GALILEAN EXPERIMENT AT THE ELEMENTARY PARTICLE LEVEL

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As is well known Einsteinian theory of gravity is based on he so called equivalence principle according of which gravity is identified with accelerated frame and therefore both - acceleration and gravity - are described by means of metric given on the space-time continuum.

Here we demonstrate that at the elementary particle level (in the framework of the quantized field theory) there is no equivalence between gravity and acceleration. As a result we may formulate the following statement: two particles with different masses (for example electron and proton) move in one and the same given external gravitational field not identical, they move with different accelerations.

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INTRODUCTION

In articles about GR [1] Einstein had very often referred .on the two following circumstances: i) For any body its inertial mass m_i is equal to its gravitational one m_g, ii) In given gravitational field all bodies move identical. So that in particular at the motion in a homogeneous gravitational field all they will have one and the same acceleration (Galilean gedanken experiment). It permits (in Einstein opinion) to identify such a field with accelerated frame.

In connection with i) we have to indicate on the other obvious circumstance: mass of any body is made up from masses of elementary particles (nucleons and electrons) consisting it and their interactions. Hereby an elementary particle is characterized by only one mass m, which is calculated in the theory, see [2]. There is no another mass of particle (called m_g) and hence of body. Therefore in our opinion there is no indeed problem of identity $m_i = m_g$, lying in the ground of so-called equivalence principle. Moreover, in [3] it is shown by means of the simple calculations in the framework of quantized field theory [1] that at the elementary particle level there is a renormalization of gravitational vertex that means the renormalization of the Newtonian constant of gravitational interaction γ. As a result the latter begins to depend on mass of particle which moves in the field. Therefore for example electron and proton (or neutron) will move in one and the same external gravitational field by different way. Universality of motion mentioned by Einstein (universality of space and geometry) is not indeed. This means that it is impossible to reduce the gravity to the metric and curvature of space-time: at elementary particle level there is no equivalence principle. Therefore we consider that the metric approach to gravity is not adequate.

It is very important to understand that the reducing of gravity to the space geometry does not permit us to discover true nature of this kind of interaction. In our opinion it hides in properties of physical substance which causes the existence of space-time as well as fundamental particles with all their inner properties and interactions. For a long time it is called as ether however in the beginning of the 20-th century it was (by mistake of course) rejected from physics.

Here we first of all try to answer the question lying in the ground of equivalence principle: whether indeed different particles move in given gravitational field by identical way or not? As the answer turns out negative we will further formulate a new approach to the gravity based on the notion of deformation of ether field lying in the ground of elementary particle theory suggested in [2].

CALCULATIONS

In quantum theory gravitational interaction is described by the Lagrangian $h_{\mu\nu}(X)T_{\mu\nu}(X)$ where $h_{\mu\nu}(X)$ is an external gravitational field and $T_{\mu\nu}$ is the energy-momentum tensor built from particle field operator ψ. This process is shown in the Feynman diagram *a* (see Fig. 1).

Further we are interested in the case of zero transferred momentum *k=0* of external gravitational field only (i.e. $h_{\mu\nu}(k=0)$).

If a particle is charged (like electron or proton) it is necessary of course to take into account electromagnetic radiative corrections [3] described by Feynman diagrams *b, c, d,* where wavy lines represent virtual photon from own electromagnetic field of particle.

[1] Hereby it is very important to know at what level (classical or quantum) gravitational interaction is switching on. Physical meaning and mathematical tool of the theory depend on this.
As is well known first pure phenomenological theory of gravity was given by Newton without explanation of the physical reason of gravitational force. Einstein considered that the reason is in the metric of space-time. In connection with this we would like to recall that the idea about applying of Riemannian geometry for gravity description was prompted to Einstein by Grossmann. Soon after this Einstein deflected such an approach, but then returned to it again.

We consider nevertheless that the metric and gravity are quite different things: the first is connected with *co-tangent fibration* of space while the second is connected with so called *material one.* More over to apply a quantization procedure to the metric (and to identify this with space quantization) makes no sense: metric is not characterized by energy-momentum tensor [1] therefore from physical point of view quantum of metric is a bad defined notion.

(Graphs *b, c* look like the Schwinger's effect containing the anomalous magnetic moment and renormalization of electric charge, graph *d* is described the interaction of photon with gravitation field). In our case all these effects lied to the renormalization of gravitational vertex or to the renormalization of the Newtonian constant γ .

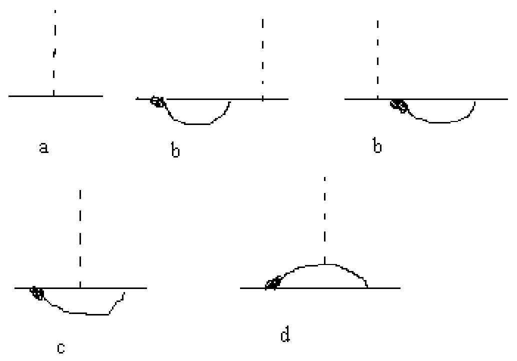

Fig. 1. *Feynman's graphs of the process. Continuous, broken, and wavy lines are the charged fermion, external gravitational field, and virtual photon, respectively; dark spot is the form-factor*

Proceeding from general reasoning we may write for renormalized Newtonian constant γ' the following expression

$$\gamma' = \gamma(1 - \frac{\alpha}{\pi} f(m^2)),$$

where γ is the «bare» constant and

$$\alpha = \frac{e^2}{4\pi}$$

is the Sommerfeld fine structure constant. Function *f* depends on mass of particle and its spin only. Namely γ' is experimentally observed quantity.

In the framework of the local interaction theory to calculate *f* is impossible because ultraviolet divergences are present in the theory [4]. But we use a new (if it may be said) improved quantized field theory of interaction, see [2], in which particle is non-point, smearing object describing by the bilocal field $\psi(X,Y)$ (here X_μ are usual space-time coordinates and Y_μ are inner coordinates describing the spatial structure of particle). Interaction of such a particle is described by usual Feynman diagrams in which at vertex there is a form-factor $\rho(p,k)$ shown in Fig. 1 by a dark spot. In the case of massive particle (for example, electron) interacting with zero mass particle (photon) $\rho(p,k)$ has the form

$$\rho(p,k) = \theta(I)\frac{\sin\sqrt{I}}{\sqrt{I}},$$

where

$$I = (pk)^2 - p^2k^2$$

and θ is the Heaviside function. As a result all Feynman's diagrams become convergent.

Contribution from diagrams *b, c* into function *f* is found in [3] and equal

$$\int_0^1 dz[2z(1-z)K_0(m^2z) + \frac{2}{3}m^2z^2(1+z)K_1(m^2z)],$$

where K_n are the Macdonald functions. Contribution from diagram *d* is

$$\int_0^1 dz(1-z)[K_0(m^2z) - \frac{1}{3}m^2z\ K_1(m^2z)].$$

In the sum we have for $f(m^2)$:

$$f(m^2) = \int_0^1 dz[(1-z)(1+2z)K_0(m^2z) +$$

$$+ \frac{1}{3}m^2z\ (2z^2 + 3z - 1)K_1(m^2z)].$$

In the case of small masses $m << 1$ (here mc/kh is a dimensionless mass; in the theory there are three fundamental constants *c, h, k,* [2]) we have

$$f(m^2) = \frac{1}{12}(17 + 10\ln 2 - 10C) - \frac{5}{6}\ln m^2$$

(C is the Euler constant). For example for electron its dimensionless mass is

$$\frac{m_e c}{kh} = 0{,}5.10^{-3}$$

($khc = 1GeV$), for proton we have

$$\frac{m_p c}{kh} = 0{,}938\ .$$

In another limit $m \to \infty$ we have

$$f(m^2) = \frac{\pi}{3m^2},$$

and we may consider the correction to be zero.

So we see that particles with different masses are characterized by different Newtonian constants γ' depending on mass of particle. Namely renormalized constant goes into all experimentally observed effects. Dependence of γ' on particle mass is shown in Fig. 2.

Obviously we have the following expression for difference $\Delta\gamma = \gamma'_p - \gamma'_e$ between γ 's for proton and electron

$$\Delta\gamma = \gamma\frac{5\alpha}{3\pi}\ln\frac{m_p}{m_e} = \varepsilon(p,e)\gamma\ ,$$

where

$$\varepsilon(p,e) = \frac{5\alpha}{3\pi}\ln\frac{m_p}{m_e} = 3.10^{-2}\ .$$

It follows from here: electron interacts with gravitational field weaker than proton (we did not take into account strong interaction of proton yet!). This circumstance is expressed in the character of electron motion in comparison with proton, namely, in time delay.

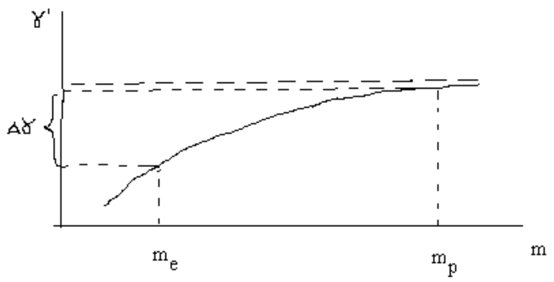

Fig. 2. *The γ constant vs the charged particle mass*

NUMERICAL RESULTS

With this aim we consider the simplest case of free falling of charged particle in homogeneous gravitational field of Earth. To estimate macroscopic time delay we can use the classical non-relativistic formulas in particular the formula for passed path

$$l = \frac{g' t^2}{2},$$

where

$$g' = M_E \gamma' / R_E^2$$

(M_E, R_E are mass and radius of Earth) [2]. For passing one and the same path l electron and proton demand different times t_e and t_p correspondingly. Hereby the difference

$$\Delta t = t_e - t_p = \frac{\Delta g t_p}{2 g_p} = \varepsilon(p,e)\sqrt{\frac{l_p}{2 g_p}}.$$

At free falling electron will come off from proton in the distance

$$\Delta l = l_p - l_e = \frac{\Delta g t_p^2}{2} = \varepsilon\, l_p .$$

These differences might be compensated by the initial velocity of electron according to the formula

$$\frac{g_p' t_p^2}{2} = \frac{g_e' t_p^2}{2} + v_e t_p .$$

Hereat v_e is equal

$$v_e = \frac{\varepsilon}{2}\sqrt{\frac{g_p l_p}{2}}.$$

[2] It is well known that at $l >> \left(\frac{h^2}{m^2 g}\right)^{1/3}$ (for electron the latter magnitude is 0,1 cm) the motion may be considered to be quasiclassical one, see [5].

If $l_p = 10^2\ cm$, $g_p = 10^3\ cm/s^2$, so

$$t_p = 0{,}44 s .$$

In this case differences in time and distance are correspondingly

$$\Delta t = 6.10^{-3} s$$

and

$$\Delta l = 3\ cm .$$

Hereby initial velocity of electron must be

$$v_e = 3{,}3 cm/s .$$

CONCLUSION

So, we may conclude: at quantum (micro) level equivalence principle is invalid. Therefore it is very interesting to carry out the Galilean experiment at the elementary particle level with electrons and protons.

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