro, S. Fubinis, G. Furlan, G. Rossettin. *Currents in hadron physics*. Amsterdam –London: "North–Holland Publishing Company", 1973, 724 p.
3. A.I. Akhiezer, V.B. Berestetskij. *Quantum electrodynamics*. M:"Nauka", 1981, 623 p. (in Russian.)
4. A.I Akhiezer, S.V Peletminskij. *Theory of main interactions.* Kiev: "Naukova Dumka", 1993, 570 p. (in Russian).