Testing Relativistic Mass-Energy Concept in Physics of Gravity and Electricity

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ABSTRACT

The problem of self-energy divergence of a point particle in the $1/r$ potential field was investigated, and the conclusion was made that the divergence is directly related to the mass concept in current field theories, in which the proper mass is assumed to be constant. In the alternative Relativistic Mechanics developed with the proper mass being field dependent the divergence is naturally eliminated due to "exhaustion" of the proper mass at $r \rightarrow 0$: this is true for both the gravitational and the Coulomb potential. Moreover, both fields are described within the same relativistic mass-energy concept. This result is important for future development of a divergence-free unified quantum field theory. To verify the alternative approach we propose realistic experimental tests with particles in gravitational and electric fields.

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1 Introduction

Modern physics is literally termed "Physics Frontiers" meaning hot areas with unresolved problems of fundamental importance. Those areas typically include physics of gravity and particle physics, totally disconnected but wanted to be unified on the same quantum footing: bridging the two theories is a challenging problem. At the same time, each of them has its own internal difficulties which could be the reason for why the bridging is impossible without recognizing and eliminating the root of a general problem. Among known difficulties is non-renormalizability of General Relativity Theory GRT) and the problem described in "the quest for mathematical understanding" of Quantum Chromodynamics (QCD), or quantum Yang-Mills theories, by Arthur Jaffe and Edward Witten; here we used a quotation from the official description of the "Yang-Mills and Mass Gap" problem in the Millennium problem list of Clay Mathematics Institute (see www.claymath.org/millennium/$YangMillsTheory$). The question is whether quantum field properties in QCD can be formulated in rigor mathematical terms (even dealing with unsolvable equations, as in GRT and QCD). Specifically, the QCD mass gap (a minimal positive level of vacuum excitation) was pointed out, understanding of which is also important for Quantum Electrodynamics.

In general, there is a common feature in field theories: the presence of divergences of certain calculated observables, such as a mass, a charge and a field strength. To remove infinite numbers, some "renormalization" procedures are used, which are a matter of mathematical art rather than physics. QCD fields are divergent; so, the proof of QCD renormalizability was considered a great success. A typical renormalization idea is to absorb infinite self-energy into a definition of mass and charge. Roughly speaking, a finite "observable" mass is constructed from a "bare" mass and a divergent " field" mass, the latter to be "cut-off". Surprisingly, this made Quantum Electrodynamics (QED) very successful in describing experiments. However, from a theoretical point of view, computed in this way predictions cannot be considered as results of a fundamental theory rested on first physical principles. The divergence problem exists also in GRT because the gravitational potential has the same point singularity $1/r$ as the Coulomb one. Thus, one can use the term "gravitational singularity" to mean the gravitational self-energy divergence analogous to that for a charged point particle; in practice, this is the GRT metric, which contains singularities. From this overview, one should conclude that a field theory truncated by an artificial renormalization procedure becomes phenomenology with the quest for physical and mathematical rigor (QCD and QED is the case). Over past years, a common belief came that divergence is a normal attribute of field concepts; "a theory of renormalization" became a part of a physical theory. We propagate a different view: infinities came with a wrong physical concept, specifically, with the assumption of constant proper mass. This statement has to be verified by experiments. The alternative concept, if confirmed, would change the status of modern problems such as classical $1/r$ singularities and divergencies of next level (Yang-Mills) theories; the formulation of mass-gap problem would be reconsidered as well.

In the present work, the divergence problem for the classical $1/r$ gravitational and Coulomb potential was studied; theoretical results are presented in the first part of the paper. In brief, we developed Alternative Relativistic Mechanics (further, it is called alternative SRT-based Mechanics, or the alternative theory), in which the proper mass is considered a field dependent quantity. New singularity-free relativistic equations of motion of a point particle or point charge in $1/r$ gravitational or Coulomb field, correspondingly, were obtained. More details are given in our previous paper [1]. The starting point was the concept of mass and its role in the relativistic generalization of Relativistic Mechanics with the inclusion of electric and gravitational forces. At some historical stage of Relativistic Mechanics development, there were numerous attempts to incorporate the Newton's formulation of gravitational law into Special Relativity Theory (SRT), see [2] with references. The Newtonian field propagates with an infinite velocity, and one might expect that this would be automatically corrected in the covariant formulation of the gravitational law. The attempts failed, first of all, because in variants of SRT-based gravitational theories the stress-energy tensor of the electromagnetic field has a vanishing trace. It means the absence of coupling of the photon to the gravitational field whereas the coupling was thought a necessary condition for explaining the observed bending of light grazing the Sun. We revisited this problem to seek for a rigor relativistic Lagrangean formulation of the problem of point particle motion in a gravitational field. It was found that the commonly used assumption of the proper mass constancy is not physically validated. In the alternative theory, a photon acquires new gravitational properties: the field acts on the photon as an optically active medium. In other words, this is a gravitational refraction rather then force attraction that causes the bending of light. Thus, the known issue of SRT incompatibility with the gravity phenomenon took a new turn: the inclusion of gravitational forces into SRT domain was justified. The result of fundamental importance is the elimination of the gravitational $1/r$ singularity by the mechanism of proper mass "exhaustion" in a strong field that is, at $r \to 0$. Another important result concerns the Coulomb field. The conclusion was made that gravitational and Coulomb potentials have the same source: the proper mass. Consequently, a natural elimination of the $1/r$ singularity in both cases occurs due to the same physical process: the proper mass variation in a field.

As always, an introduction of a new physical concept requires experimental testing; the second part of this paper is devoted to proposed experimental tests. Our analysis showed that the alternative SRT-based Mechanics is consistent with "weak-field" gravitational experimental data available. New predictions are made in a broad energy range, and the corresponding tests are proposed to verify the alternative versus conventional theory. The first experiment is intended to verify refracting properties of a gravitational field. According to the alternative theory, a light signal (or a photon) slows down when approaching a gravitational center. As for a massive particle, it accelerates and may become superluminal if has a sufficient initial energy. In other words, its speed could be greater than the speed of light in a gravitational field but cannot exceed the ultimate speed of light c_0 at infinity. The GRT picture of a photon motion is similar to that in the alternative theory, but the particle behaves differently: at some oint, it starts slowing down as the photon does and never becomes superluminal. Strangely enough, a gravitational force acting on an incident particle of a speed $c_0/\sqrt{3}$ is pure repulsive regardless of field strength [3]. Such a picture is in contradiction with the energy conservation law in Newtonian physics and in the alternative theory. The difference in predictions can be experimentally checked; one may look for a specific Cherenkov radiation emitted by a superluminal particle, as predicted by the alternative theory. A particle (a proton or an electron) would be superluminal in the gravitational field of Earth if its incident energy could exceed the threshold $\gamma_0 = E_{tot}/m \sim 10^4$. Such particles are present in the ultra-high energy tail of cosmic rays. Satellite technique is needed to conduct such an observational test. The second test is intended to check discrepancies in a predicted rate of atomic clocks in GPS (Global Positioning System) [4, 5]. The GPS operational parameters can be reinterpreted in the alternative theory framework and compared with theoretical predictions. Finally, in the third proposed experiment, energies of an electron in the attractive Coulomb field should be measured. Such a test can be conducted in electrostatic laboratories (van de Graaf accelerator facilities). According to our prediction, a graph of electron energy as a function of a sphere potential reveals a saturation at voltages exceeding the electron proper energy of 511 keV while the conventional electromagnetic theory [6] predicts a linear function.

We believe that the results of our study are important for the resolution of divergence problems in field theories and for the future development of a singularity-free unified theory.

2 Relativistic Equation of Motion of Point Particle

2.1 Gravitational $1/r$ *potential field*

The following alternative Relativistic Mechanics equations of a point particle motion were obtained [1]

$$\frac{d}{dt}(\gamma m v^i) = F^i, \quad c_0^2 \frac{d}{dt}(\gamma m) = F^i v_i + \frac{c_0^2}{\gamma}\frac{dm}{dt} \tag{1}$$

where $m = m(r)$ is a variable proper mass of a test particle, v^i is a 3-velocity in a 3-orthogonal coordinate system, and F^i is a usual 3-force vector. The energy conservation law for a spherical symmetric attractive potential field is expressed in the form $\gamma m c_0^2 = m_0 c_0^2$, and the corresponding energy balance is described by

$$p^2 + m^2 c_0^2 = m_0^2 c_0^2, \quad \gamma m c_0^2 = \gamma_r m c_0^2 = m_0 c_0^2 \tag{2}$$

where the 3-momentum is $p = c_0 m \gamma \beta$, $\gamma_r = m_0/m(r) = (1-\beta(r)^2)^{-1/2}$, c_0 is the speed of light at infinity, $\beta = \beta(r)$, and $c_0 m_0^2$ is the total energy. Given (2) satisfied, both equations in (1) become equivalent.

Let us consider a static spherical symmetric gravitational field due to a point or spherical source of mass M. To use the equation (1) we need the expression of gravitational force with the variable proper mass; it can be found from the expression for an elementary work of gravitational force acting on the test particle of mass $m(r)$ at a distance r from the center

$$F_g(r)dr = -GMm(r)/r^2 = c_0^2 m(r) d(r_g/r) \tag{3}$$

Here we introduced "the gravitational radius" $r_g = GM/c_0^2$. In (3), as in [1], we assumed that the mass M was not affected by the internal field. In other words, a binding energy of the sphere (a mass defect) ΔM was ignored, which is $M - M_0 = M - \sum_i m_{0i}$, where m_{i0} are proper masses "at infinity" of particles comprising the sphere. In our approach this difference is a potential energy of the sphere (in mass units). Hence, it would be logical to express the force in terms of the gravitational radius with the sphere mass corrected for the mass defect that is, $r_{g0} = GM_0/c_0^2$. A reasonable assumption would be $M_0/M = m_0/m$, which is valid at $r = R$; this prevents a jump discontinuity of fields in exterior and interior regions. In fact, the quantity r_g is a model parameter of our one-parameter relativistic field representation, and it could be different in different models of boundary conditions when the static relativistic solution deviates from the classical Newton's law. Now, we write (3) in the form

$$F(r)dr = GM_0(m^2/m_0)dr(1/r) = m_0c_0^2(m/m_0)^2d(r_{g0}/r) \tag{4}$$

which is reduced to the classical gravitational law at $r_{g0} << 1$. Further the 0-index in r_{g0} will be omitted. We are interested in a radial motion of a particle in free fall from infinity, and want to find a solution as a function of r with $dr = vdt$. In particular, we look for the ratio $m(r)/m_0 = 1/\gamma_r$. If a particle in a radial fall has initial energy at infinity $E_0 = \gamma_0 m_0 c_0^2$ then, due to the total energy conservation law, in the above formulae one should replace m_0 by $\gamma_0 m_0$ and take $\gamma = \gamma_0\gamma_r$ in (2). From (1) and (4) we have the equation for an exterior region (outside of a uniform massive sphere of a radius R):

$$\gamma^2\beta d\beta = d(r_g/g) \tag{5}$$

with the solution

$$1/\gamma_r = m(r)/m_0 = \exp(-r_g/r), \quad r \geq R \tag{6}$$

From $\gamma = \gamma_0\gamma_r = (1-\beta^2)^{-1/2}$, it follows

$$\gamma = \gamma_0 \exp(r_g/r), \quad \beta = \left[1 - (1/\gamma_0^2)\exp(-2r_g/r)\right]^{1/2} \tag{7}$$

The 3-momentum is

$$p = c_0\gamma\beta m = c_0\gamma_0\beta m_0 \tag{8}$$

and the expressions for total and kinetic energy are

$$E_{tot}^2 = \gamma_0^2 m_0^2 c_0^4 = p^2c_0^2 + m^2c_0^4 = c_0^2m_0^2\beta^2 + m^2c_0^4 \tag{9}$$

$$E_{kin} = E_{tot} - mc_0^2 = m_0c_0^2\left[\gamma_0 - \exp(-r_g/r)\right] \tag{10}$$

Finally, potential energy $W(r) = m\Phi(r)$ and potential function $\Phi(r)$ of the test particle are found

$$W(r) = \int_r^\infty \gamma_r F(r)dr = -m_0c_0^2(1 - m/m_0) = -m_0c_0^2\left[1 - \exp(-r_g/r)\right] \tag{11}$$

$$\Phi(r) = W(r)/m_0 = -c_0^2\left(1 - \exp(-r_g/r)\right), \quad (-c_0^2 \leq \Phi(r) \leq 0) \tag{12}$$

The gamma-factor in (11) is needed to account for SRT metric scaling of the potential function.

It is seen that the proper mass of a particle in an attractive $1/r$ field due to a point source tends to vanish at $r \to 0$ for a point source. The same tendency of "proper mass exhaustion" takes place in a strong field when $r_g \to R$ and $r \to R$ for a spherical source of a radius R. Consequently, there is no divergence of potential energy and a potential function: the divergence problem is eliminated.

With the field strength parameter r_g/r we have a criterion of *week field approximation* $r_g/r << 1$ when $\exp(-r_g/r) \approx (1 - r/g/r)$ and

$$1/\gamma_r = m(r)/m_0 = (1 - r_g/r), \quad \beta = [1 - (1 - 2r_g/r)/\gamma_0)]^{1/2} \qquad (13)$$

$$E_{kin} = \gamma_0 m_0 c_0^2 - mc_0^2 = m_0 c_0^2 (\gamma_0 - 1 + r_g/r) \qquad (14)$$

$$W = -m_0 c_0^2 (r_g/r),\ \Phi = W/m_0 = -(r_g/r),\ -c_0^2 \leq \Phi \leq 0 \qquad (15)$$

with the Newtonian limit $E_{kin} = mv^2/2$ for $\gamma_0 = 1$.

2.2 Coulomb Field

We are not interested in effects due to a magnetic field; our topic is narrowed to the energy balance for an electron in the Coulomb field. A classical electric (Coulomb) force acting on an electron of a charge e and a proper mass m due to a source of a charge $Q >> e$ and a mass $M >> m$ is

$$F_e = \frac{kQe}{r^2} \qquad (16)$$

where k is the electric constant. Bearing in mind the total energy conservation $\gamma m = m_0$, $\gamma = \gamma_0 \gamma_r$, from (1) and (16) it follows for a free radial fall from infinity:

$$F_e dr = keQd(r_e/r) = m_0 c_0^2 d(r_e/r) = m_0 v dv, \quad \beta d\beta = d(r_e/r) \qquad (17)$$

with the solution

$$m/m_0 = 1/\gamma_r = (1 - 2r_e/r)^{1/2}, \quad (r \geq R \geq 2r_e) \qquad (18)$$

The introduced electric radius $r_e = keQ/m_0 c_0^2$ is analogous to r_g; it characterizes electric field strength by the criterion of weak-field conditions $r_e/r << 1$ for the electron.

It is assumed further that the electric field does not affect a gravitational interaction, and a ratio of gravitational to Coulomb force does not depend on a gravitational or electric field (a proportionality hypothesis). Consequently, k should differ from k_0 at infinity; namely

$$k(r)/k_0 = 1/{\gamma_r}^2 \tag{19}$$

Then the Coulomb force has exactly the same form as the gravitational force: all formulae obtained for the gravitational force are valid for the Coulomb force after replacing r_g by r_e ensuring a junction of internal and external fields. We have for the external field

$$1/\gamma_r = m(r)/m_0 = \exp(-r_e/r), \quad r \geq R \tag{20}$$

$$\gamma = \gamma_0 \exp(r_e/r), \quad r = r(\beta) \tag{21}$$

$$\beta = \left[1 - (1/\gamma_0^2)\exp(-2r_e/r)\right]^{1/2} \tag{22}$$

$$p = c_0\gamma\beta m = c_0\gamma_0\beta m_0 \tag{23}$$

and the expressions for total and kinetic energy:

$$E_{tot} = \gamma_0^2 m_0^2 c_0^4 = p^2 c_0^2 + m^2 c_0^4 \tag{24}$$

$$E_{kin} = E_{tot} - mc_0^2 = m_0 c_0^2 \left[\gamma_0 - \exp(-r_e/r)\right] \tag{25}$$

Under weak-field conditions we have

$$\gamma = \gamma_0(1 + r_e/r), \quad \beta = \left[1 - (1 - r_e/r)/\gamma_0)\right]^{1/2} \tag{26}$$

$$E_{kin} = m_0 c_0^2(\gamma_0 - 1 + r_e/r) \tag{27}$$

$$W = -m_0 c_0^2(r_e/r),\ \Phi = W/m_0 = -(r_e/r),\ -c_0^2 \leq \Phi \leq 0 \tag{28}$$

and the Newtonian limit $E_{kin} = mv^2/2$.

2.3 Motion of a photon

Next, let us consider a radial motion of a photon in a gravitational field. Unlike the particle, the photon does not have a proper mass; its total mass is kinetic one. The photon emitted by a standard atomic clock (what is a quantum oscillator) is called the standard photon. A photon frequency f_{ph} must be proportional to an atomic clock frequency f obeying the quantum-mechanical relation $m(r)c_0^2 = hf(r) \sim \exp(-r_g/r)$; in other words, the emission frequency of the photon is field dependent similarly to the proper mass of the atomic clock. We assert that the energy (frequency) of the photon does not change during its travel in a gravitational field; this is due to the total energy conservation law. Therefore, the momentum (or the wavelength) and the speed of light change proportionally. The following formulae describe characteristics of the photon emitted at a point r' and detected at a point r:

$$f_{ph}(r' \to r) = f_0 \exp(-r_g/r') \tag{29}$$

where f_0 is the photon frequency at infinity; the photon does not change the initial (emission) frequency during its flight. The photon, or light speed is

$$c_{ph}(r' \to r) = c_0 \exp(-r_g/r) \tag{30}$$

So far, we consider results valid for all frequencies (there is no dispersion); hence, a photon and light propagate similarly. The speed of light at point r does not depend on a point of emission. The photon wavelength is

$$\lambda_{ph}(r' \to r) = \lambda_0 \exp(r_g/r' - r_g/r) \tag{31}$$

The photon wavelength at any point of emission equals the wavelength at infinity λ_0. Finally, the proper period of a resonance line of atomic clock is

$$T(r') = 1/f_{res}(r') = T_0 \exp(r_g/r') \tag{32}$$

which should be distinguished from the proper time interval $d\tau$, as discussed later. All quantities with “zero” subscript are measured at infinity. The gravitational time dilation is due to (32) and the red shiftn is described by (31). The speed of light is influenced by the gravitational potential according to (30); further a dimensionless form is used

$$\beta_{ph}(r) = c(r)/c_0 = \exp(-r_g/r) \tag{33}$$

In fact, this is the speed of light wave propagation.

As was emphasized, the standard photon in flight keeps the emission frequency unchanged while its speed and wavelength vary; light slows down when approaching the source. Physical processes described by the above formulae are time reversal in accordance with the energy conservation. It is seen from (30) that the speed of light is constant on an equipotential surface $r = r_0$, and it may be termed a tangential, or arc speed. One can define also the radial (“coordinate”) speed $\tilde{c}_{ph}(r) = \tilde{\beta}_{ph}(r)c_0$, which is measured by the differential time-of-flight method by an observer at infinity with the use of her "wristwatch" (a standard clock). If a unit length were found from sphere circumference measurements, the radial scale would be determined by the field-dependent length unit proportional to the wavelength of the standard photon emitted from infinity: $dr/d\lambda = \exp(-r_g/r)$. From this, the coordinate speed of the photon was obtained

$$\tilde{\beta}_{ph}(r) = \exp(-2r_g/r) \tag{34}$$

Under weak-field conditions, it coincides with the corresponding GRT formula. It is seen that the photon propagates in space of a gravitational field as in a refracting medium with the index of gravitational refraction $n_g = 1/\tilde{\beta}_{ph}$. It should be noted that a possibility of the gravitational refraction effect (a dependence of permittivity and permeability of space on a gravitational field) was discussed in [7] and later on, including current literature, in the GRT framework. In our view, it is not appropriate to do unless an attempt of GRT revision is meant because in a physical underlining process (a photon interaction with a field) must be interpreted in terms of curved space-time but not electromagnetic forces. The complete GRT explanation of the gravitational bending of light was given by Einstein and cannot be reinterpreted.

All above formulae were obtained in the SRT-based Mechanics with the metric $ds^2 = c_0^2 dt^2 - dr^2$ where $ds = c_0 d\tau = c_0 dt/\gamma$. The proper time interval $d\tau$ of a moving clock is related to the corresponding time interval dt determined by the rest observer at infinity with the use of her "wristwatch". In the absence of field, only the SRT dilation effect takes place: a cumulative proper time reading is lagging as compared to the identical clock at infinity. A new element in Alternative Relativistic Mechanics is a field dependence of quantum oscillator characteristics and time-distance scales, correspondingly. A scale measurement is based on a detection of a light signal sent to the observer at infinity from an atomic clock (moving or at rest) in the region of gravitational field at point r; the measured time interval $dt(r)$ as compared to dt_0 may be called the coordinate (or improper) time interval. The observer has to conclude that the standard atomic clock in a gravitational field physically runs slower due to impact of the field. This was tested directly by comparing clock readings. The idea of the test is simple. An experimenter slowly moved an atomic clock to some place of a different potential and after some period of time returned it back to compare a time reading with a stationary clock (corrections for the motion can be made however small). The fact is that a period $T(r)$ of clock oscillation rises with field strength (32). At the same time, the observer at infinity finds the corresponding proper time $d\tau(r)$ in her units smaller due to the reduction of the proper mass in a field by factor γ_r:

$$d\tau(r) = d\tau_0/\gamma_r = d\tau_0 \exp(-r_g/r) \tag{35}$$

The gravitational time dilation effect is present in red shift measurements. If a remote clock is in free fall, the combined SRT and gravitational time dilation and Doppler effect takes place. This is not a trivial issue, which is discussed in [3] and elsewhere.

2.4 Speculations on a scalar field concept

It should be noted that we use a term "field" related to the $1/r$ field potentials. A mediating field (a force transmitting mechanism) is a different problem not considered in this work, though a brief comment on it would be appropriate. The concept of gravitational and electric radius exhibits a connection between two types of forces. This might be a clue about a force unification with the idea of a gravitational field being a scalar component added to the electromagnetic field. This question is not new; it was discussed, for example, in [8], where a possibility of a proper mass variation was noticed but ruled out as unphysical. However, the idea may be perspective in the alternative concept in view of our finding that the gravity phenomenon is compatible with SRT, and the proper mass plays a role of the common (gravitational and electric) field source. Our results can relate to the Klein-Gordon equation

$$\left\{\frac{1}{c_0^2}\frac{\partial^2}{\partial t^2} - \nabla^2 + \frac{m^2 c_0^2}{\hbar^2}\right\}\phi(x^\mu) = 0 \tag{36}$$

For a particle in the Coulomb field, for example, the proper mass in (36) should be field dependent $m = m_0 \exp(-r_e/r)$, as in (20. One may consider (36) a mediating field equation for virtual massless photons, which are not observables: they are excitation states of field in a dynamical process of proper-to-kinetic mass transformation. The solution can be found by known methods of Fourier analysis. It must reveal a relativistic picture of the de Broglie wave development, which cannot be interpreted in Schroedinger's wave mechanics terms [1]. This speculative scheme requires an introduction of a neutral current associated with the gravitational field. The question why the gravitational force is as weak as it is (or where the ratio r_g/r_e comes from), should be addressed to a next level theory, such as Yang-Mills theories, for example.

3 Experiments and Alternative versus Conventional Theory Testing

3.1 Classical tests

There are four types of classical experimental tests of GRT: the gravitational red-shift, the bending of light, the time delay of light, and the advance of perihelion of planets. They are related to weak-field conditions and usually presented in literature as a solid GRT confirmation of the space-time curvature concept [9]. We conducted a metric analysis within the alternative framework. It led us to a different physical interpretation of the experiments, while no meaningful numerical difference between GRT and the alternative theory predictions of the above weak-field effects were found (with the exception of proper mass and related quantities). A brief review of the results is given next.

3.1.1 The gravitational red-shift

The term “red-shift” means that the wavelength of a photon emitted by an atomic clock at some point of lower potential appears to be increased when detected at some point of higher potential. It is impossible from this type of observations alone to find out what happens to a photon during its travel from an emitter to a detector. Our interpretation of the experiment was explained earlier: the effect is due to a combination of the gravitational shift of the emission-detection resonance line and the dependence of the speed of light on field strength while a frequency of a photon in flight is constant and equals the emission frequency. This interpretation is consistent with total energy and angular momentum conservation laws in the alternative theory. A suggestion to interprete the red-shift in terms of dependence of emission frequency on a gravitational potential in GRT framework was discussed in [3] without taking into consideration of behavior of a photon and a particle in a gravitational field.

3.1.2 The bending of light

The bending of light is due to the “gravitational refraction”. We conducted different calculations of the bending effect: using a refraction model and the angular momentum conservation; in both cases, the result was the same and similar to that in GRT.

3.1.3 The time delay of light

The time delay effect was measured in radar echo experiments with electromagnetic pulses passing near the Sun. The effect can be calculated by integrating the time of light travel over the path with the field-dependent coordinate speed (34); the result will be equivalent to GRT predictions.

3.1.4 Planetary perihelion precession and other astrophysical observations

This test is related to a particle motion in a gravitational field. It adds nothing new to our conclusion about absence of numerical difference in predictions of weak-field effects in the alternative versus conventional theory. The exception is the proper time interval (the quantity complementary to the proper mass, as was discusses before), the alternative prediction of which is different. As for a perihelion precession effect, it can be assessed in GRT by comparing radial and orbital frequencies in the Schwarzschild metric under weak-field approximation or in the post-Newtonian parameterization model. In the alternative theory, the corresponding physical treatment is equivalent to that in the effective potential model, in which dynamical quantities of orbital motion are influenced by the first-order field dependence of the proper mass in the Minkowski space.

There are also other GRT-interpreted astrophysical observations related to weak-field perturbations (the Moon laser ranging, for example) as well as strong-field effects (the so-called black holes, radiating binary star systems, and others). The alternative theory predicts strong-field effects around astrophysical objects of super-high density. Practically, they might look like"black holes" but they cannot be result of "gravitational collapse: such hypothetical phenomenon and the corresponding"light trap" is out of the competence of our work. In the alternative theory, the gravitational time dilation could be however great but the process of a particle and photon motion is inverse in time. Our firm opinion is that the GRT "black hole" theory is a long-standing physical misconception. The practical difficulty with astrophysical observations and their interpretations is that GRT predicted strong-field phenomena are hard to separate from the background of observed global system dynamics; quite often a quantity of interest is not directly measured. Therefore, one has a room for speculations and assumptions beyond the theory under investigation.

3.2 Theoretical Comparison and Test Proposals

3.2.1 A particle in a static spherical symmetric gravitational field

As was mentioned before, the coordinate speed of a particle in GRT is measured by an imaginary rest observer at infinity with the use of time-of-flight technique. The following GRT expression is obtained from the Schwarzschild metric and a geodesic equation of motion for the case of free radial fall (for GRT methodology, see [4], [2], and elsewhere):

$$\beta = (1 - 2r_g/r)[1 - (1 - 2r_g/r)/\gamma_0]^{1/2} \tag{37}$$

where a doubled gravitational radius is the so-called Schwarzschild radius $r_s = 2r_g$. It is seen that $\beta \to 0$ when $r \to r_s$. The particle can cross the Schwarzschild sphere for a finite time as recorded by a comoving observer's wristwatch. During free radial fall from infinity, the particle starts decelerating at some radial point depending on γ_0; at $\gamma_0 \geq 3/2$ the particle always decelerate ($d\beta/dt < 0$). It is different from our result (7), which shows that the particle moving towards the center always accelerates ($d\beta/dt > 0$); its speed can exceed the speed of light $\tilde{c}_{ph}(r)$ in a gravitational field (but not the ultimate speed c_0) as occurs in refracting media. The GRT formula (37) is consistent with the GRT form of total energy conservation law [4]

$$E/m = Const \tag{38}$$

We cannot comment this equation because do not understand it.

3.2.2 A photon

In GRT [4], a photon radial coordinate speed in a spherical symmetric static field is given by

$$\hat{\beta}_{ph} = 1 - 2r_g/r \tag{39}$$

to be compared with our result (34); it is similar to our prediction in a weak-field approximation. Thus, in GRT a particle speed can never exceed the speed of light, while it is possible in the alternative (gravitational refraction) concept. According to the alternative theory, superluminal particles in a gravitational field could exist. Such particles should have an energy above some threshold and enter a gravitational field region from an external high-energy source located at a higher potential level (ideally, at infinity). This is subject to experimental verification.

3.2.3 Test-1 proposal: superluminal particles?

The test proposal was previously discussed in Author's e-prints preprint PhilSci-Archive "On the possibility of motion with the speed greater than the speed of light" (Feb., 2003); gr-qc /0311063; physics /0402117. It is practically impossible to produce superluminal particles in a physical laboratory. However, one may take advantage of existence of the natural ultra-high energy cosmic rays bombarding Earth. Superluminal particles, if exist, could be detected in cosmic rays with the use of satellite physical instrumentation. The critical threshold energy γ_0 can be readily found by comparing ($\beta > \hat{\beta}_{ph}$) in (7) and (34). In a weak-field approximation $r_g/r << 1$) particles having energy above the threshold

$$\gamma_0 > (4r_g/r)^{-1/2} \tag{40}$$

become superluminal: the weaker the field, the greater the threshold should be. Under Earth conditions, particles become superluminal at a typical satellite hight of 450 km above the surface of Earth, if $\gamma_0 > 4 \cdot 10^4$, that is for protons in the energy range approximately $E > 5 \cdot 10^{13}\ eV$. At this height, the intensity of cosmic ray protons is known about one proton per square meter per hour. Superluminal particles can be discovered by the detection of Cherenkov radiation due to the interaction with gravitational field. A general picture should be analogous to what is usually observed in transparent refracting media. The radiation is likely to consist of photons with maximal emission angle given by

$$\cos\delta_{max} = 1/n_g \tag{41}$$

The radiation is emitted by a particle backward in an extremely narrow cone at frequencies determined by the condition

$$n_g(\omega) > 1 \tag{42}$$

The function (42) is unknown except that it should behave like $n_g(\omega) \to 1$ with frequency increase; this could be possible if energetic photons inelastically interact with field. Thus, superluminal particles should be accompanied by a specific Cherenkov gamma radiation, presumably, with gamma-ray spectrum in keV energy region with a smooth cut-off at some upper energy. From this, the assessment can be made of the total energy of a single Cherenkov pulse about hundreds of keV in the form of a photon “flash” emitted by a superluminal proton along a path of up to 450 km. When observed from a satellite, the radiation should appear "coming from Earth". Each gamma flash is beamed with a typical pulse duration about $\delta t \approx 1.5$ ms (the time of a radiation collection from 450 km radial path). There must be a statistical distribution of δt due to the dispersion of distances, which depend on a direction of trajectory and a position of the detector with respect to a photon trajectory line. Only those photons could be collected which belonged to the underneath part of a proton path, and were swept immediately after they grazed the satellite front. The "grazing distance" is a distance traveled by the satellite during a photon collection (about 12 m). A pulse shorter than 1.5 ms could appear when the detector swept a pulse tail. A maximal count rate is determined by a superluminal proton intensity and an overall detector efficiency. It should be noted that protons passing Earth in the direction to the Sun have essentially lower threshold energy in the much stronger field of the Sun, but their detection would require more sophisticated technique. One cannot exclude that superluminal cosmic particles have been observed but not recognized.

3.2.4 Test-2 proposal: the proper time interval

In GRT the proper time interval for a particle in free radial fall is a function of a position

$$d\tau = d\tau_0(1 - 2r_g/r) \tag{43}$$

and it is different from our result (35). The difference can be subjected to experimental tests with atomic clocks. With the development of atomic clock technology and the Global Positioning System (GPS), it became possible to test a gravitational theory in experiments under weak-field conditions [4, 5]. The current GPS philosophy is based on the Schwarzschild metric in a weak-field approximation. In fact, it contains parts of Newtonian Physics, SRT, and GRT. The ultimate positioning precision in current GPS versions appreciably depends on an incessant adjustment of atomic clock synchronization by reference signals from known locations on Earth. Our interpretation of GPS operational data is different. Therefore, testing the practical positioning accuracy for different models of gravitational theory will allow distinguishing between theories in a weak-field domain.

3.2.5 Electrodynamics: a charged particle in the Coulomb field

In the conventional Relativistic Dynamics [6] the equation of relativistic radial motion of a point charge in the Coulomb field is

$$c_0 m_0 d(\gamma\beta)/dt = F_e \tag{44}$$

The proposed test is related to the radial motion of an electron in the Coulomb attractive field due to a positively charged spherical shell. The goal is to verify our prediction of a proper mass "exhaustion" in a strong field. A general problem of a relativistic motion of a structureless electron was thoroughly discussed in literature (see, for example, [6, 10] with further references). The classical Coloumb law may be formally presented in the form $F_e(r)dr = m_0 c_0^2 d(r_e/r)$ with $r \geq R$ for a uniformly charged sphere or a spherical shell of a radius R. Remember, that in the conventional theory the proper mass of the electron $m = m_0$ and the electric constant $k = k_0$ are field independent physical constants; therefore, the electric radius concept does not have much physical sense, while it does in the alternative theory. Thus, the conventional equation of motion is:

$$m_0 \frac{d}{dt}(\gamma v) = -\frac{k_0 Qe}{r^2} dr, \quad (r \geq R) \tag{45}$$

or equivalently (using $dr = c_0 \beta dt$)

$$d\gamma = d(r_e/r), \quad (r \geq R) \tag{46}$$

with the solution for free fall from rest at infinity ($\gamma_0 = 1$)

$$\gamma = 1 + r_e/r, \quad \beta = \sqrt{1-(1+r_e/r)^{-2}} \tag{47}$$

$$p = \gamma\beta m_0 c_0 = \sqrt{(1+r_e/r)^2 - 1]} \tag{48}$$

$$E_{tot} = m_0 c_0^2 (1 + r_e/r) = \gamma m_0 c_0^2 \tag{49}$$

$$E_{kin} = (\gamma - 1) m_0 c_0^2 = m_0 c_0^2 (r_e/r) = k_0 Qe/r \tag{50}$$

or for $r = R$

$$E_{kin} = k_0 Qe/r = eV_s \quad (r \geq R) \tag{51}$$

where V_s is a positive voltage of the attractive spherical shell. Clearly, from (51) it follows that the kinetic energy of the electron falling onto a positively charged shell indefinitely rises with the potential. An introduction of field dependence of the electric constant does not change this conclusion. The conventional result (51) should be compared with the alternative prediction (25)

$$E_{kin} = m_0 c_0^2 (1 - \exp(-eV_s/m_0 c_0^2) \quad (r \geq R) \tag{52}$$

which reads that the electron under above conditions cannot be accelerated to energies higher than $m_0 c_0^2$=511 keV regardless of how big the potential (the voltage) is. In fact, it means that in a relativistic theory the potential and the voltage are not equivalent physical notions. The difference occurs under strong field conditions, what is the case for the electron in a high potential (strong) field according to the criterion $r_e/r \sim 1$. It should be noted that for a proton the similar conditions occur at much higher potential (by factor $m_p/m_e \approx 2000$), what is not realistic. As is known, conventional Electrodynamics is a linear theory: a photon is not affected by a field; also, the electron kinetic energy is proportional to the potential (51), while in the alternative theory it is true only under weak-field conditions. Our statement is that the conventional theory is, in fact, a linear approximation of a more general non-linear theory with the variable proper mass.

At this point, we need to return to the issue of the electron radius concept r_e. The matter is that we did not and could not study an internal electric field that is, the field in the spherical shell material and a spherical cavity: this is an issue of materials science and Physics of a double-layer potential formation. In the alternative theory, electrons in the layer of positively charged sphere or a shell are "squeezed" by electric forces, and their proper mass is reduced. To avoid this sophisticated (materials science) problem, we introduced the electron radius as a model parameter. The same thing should be done in the conventional theory, but it would not eliminate the divergence in principle (what is easy to check); the matter is that the divergence is caused by the proper mass constancy solely. The question arises how the model could affect our prediction of the kinetic energy "saturation" at energies above 511 keV. A frank answer is: we do not know now. However, we expect an appreciable deviation of experimental results from the conventional prediction in favor of the alternative theory after introducing possible model corrections (specific for experimental conditions). Thus, we proposed a test experiment: measurements of kinetic energy of electrons accelerated by the attractive Coulomb field.

3.2.6 Test-3: Acceleration of an electron in the attractive Coulomb field

Measurements of energy of electrons accelerated by the attractive Coulomb field can be conducted at Van de Graaf (static accelerator) facilities. Typical construction of the accelerator includes a source of particles, a spherical shell (a conductor) isolated from ground, and a focusing system. The conductor may be "pumped" by an electric transporter up to millions of volts of a positive or negative potential. In a typical regime, the machine accelerates beams of protons and other positively charged particles up to the energy of a positive potential (in eV units). Sometime, electrons accelerated in the repulsive potential field due to a negatively charged conductor are utilized. In this case, the initial proper mass of accelerated electrons, according to the alternative theory, should be bigger than m_0 (it can be easily verified), and the difference $m - m_0$ determines kinetic energy. In this case, non-linear effects are not so pronounced as in the attractive field. We do not have any information about practice of electrons accelerated by the attractive Coulomb field (that is, due to a positive potential). Such electrons are accelerated toward a conductor; therefore, an experimenter needs to place a registration device on or inside the conductor under high voltage. The device should be completely isolated from the ground, and a data acquisition system should include either a fiber-optic or radio-transmitting line. Besides van de Graaf facilities, electron beams of any energy are easily produced by linear accelerators but experiments with such electrons are not interesting for us.

There is no evidence of an anomalous behavior of light in a static electric field. It means that a product of permittivity and permeability of space is not affected by an electric field. In other words, the speed of light does not change, what is consistent with our relativistic model of the Coulomb force. However, one cannot exclude that an introduction of additional external magnetic field will make a difference.

4 Discussions and Conclusion

In the conclusion, let us present the Author's view of the problem retrospectively. The current situation in field theories seems to be controversial. One may insist that GRT, QED, and QCD are completed (but different) physical theories all proved to be true by virtue of numerous highly accurate experiments. On the other hand, there is a strong demand for mathematical rigor and consistent definitions. Thereafter, one would be advised to look for new physics "beyond a theory". We think, however, that modern physics is to a great extent "new physics" in a sense of drastic departure from classical relativistic physical concepts; so, one would better step back to appreciate reasons for mathematical rigor quest. As was clearly pointed out in [6], a classical field theory is well defined but inevitably contains internal contradiction: a point particle has no structure there; consequently, a density of mass, charge and energy is infinite; a self-interaction and particle-particle interaction lead to field divergence. Attempts to introduce an electron structure of a single particle were started by a pioneering Lorentz work [11] (Lorenz-Abraham electron theory) and continued throughout physics history but did not contribute to the divergence problem resolution. Meanwhile, Quantum Chromodynamics (QCD) and Yang-Mills theories emerged at a new fundamental level. One can see three historical stages in the field theory development: 1. Classical and pre-quantum fields (Newton's and Maxwell's potential fields, Schroedinger's and Klein-Gordon wave theories, and GRT); 2. Electromagnetic field quantization (QED); 3. Particle Physics (QCD and Yang-Mills theories). In the stage-2, fields in terms of potentials and wave functions were given an advanced interpretation in terms of vectors in a Hilbert space; however, field definitions became not clear because of a physically meaningless renormalization procedure. The situation aggravated in particle structure models (stage-3) when an hierarchy of new point particles was introduced for serving a force transmitting role while fields remained divergent. Mass and charge were left with a traditional role of coupling physical constants, the relativistic mass-energy concept remained unchanged since Lorentz work. In the alternative relativistic point particle mechanics, the concept is revised to make a field originally free of divergence without introducing a particle structure. Moreover, a field dependent proper mass of a test particle, as it follows from Dynamics equations, may be thought as a general definition of field. It means (as concerns the question about a gravitational field quantization) that the proper mass is subject to quantization.

Remarkably, back in 1905 and a post-SRT era, in a process of GRT development Abraham, Einstein and others considered a dependence of the proper mass and the speed of light on gravitational field, apparently, without connections with a singularity problem [12]. Later on, some relativity experts posed similar questions about the proper mass variation but did not consider its practical implementations [7], [8], [13]. One can ask why a variation of the proper mass makes a difference. The matter is that in a renormalization procedure the radius of electric interaction is "effectively" cut off at the r_e (annihilation) level to cope with the theoretical problem not existing in physical reality. As for the gravitational radius, it is 42 orders smaller (say, zero), and no procedure could be accomplished without destroying electric properties of particles. The theoretical problem was dragged into the stage-3 of microscopic theory of particle structure. A practical success of QCD in describing experiments cannot be denied and cannot be overestimated (because of multi-parameter fitting); the quest for a physical and mathematical rigor and definitions remains. We believe that a revision of the existing mass-energy concept is needed at all field theory levels because the proper mass constancy is not required by Nature: this is an assumption. Hence, the alternative assumption cannot be refuted by purely theoretical arguments but should be tested experimentally. This paper contains our explanation why the alternative Relativistic Mechanics is consistent with existing first order macroscopic theories and weak-field observations, and how its validity should be tested in the whole energy region. To the conclusion, let us summarize the content of this work.

- Alternative Relativistic Mechanics of a point particle is developed, the novelty of which is a field dependence of the proper mass, the speed of light, and the electric constant.

- The gravitational force is shown to be compatible with SRT.

- The gravitational and Coulomb forces are shown to have the common source, the proper mass; the divergence of $1/r$ potential is not present in the equations of motion.

- Experimental tests are proposed.

-Speculations about perspectives are discussed with expectations of divergence problem solution in a quantum field theory.

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