Article

On the Theory of Gravitation Part 5: Interrelation of Mass and Gravitation according to NTEP and SM

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Abstract

According to the relativistic gravitation theory of Einstein-Hilbert, a gravitational field is described by the components of the energy-momentum tensor, which in all approximate solutions are expressed in terms of the mass of bodies and fields. The present article examines two hypotheses about the origin of mass as origin of the gravity: 1) mass production theory developed in the framework of the nonlinear theory of elementary particles (NTEP), and 2) the Higgs mechanism of mass generation in the Standard Model (SM). The comparison of theories confirms that the results of NTEP are more consistent with the theory of gravity.

Keywords: non-linear quantum theory, Standard Model, mass origin, Higgs mechanism, gravitation.

1. Introduction to mass theory

To explain the contemporary views on the considered issues, we will use the works of Quigg, Dawson (Quigg, 2007; Dawson, 1999) and others.

Mass remained an essence - part of the nature of things - for more than two centuries, until J.J. Thomson and Lorentz (Thomson, 1881; Lorentz, 1916; 2003; Jackson, 1998) sought to interpret the electron mass as electromagnetic self-energy.

Our modern conception of mass has its roots in known Einstein's conclusion: "The mass of a body is a measure of its energy content. Among the virtues of identifying mass as $m = \varepsilon_0 / c^2$, where ε_0 designates the body's rest energy, is that mass, so understood, is a Lorentz-invariant quantity, given in any frame as $m = (1/c^2)\sqrt{\varepsilon^2 - p^2c^2}$. But not only is Einstein's a precise definition of mass, it invites us to consider the origins of mass by coming to terms with a body's rest energy. We understand the mass of an atom or molecule in terms of the masses of the atomic nuclei, the mass of the electron, and small corrections for binding energy that are given by quantum electrodynamics. ‘Small correction’ is, e.g., the 13.6 eV binding energy of the 1S electron in the hydrogen atom is but 1.45×10−8 of the atom’s mass.

Nucleon mass is an entirely different story, the very exemplar of $m = \varepsilon_0 / c^2$. Quantum chromodynamics (QCD), the gauge theory of the strong interactions, teaches that the dominant

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contribution to the nucleon mass is not the masses of the quarks that make up the nucleon, but the energy stored up in confining the quarks in a tiny volume (Wilczek, 1999). The masses m_u and m_d of the up and down quarks are only a few MeV each. The quarks contribute no more than 2% to the 939 MeV mass of an isoscalar nucleon (averaging proton and neutron properties), because $(3/2)(m_u + m_d) = 7.5–16.5$ MeV.

Hadrons such as the proton and neutron thus represent matter of a novel kind. In contrast to macroscopic matter and beyond what we observe in atoms, molecules and nuclei, the mass of a nucleon is not equal to the sum of its constituent masses - quarks; it is, basically, a confinement energy of gluons!

2. Electromagnetic wave theory of mass

In the history of physics a theory under this name is absent. But a number of meaningful results, obtained even in the 19th century, makes it possible to choose this approach as electromagnetic wave theory of mass. In the Maxwell-Lorentz electromagnetic theory the initial existing waves are the electromagnetic waves. At the beginning of the 20th century it was revealed that these waves are quantized and consist of particles - the quanta of electromagnetic (EM) field, i.e. photons; moreover, photons are mass-free particles. Thus, on the basis of the contemporary ideas, the only possibility of the generation of massive particles in the electromagnetic theory is some transformation of photons, as a result of which special massive electromagnetic waves-particles must appear.

Here we will recall some results of the 19th century and estimate them from the results of contemporary theory point of view. Because of the dualism wave-particle, we will further examine photon as electromagnetic wave and particle simultaneously.

2.1. Energy and momentum of electromagnetic wave

The fact that EM wave has an energy and a momentum, it was discovered already into the 19th century. The EM wave presses the metallic wall, and also it can revolve a light rotator. By this we can assume that EM wave (photon) has a mass.

For the time average of the pressure of the train of EM waves with area s and length l, the following expression (Becker, 1982) is obtained: $\mathrm{P} = \frac{1}{8\pi}\left(\vec{\mathrm{E}}^2 + \vec{\mathrm{H}}^2\right) = u$, where u is the energy density of EM wave. The important dependence between energy and momentum of wave is already included in this equation. The total momentum, transmitted from EM train to wall will be equal to: $p = u \cdot s \cdot t$, where $t = l/c$ is the time of action of train. Thus, the transmitted momentum is equal to: $p = u \cdot s \cdot l/c$. Since the numerator $u \cdot s \cdot l = \varepsilon$ is the energy of train, we obtain $p = \varepsilon/c$. If we assign to EM wave a mass m', then it is possible to consider that $p = m'c$. In that case we obtain $m' = \varepsilon/c^2$ - the known relationship of Einstein.

Nevertheless, later it was proven that photon is a mass-free particle in the sense that its rest mass is equal to zero. But if we interpret the collision of EM wave with the wall as the stoppage of EM wave, then it is possible to say that the "stopped" photon acquires mass m'.This result led, evidently, to a study of other methods of the "stoppage" of EM waves for the purpose of understanding the origin of mechanical mass of the material bodies

2.2. The Mass of a Box Full of Light (The authors, 2005)

"The experimental confirmation of the pressure of light in 1901 led to new theoretical work. In 1904, Max Abraham computed the pressure produced by radiation upon a moving surface, when the beam of light reaches the surface in a mirror in any angle. Starting from Abraham's results, Friedrich Hasenoehrl (1874-1916) studied the dynamics of a box full of radiation.

Imagine a cubic box with perfectly reflecting internal surfaces, full of light. When the box is at rest, the radiation produces equal forces upon all those surfaces. Now, suppose that the box is accelerated, in such a way that one of its surfaces moves in the x direction. It is possible to prove that, when the radiation inside the box strikes this surface, the pressure will be smaller, and when it strikes the opposite surface, the pressure will be greater, than in the case when the box is at rest (or in uniform motion). Therefore, the radiation inside the box will produce a resultant force against the motion of the box. So, to accelerate a box full of light requires a greater force than to accelerate the same box without light. In other words, the radiation increases the inertia of the box. In the case when the radiation inside the box is isotropic, there is a very simple relation between its total energy E and its contribution m to the inertia of the box (Hasenoehrl, 1904; 1905): $m = \frac{4\varepsilon}{3c^2}$.

Note that here, as in the theory of the electron, there appears a numerical factor 4/3. This is not a mistake. The relation between those equations and the famous $\varepsilon = mc^2$ will be made clear later (Fadner, 1988).

Hasenoehrl also computed the change of the radiation energy as the box was accelerated. He proved that the total radiation energy would be a function of the speed of the box. Therefore, when the box is accelerated, part of the work done by the external forces is transformed into the extra radiation energy. Since the inertia of the radiation is proportional to its energy, and since this energy increases with the speed of the box,, the inertia of the box will increase with its speed. Of course, if the internal temperature of the box were increased, the radiation energy would augment, and the inertia of the box would also increase. Therefore, Hasenoehrl stated that the mass of a body depends on its kinetic energy and temperature".

2.3. A "Box Full of Light" as massive particle

As we can see, the radiation inside the box behaves like a massive body or particle. Let us conditionally name the totality of EM waves in a box as 'EM-particle'. From the foresaid above it is obvious that the mass of 'EM-particle', calculated according to Lorentz's theory, will also have a coefficient of 4/3 like the mass of classical electron. Obviously, upon consideration of the stresses of Poincare we will obtain the coefficient one. The stresses of Poincare were introduced for the stabilization of the electrostatic field of classical electron. In the case in question the stability exists due to interaction of EM wave with the walls of the box. These interactions play in this case the role of the stresses of Poincare, which ensure the stability of 'EM particle'. Naturally, if we take into account the presence of these stresses, we will also obtain the coefficient one (of course this result will also appear, if we use Einstein's approach).

With the perpendicular fall of EM waves on the walls of the box the stress is pressure. With inclined fall the components of stress will formally consist both of pressures and tangent stresses (as a result of the resolution of momentum on perpendicular and tangential components). The stress tensor of Maxwell (and generally, continuous medium tensor) consists precisely of such components. In this example the stresses are not mechanical: EM waves interact with the electrons of the wall atoms by means of EM Lorentz's forces. Nevertheless, these stresses are external with respect to EM waves in the box, i.e., they are not organized by the EM waves themselves.

The question arises: are such conditions possible, when EM wave can ensure themselves the stability of 'EM-particle' without the presence of external actions? In this case we will actually have a massive "particle", generated by EM waves. Obviously, this case can be realized only as a result of the self-interaction of fields of EM waves. This means that the equation of EM wave-particle must be nonlinear.

We can improve our model for the purpose to do approach the quantum field theory. Let us select a box with mirror walls of the size of the order of a wavelength λ . If we consider resonance conditions, the box itself will select the appropriate wavelength. This corresponds to the case when we placed into this box one photon. In the case of quantum theory we can speak about the photon in a cell of phase size. If we ignore the presence of walls, it is possible to consider photon in the box as a new elementary particle. This particle possesses spin one and mass, determined by its energy $m' = \varepsilon / c^2 = \hbar / \lambda c$. In other words, we have a model of the neutral massive boson, similar to intermediate boson.

2.4. The mathematical description of "EM-particle"

The mathematical description of this model in the classical case can be given on the basis of the theory of waveguides and resonators (Crawford Jr., 1968; Broglie, 1941). As is known, the motion of waves is determined by the dispersion equation (or by another dispersion relationship).

Dispersion equation is the relationship, which connects angular frequencies ω and wave vectors k of natural harmonic waves (normal waves) in linear uniform systems: continuous media, waveguides, transmission lines and others. Dispersion equation is written in the form

$$\omega = \omega(k), \tag{5.2.1}$$

Dispersion equations are the consequence of the dynamic (in the general case integrodifferential) equations of motion and of boundary conditions. And also, vice versa, on the base of the form of dispersion equation the dynamic equations of processes can be restored with the replacement:

$$i\omega \to \frac{\partial}{\partial t},\ ik_x \to -\frac{\partial}{\partial x},\ \frac{1}{i\omega} \to \int (...)dt,\ \frac{1}{ik_x} \to \int (...)dx, \tag{5.2.2}$$

It is easy to obtain the dispersion equation for the infinite wave without any limiting conditions, $\vec{\Phi} = \vec{\Phi}_o e^{-i(\omega t - ky)}$, using the homogeneous wave equation:

$$\left(\frac{\partial^2}{\partial t^2} - c^2 \vec{\nabla}^2\right)\vec{\Phi} = 0\,, \tag{5.2.3}$$

where $\vec{\Phi}$ are in our case any vector components of electrical and magnetic field. Putting this solution, we obtain $\omega^2 - \upsilon^2 k^2 = 0$ or $\omega = \upsilon \cdot k$.

In the case of the presence of limitations, superimposed on the wave by medium or by it self, the equation becomes heterogeneous:

$$\left(\frac{\partial^2}{\partial t^2} - c^2 \vec{\nabla}^2\right)\vec{\Phi} = \vec{\Phi}_0\,, \tag{5.2.4}$$

where $\vec{\Phi}_0$ is certain function of the electromagnetic fields. In this case dispersion relationship becomes more complex: new terms are introduced and its linearity is disrupted.

The same relationship dispersion equation:

$$\omega^2 = \omega_0^2 + \upsilon^2 k^2\,, \tag{5.2.5}$$

can correspond to: 1) EM waves in the isotropic plasma; 2) plasma waves; 3) waves in the waveguides; 4) waves in the acoustic waveguides; 5) elementary particle in relativistic wave mechanics ($\upsilon = c$, $\omega_0 = m_0 c^2 / \hbar$, m_0 is rest mass).

In the latter case the discussion deals with de Broglie wave dispersion relation. Energy, momentum, and mass of particles are connected through the relativistic relation

$$\varepsilon^2 = \left(m_0 c^2\right)^2 + \left(pc\right)^2\,, \tag{5.2.6}$$

Elementary particles, atomic nuclei, atoms, and even molecules behave in some context as matter waves. According to the de Broglie relations, their kinetic energy ε can be expressed as a frequency ω: $\varepsilon = \hbar\omega$, and their momentum p as a wave number k: $p = \hbar k$.

(Broglie, 1941): *"The relationships, obtained for EM wave in a waveguides or in a box, are completely analogous to those, which exist in wave mechanics, in which the rectilinear and uniform particle motion with the rest mass m_0 depicts in the form of propagation of plane simple harmonic wave $\psi = \psi_0 e^{i(\omega t - kr)}$.*

As we noted, $\omega = ck$ corresponds to the propagation of EM wave in the vacuum. But if EM wave is in the waveguide, then between ω and k we have the relationship (5.2.6), *where ω_0 is different from zero and it is equal to one of its eigenvalues, which correspond to the form of the waveguide in question. From the point of view of wave mechanics everything happens as if the photon had its own* *mass, determined by the form of waveguide and by the eigenvalue $\omega_{0i} = m_{0i}/\hbar$. Thus, it is possible to say that in this waveguide the photon can possess a series of possible own masses".*

From a contemporary point of view we can interpret the appearance of photon mass as follows. A photon, until its entry into a waveguide or resonator, obeys to the linear equation

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{\Phi} \equiv \sum_\nu \frac{\partial^2}{\partial x_\nu^2}\vec{\Phi} \equiv \partial_\nu \partial^\nu \vec{\Phi} = 0\,, \qquad (5.2.7)$$

Lagrangian of which

$$L = \frac{1}{2}\left\{\left(\frac{\partial\vec{\Phi}}{\partial t}\right)^2 - c^2\left(\vec{\nabla}\psi\right)^2\right\} \equiv \frac{1}{2}c^2\sum_\nu\left(\frac{\partial\vec{\Phi}}{\partial x_\nu}\right)^2 \equiv \partial_\nu\vec{\Phi}\partial^\nu\vec{\Phi}\,, \qquad (5.2.8)$$

describes the mass-free field. After entry to a box the photon experiences a certain spontaneous transformation and becomes massive particle. Each component of the field of this massive particle obeys to Klein-Gordon wave equation (Wentzel, 2003):

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - m^2\right)\vec{\Phi} \equiv \left(\sum_\nu \frac{\partial^2}{\partial x_\nu^2} - m^2\right)\vec{\Phi} \equiv \left(\partial_\nu\partial^\nu - m^2\right)\vec{\Phi} = 0\,, \qquad (5.2.9)$$

This is achieved by choosing the following, evidently Lorentz-invariant Lagrangian:

$$L = \frac{1}{2}\left\{\left(\frac{\partial\vec{\Phi}}{\partial t}\right)^2 - c^2\left(\vec{\nabla}\vec{\Phi}\right)^2 - c^2m^2\vec{\Phi}^2\right\} \equiv -\frac{1}{2}c^2\left\{\sum_\nu\left(\frac{\partial\vec{\Phi}}{\partial x_\nu}\right)^2 + m^2\vec{\Phi}\vec{\Phi}^+\right\} \equiv \partial_\nu\vec{\Phi}\partial^\nu\vec{\Phi} - c^2m^2\vec{\Phi}^2$$

(5.2.10)

The question arises: whether can EM wave ensure themselves the stability as 'EM-particle', but without the presence of external actions? In this case we will actually have a massive "particle", generated by EM wave itself. Obviously, this case can be realized only as a result of the self-interaction of fields of EM waves. This means that the equation of EM wave-particle must be nonlinear.

Namely this transformation – from free wave to the self-actioning wave - is realized due to mechanism of particle masses production in nonlinear theory of elementary particles (NTEP), as presented in the series of papers published in the "Prespacetime Journal" for the years 2010-2011 and in earlier publications in various journals. We pass on to a brief consideration of this mechanism.

3. Mass production mechanism in NTEP

The mechanism of mass production in NTEP is based on the conversion of massless boson into a strong electromagnetic field, by means of the self-action of its fields, in the massive vector boson. Let us consider it briefly (for details, see Kyriakos, 2010a,b,c,d; 2011). (Note that the wave function is represented here by vectors of the electromagnetic field).

3.1. The postulate of generation of massive elementary particles

As is known (Dawson, 1999; Quigg, 2007), in the SM all particles do not have a mass at the initial stage. Here, the mass-free particles acquire mass because of the spontaneous breakdown of the gauge symmetry of vacuum. This mechanism is called Higgs's mechanism.
In the framework of axiomatic nonlinear theory of elementary particle (NTEP), in contrast to SM, only a quantum of an electromagnetic wave (photon) does not have mass.

In the proposed theory we accepted the following basic postulate, which ensure the generation of massive particles:

The fields of an electromagnetic wave quantum (photon) can under specified conditions undergo a rotation transformation, which generate massive elementary particles.

From this hypothesis it follows that in this case take place a *breaking* of the *initial symmetry* of photon field, and the equations of elementary particles must become nonlinear modification of the equations of quantized electromagnetic wave. Note that the mathematical description of mass generation of elementary particles in NTEP and in SM has many similarities.

3.2. Photon as a gauge field

As one of the simplest examples of the generation of massive fields (particles) we can consider the photoproduction of the electron-positron pair:

$$\gamma + p \rightarrow e^{+} + e^{-} + p$$

Actually, the photon γ is a mass-free gauge vector boson. The EM field of proton p (or some atom nucleous) initiates its transformation into two massive particles: electron and positron**.** The fields of the electron and positron e^{+}, e^{-} are spinors, which are not transformed like vector fields. Thus, we can say that *the reaction of photoproduction describes the process of symmetry breaking of the initial mass-free vector field in order to generate the massive spinor particles.*

Let us examine the Feynman diagram of the above reaction of a pair production (Fig. 5.1):

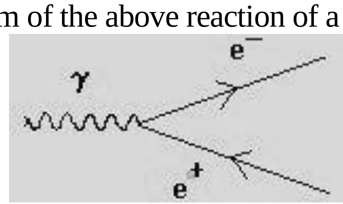

Fig. 5.1

It is known that using Feynman's diagrams within the framework of SM, we can precisely calculate all characteristics of particles with the exception of charge and mass. Nevertheless, the reaction of photoproduction remains mysterious: we do not know how the process of transformation of the mass-free boson field into the massive spinor fields happens, and how the electrical charge appears.

Based on this evidence, let us assume that in the vertex of the Feynman's diagram the rotation transformation of the "linear" photon (in the sense that it obeys a linear wave equation) into the "nonlinear" photon (that obeys a nonlinear wave equation), which acquires rest mass, is achieved.

These ideas can be translated into mathematical language. Let us now describe the rotation transformation of a photon.

First, we recall the quantum equation of a "linear" photon (see (Kyriakos, 2010a).

3.3. Quantum equation of the photon

For certainty, we will examine the same circularly polarized photon moving along the y - axis. The Feynman diagram's lines of the photon γ correspond to linear wave equations:

$$\left[(\hat{\alpha}_o \hat{\varepsilon})^2 - c^2 \left(\hat{\vec{\alpha}}\ \hat{\vec{p}} \right)^2 \right] \Phi = 0 \ , \qquad \text{(a)}$$

or, to the equivalent system:

$$\begin{cases} \Phi^+ \left(\hat{\alpha}_o \hat{\varepsilon} - c \hat{\vec{\alpha}}\ \hat{\vec{p}} \right) = 0 \\ \left(\hat{\alpha}_o \hat{\varepsilon} + c \hat{\vec{\alpha}}\ \hat{\vec{p}} \right) \Phi = 0 \end{cases} , \qquad \text{(b)}$$

where $\hat{\varepsilon} = i\hbar \dfrac{\partial}{\partial t}, \hat{\vec{p}} = -i\hbar \vec{\nabla}$ are the operators of energy and momentum, correspondingly, $\left\{ \hat{\alpha}_0, \hat{\vec{\alpha}} \right\}$ are Dirac's matrixes and $\vec{\Phi}(y)$ is the matrix (3.2.8), which contains the components of wave function of photon:

$$\Phi = \begin{pmatrix} \Phi_1 \\ \Phi_2 \\ \Phi_3 \\ \Phi_4 \end{pmatrix} = \begin{pmatrix} \mathrm{E}_x \\ \mathrm{E}_z \\ i\mathrm{H}_x \\ i\mathrm{H}_z \end{pmatrix}, \qquad \text{(c)}$$

3.4. The rotation transformation of photon fields

The rotation transformation of the "linear" photon wave to a "curvilinear" one can be conditionally written in the following form:

$$\hat{R}\Phi \rightarrow \Phi' , \qquad (5.3.1)$$

where $\hat{R}$ is the rotation operator for the transformation of a photon wave from linear state to curvilinear state, and Φ' is some final wave function:

$$\Phi' = \begin{pmatrix} \Phi'_1 \\ \Phi'_2 \\ \Phi'_3 \\ \Phi'_4 \end{pmatrix} = \begin{pmatrix} \mathrm{E}'_x \\ \mathrm{E}'_z \\ i\mathrm{H}'_x \\ i\mathrm{H}'_z \end{pmatrix}, \qquad (5.3.2)$$

which appears after the nonlinear transformation (5.3.1); here, $\left(\mathrm{E}'_x \quad \mathrm{E}'_z \quad -i\mathrm{H}'_x \quad -i\mathrm{H}'_z \right)$ are electromagnetic field vectors after the rotation transformation, which correspond to the wave functions Φ'.

It is known that the transition of vector motion from linear to curvilinear state is described by differential geometry (Eisenhart, 1960). Note also that this transition is mathematically equivalent to a vector transition from flat space to curvilinear space, which is described by Riemann geometry. In relation to this, let us remind ourselves that the Pauli matrices, as well as the photon matrices, are the space rotation operators – 2-D and 3-D accordingly (Ryder, 1985).

3.4.1. ***The rotation transformation description in differential geometry***

Let us consider a plane-polarized EM wave, which has the field vectors $(\mathrm{E}_x, \mathrm{H}_z)$ (see fig. 5.2):

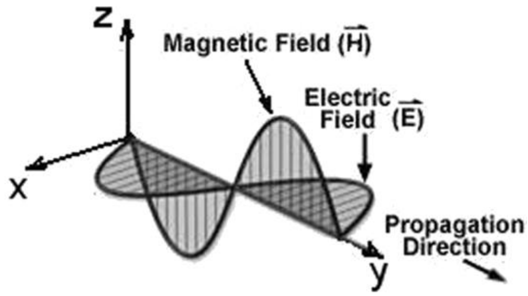

Fig. 5.2

Let this wave is rotated, by some radius r_p, in the plane (X',O',Y') of a fixed co-ordinate system (X',Y',Z',O') around the axis Z', so that E_x is parallel to the plane (X',O',Y'), and H_z is perpendicular to this plane (fig. 5.3).

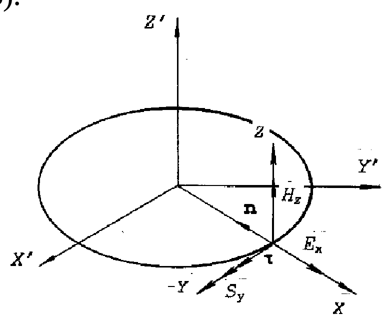

Fig. 5.3

According to Maxwell, the following term of equations (b) $\hat{\alpha}_0 \hat{\varepsilon}\Phi = i\hbar \frac{\partial \Phi}{\partial t}$ contains the Maxwell's displacement current, which is defined by the expression:

$$j_{dis} = \frac{1}{4\pi}\frac{\partial \vec{\mathrm{E}}}{\partial t}, \qquad . \qquad (5.3.3)$$

The electrical field vector $\vec{\mathrm{E}}$ above, which moves along the curvilinear trajectory (assume its direction is from the center), can be written in the form:

$$\vec{\mathrm{E}} = -\mathrm{E} \cdot \vec{n}, \qquad (5.3.4)$$

where $\mathrm{E} = \left|\vec{\mathrm{E}}\right|$, and $\vec{n}$ is the normal unit-vector of the curve, directed to the center. Then, the derivative of $\vec{\mathrm{E}}$ can be represented as follows:

$$\frac{\partial \vec{\mathrm{E}}}{\partial t} = -\frac{\partial \vec{\mathrm{E}}}{\partial t}\vec{n} - \mathrm{E}\frac{\partial \vec{n}}{\partial t}, \qquad (5.3.5)$$

Here, the first term has the same direction as $\vec{\mathrm{E}}$. The existence of the second term shows that at the rotation transformation of the wave an additional displacement current appears. It is not difficult to show that it has a direction tangential to the ring:

$$\frac{\partial \vec{n}}{\partial t} = -\upsilon_p \mathrm{K}\vec{\tau}, \qquad (5.3.6)$$

where $\vec{\tau}$ is the tangential unit-vector, $\upsilon_p \equiv c$ is the electromagnetic wave velocity, $\mathrm{K} = \frac{1}{r_p}$ is the curvature of the trajectory, and r_p is the curvature radius. Thus, the displacement current of the plane wave moving along the ring can be written in the following form:

$$\vec{j}_{dis} = -\frac{1}{4\pi}\frac{\partial \mathrm{E}}{\partial t}\vec{n} + \frac{1}{4\pi}\omega_p \mathrm{E}\cdot\vec{\tau}, \qquad (5.3.7)$$

where $\omega_p = \frac{m_p c^2}{\hbar} = \frac{\upsilon_p}{r_p} \equiv c\mathrm{K}$ is an angular velocity. Furthermore, here, $m_p c^2 = \varepsilon_p$ is photon energy, where m_p is some mass, corresponding to the energy ε_p.

Obviously, the terms $\vec{j}_n = \frac{1}{4\pi}\frac{\partial \mathrm{E}}{\partial t}\vec{n}$ and $\vec{j}_\tau = \frac{\omega_p}{4\pi}\mathrm{E}\cdot\vec{\tau}$ are the normal and tangent components of the displacement current of the rotated electromagnetic wave accordingly. Thus:

$$\vec{j}_{dis} = \vec{j}_n + \vec{j}_\tau, \qquad (5.3.8)$$

This is a remarkable fact that the currents $\vec{j}_n$ and $\vec{j}_\tau$ are always mutually perpendicular, so that we can write (5.3.8) in complex form as follows:

$$j_{dis} = j_n + ij_\tau, \qquad (5.3.8')$$

where $j_n = \frac{1}{4\pi}\frac{\partial \mathrm{E}}{\partial t}$ is the absolute value of the normal component of the displacement current, and

$$j_\tau = \omega_p \frac{1}{4\pi}\mathrm{E} \equiv \frac{m_p c^2}{\hbar}\frac{1}{4\pi}\mathrm{E} \equiv \frac{\upsilon_p}{r_p}\frac{1}{4\pi}\mathrm{E} \equiv \mathrm{K}\frac{c}{4\pi}\mathrm{E}, \qquad (5.3.9)$$

is the absolute value of the tangential component of the displacement current.

Thus, the appearance of the tangent current leads to origination of the imaginary unit in a complex form of particles' equation. So, we can assume that the appearance of the imaginary unit in the quantum mechanics is tied to the appearance of tangent currents .

3.4.2. ***A description of the rotation transformation in curvilinear space of Riemann geometry***

We can consider the Maxwell-like wave equations (b) with the wave function (c) as Dirac's equation without mass. The generalization of the Dirac equation on the curvilinear (Riemann) geometry is connected to the parallel transport of the spinor in curvilinear space (Fock, 1929a,b; Fock and Ivanenko, 1929).

In order to generalize the Dirac equation in the form of Riemann geometry, we replace the usual derivative $\partial_\mu \equiv \partial / \partial x_\mu$ (where x_μ are the co-ordinates in the 4-space) with the covariant derivative, which will be sufficient:

$$D_\mu = \partial_\mu + \Gamma_\mu , \qquad (5.3.10)$$

where $\mu = 0, 1, 2, 3$ are the summing indices, and Γ_μ is the analogue of Christoffel's symbols in the case of spinor theory, which are called Ricci symbols (or connection coefficients).

When a spinor moves along a straight line, all the symbols $\Gamma_\mu = 0$, and we have the usual derivative. However, if the spinor moves along the curvilinear trajectory, not all Γ_μ are equal to zero, and in this case an additional term appears. Typically, the last term is not the derivative, but is equal to a product of the spinor itself with some coefficient Γ_μ, which is an increment in the spinor. It is easy to see that the tangent current j_τ corresponds to the Ricci connection coefficients (symbols) Γ_μ.

According to the general theory (Sokolov and Ivanenko, 1952), we can obtain as an additional term of equations (b) the following term: $\hat{\alpha}_\mu \Gamma_\mu = \hat{\alpha}_i c p_i + i \hat{\alpha}_0 p_0$, where p_i and p_0 are real values. Since the increment in spinor Γ_μ has the form and the dimension of the energy-momentum 4-vector, it is logical to identify Γ_μ with a 4-vector of the energy-momentum of the photon's electromagnetic field:

$$\Gamma_\mu = \{\varepsilon_p , c\vec{p}_p\}, \qquad (5.3.11)$$

where ε_p and p_p are the photon's energy and momentum respectively (not the operators). In other words, we have:

$$\hat{\alpha}_\mu \Gamma_\mu = \hat{\alpha}_0 \varepsilon_p + \hat{\vec{\alpha}} c\vec{p}_p , \qquad (5.3.12)$$

Taking into account that according to the law of conservation of energy $\hat{\alpha}_0 \varepsilon_p \mp \hat{\vec{\alpha}} c\vec{p}_p = \pm \hat{\beta} m_p c^2$, we can see that the additional term contains mass of the transformed wave as a tangential current (5.3.9).

3.4.3. ***Physical sense of the rotation transformation***

Let us examine what meaning the rotation transformation can have in contemporary physics.

In quantum field theory (see first chapter of book (Ryder, 1985)), it is shown that the rotation transformation of the particle's internal symmetry (which is also taking place in our case) is equivalent to a gauge transformation, which generates the gauge fields. Recall also (Ryder, 1985) that the matrices of gauge transformation are rotation matrices in the internal space of particles.

We can easily show the identity of both transformations if we represent the energy and momentum of the intrinsic field in equation (5.3.12), using the 4-potential A_μ, which is the gauge field within the framework of SM:

$$\hat{\alpha}_\mu \Gamma_\mu = \hat{\alpha}_0 \varepsilon_p + \vec{\hat{\alpha}} c \vec{p}_p = e \alpha_\mu A^\mu \qquad (5.3.13)$$

Our conclusion is also confirmed by the fact that the matrices of Pauli and Gell-Mann, that are generators of the gauge transformation of groups *SU*(2) and *SU*(3) respectively, describe rotations in 2- and 3-dimensional space accordingly. Thus, the transformation $\hat{R}$, described by the relationship (5.3.1), can be referred to as the gauge transformation, and the connection coefficients (symbols) of Ricci (or, in a general case, Christoffel's coefficients) are the gauge fields.

Thus, we can say that within the framework of NEPT the mass-free boson obtains its mass due to rotation (or gauge) transformation of particle fields. Let us note with regard to SM that in this case the role of the Higgs's boson serves the electromagnetic nuclear field. Moreover, this transformation simultaneously leads to the generation of an internal current in particle.

3.5. An equation of the massive intermediate photon

As it follows from the previous sections, some additional terms $K = \hat{\beta}\, m_p c^2$, corresponding to tangent components of the displacement current, must appear in equation (a) due to a curvilinear motion of the electromagnetic wave:

$$\left(\hat{\alpha}_o \hat{\varepsilon} - c\hat{\vec{\alpha}} \cdot \hat{\vec{p}} - K\right) \left(\hat{\alpha}_o \hat{\varepsilon} + c\hat{\vec{\alpha}} \cdot \hat{\vec{p}} + K\right)\Phi' = 0\,, \qquad (5.3.14)$$

Thus, in the case of the curvilinear transformation of the electromagnetic fields of a photon, we obtain the following Klein-Gordon-like equation with mass (Schiff, 1955), instead of equation (a):

$$\left(\hat{\varepsilon}^2 - c^2 \hat{\vec{p}}^2 - m_p^2 c^4\right)\Phi' = 0, \qquad (5.3.15)$$

This is remarkable that due to a rotation transformation of the initial photon the tangential current is formed. At the same time, the current characteristics are unambiguously related to the mass of transformed photon. This mass is equal to its energy divided by a square of the speed of light. This, by the way, explains why mass divergence in electron theory is always connected with the divergence of its electrical charge.

Equation (5.3.15) is similar to the Klein-Gordon equation. However, the latter describes the **scalar** field, i.e. the massive boson with zero spin of the type of the hypothetical Higgs boson (let us also recall that Higgs's mechanism of mass generation is based on the scalar equation of Klein-Gordon). . It is not difficult to prove, using an electromagnetic form that (5.3.15) is an equation of a massive **vector** particle.

As we can see, the Φ'-function that appears after the transformation of the electromagnetic wave, and that satisfies equation (5.3.15), is not identical to the Φ-function before the transformation. The Φ-function is a classical linear electromagnetic wave field that satisfies the wave equation (a). At the same time, the Φ'-function is a non-classical curvilinear electromagnetic wave field that satisfies equation (5.3.15).

Moreover, equation (5.3.15), whose wave function is a 4×1- matrix with electromagnetic field components, *cannot be a scalar field equation.* Let us analyze the objects, which this equation describes.

It follows from the Maxwell's equations that each of the components E_x, E_z, H_x, H_z of vectors of the EM wave fields $\vec{E}, \vec{H}$ is included into the same scalar wave equations. In the case of a linear wave, all field components are independent. So, studying each of $\vec{E}, \vec{H}$ vector components, we can consider the vector field as scalar. However, we cannot proceed to scalar theory after the curvilinear transformation when a tangential current appears. In fact, the components of vector $\vec{E}'$ are not independent functions, as it follows from the condition (which is the Maxwell law) $\vec{\nabla}\cdot\vec{E}' = \frac{4\pi}{c}\vec{c}^{\,0}\cdot\vec{j}$, where $\vec{c}^{\,o}$ is a unit vector of wave velocity.

With this regard, this equation plays a role of the Procá equation. The Procá equation can be recorded in a form, similar to equation (5.3.15)

$$\left(\hat{\varepsilon}^2 - c^2\hat{\vec{p}}^{\,2} - m_p^2 c^4\right)A_\mu = 0, \qquad (5.3.16)$$

As it is known (Ryder, 1985), this equation is considered in SM as equation of intermediate bosons. The Procá equation is an equation for a four-dimensional vector potential, which can be used to describe a massive particle with spin equal to one.

The difference of (5.3.16) from the equation (5.3.15) lies in the fact that the free term of Procá equation is written through the 4-potential and is not gauge invariant in the case when m_p is a particle mass. In our case the mass term is expressed through the field strengths, i.e., through the wave function itself, and does not disrupt the invariance of the equations. In order to avoid difficulties of the designation, we will call the equation (5.3.15) the equation of "nonlinear photon" or the "equation of intermediate massive photon".

According to the results presented above, we need to assume that the more detailed Feynman's diagram of photoproduction of an electron-positron pair must include a massive intermediate photon. So, the diagram must have the following form (Fig. 5.4):

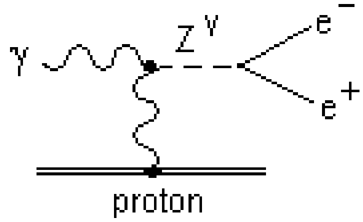

Fig. 5.4.

where we designated the nonlinear photon Z^{γ} like as an neutral intermediate massive Z^0-boson, described by the electro-weak theory within the framework of the Standard Model

The Lagrangian of the equation (5.3.16) can be written in the form:

$$L = D_\mu \Phi'^{+} D^\mu \Phi' = \partial_\mu \Phi'^{+} \partial^\mu \Phi' - \Phi'^{+} m_p^2 c^4 \Phi' , \qquad (5.3.17)$$

where the term containing the boson mass can be represented as a first approximation in view:

$$\Phi' m_p^2 c^4 \Phi' = \frac{\Delta\tau}{8\pi} \Phi' \left[\left(\Phi'^{+} \hat{\alpha}_0 \Phi' \right)^2 - 4 \left(\Phi'^{+} \hat{\vec{\alpha}} \Phi' \right)^2 \right] \Phi' , \qquad (5.3.18)$$

and describes in the nonlinear theory the self-action of the particles fields.

(Note that this mathematics has some common features with Higgs's mechanism in SM).

4. Sources of mass in the electroweak theory of SM (Quigg, 2007)

We build the standard model of particle physics[3] on a set of constituents that we regard provisionally as elementary: the quarks and leptons, plus a few fundamental forces derived from gauge symmetries. The quarks are influenced by the strong interaction, and so carry *colour*, the strong-interaction charge, whereas the leptons do not feel the strong interaction and are colourless. We idealize the quarks and leptons as pointlike, because they show no evidence of internal structure at the current limit of our resolution ($r \le 10^{-18}$ m).

The electroweak theory is a gauge theory, in which interactions follow from symmetries. Already in the 1932 Fermi Fermi, 1933) proposed descriptions of the weak interaction in analogy to the emerging theory of quantum electrodynamics (QED). The correct electroweak gauge symmetry, *emerged through trial and error*, guided by experiment. Here we have idealized the neutrinos as massless

The $SU(2)_L \otimes U(1)_Y$ electroweak gauge group implies two sets of gauge fields: a weak isovector $\vec{b}_\mu$, with coupling constant *g*, and a weak isoscalar A_μ, with independent coupling constant *g*'.

Although the weak and electromagnetic interactions share a common origin in the $SU(2)_L \otimes U(1)_Y$ gauge symmetry, their manifestations are very different. Electromagnetism is a force of infinite range, while the influence of the charged-current weak interaction responsible for radioactive beta decay only spans distances shorter than about 10^{-15} cm. The phenomenology is thus at odds with the theory we have developed to this point. The gauge Lagrangian contains four massless electroweak gauge bosons, namely $A_\mu, b_\mu^1, b_\mu^2, b_\mu^3$, because a mass term such as $\frac{1}{2}m^2 A_\mu A_\mu$ is not invariant under a gauge transformation. Nature has but one: the photon.

To give masses to the gauge bosons and constituent fermions, we must hide the electroweak symmetry, recognizing that a symmetry of the laws of Nature does not imply that the same symmetry will be manifest in the outcomes of those laws. How the electroweak gauge symmetry is spontaneously broken – hidden -to the $U(1)_{em}$ phase symmetry of electromagnetism is one of the most urgent and challenging questions before particle physics.

The superconducting phase transition offers an instructive model for hiding the electroweak gauge symmetry^. To give masses to the intermediate bosons of the weak interaction, we appeal to the Meissner effect - the exclusion of magnetic fields from a superconductor, which corresponds to the photon developing a nonzero mass within the superconducting medium. What has come to be called the Higgs mechanism is a relativistic generalization of the Ginzburg-Landau phenomenology (Ginzburg and Landau, 1950) of superconductivity.

Let us see how spontaneous symmetry breaking operates in the electroweak theory. We introduce a complex doublet of scalar fields

$$\phi \equiv \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}, \qquad (5.4.1)$$

with weak hypercharge $Y_\phi = +1$. Next, we add to the Lagrangian new (gauge-invariant) terms for the interaction and propagation of the scalars,

$$L_{scalar} = \left(D^\mu \phi\right)^+ \left(D_\mu \phi\right) - V\left(\phi^+ \phi\right), \qquad (5.4.2)$$

where the gauge-covariant derivative is

$$D_\mu = \partial_\mu + i\frac{g'}{2} A_\mu Y + i\frac{g}{2}\vec{\tau}\cdot\vec{b}_\mu, \qquad (5.4.3)$$

and (inspired by Ginzburg and Landau) the potential interaction has the form

$$V\left(\phi^+\phi\right) = \mu^2\left(\phi^+\phi\right) + |\lambda|\left(\phi^+\phi\right)^2, \qquad (5.4.4)$$

We are also free to add gauge-invariant Yukawa interactions between the scalar fields and the leptons (*l* runs over e, μ, τ as before),

$$L_{Yukawa-l} = -\zeta_l\left[\left(\bar{\mathrm{L}}_l \phi\right)\mathrm{R}_l + \bar{\mathrm{R}}_l\left(\phi^+ \mathrm{L}_l\right)\right], \qquad (5.4.5)$$

and similar interactions with the quarks.

We then arrange their self-interactions so that the vacuum state corresponds to a broken-symmetry solution. The electroweak symmetry is spontaneously broken if the parameter μ^2 is taken to be negative. In that event, gauge invariance gives us the freedom to choose the state of minimum energy - the vacuum state - to correspond to the vacuum expectation value

$$\langle \phi \rangle = \begin{pmatrix} 0 \\ \upsilon/\sqrt{2} \end{pmatrix}, \quad (5.4.6)$$

where $\upsilon = \sqrt{-\mu^2/|\lambda|}$.

Let us verify that the vacuum of (5.4.6) does break the gauge symmetry $SU(2)_L \otimes U(1)_Y \longrightarrow U(1)_{em}$. The vacuum state $\langle \phi \rangle$ is invariant under a symmetry operation corresponding to the generator G provided that $e^{i\alpha G}\langle \phi \rangle = \langle \phi \rangle$, i.e. if $G\langle \phi \rangle = 0$. Direct calculation reveals that the original four generators are all broken, but electric charge is not. The photon remains massless, but the other three gauge bosons acquire masses, as auxiliary scalars assume the role of the third (longitudinal) degrees of freedom.

5. Gravitation and mass of particles

According to the relativistic gravitation theory of Einstein-Hilbert, the gravitational field is not just coupled to mass, it's coupled to the stress-energy tensor which includes energy, momentum and stress. For example gravitation couples to photons, which have no mass. But the gravitation force of the bodies in rest (non-relativistic case) is determined almost entirely by the masses of these bodies.

Based on the above theories of mass of particles in the SM and NTEP let us compare the possibility of including the theory of gravitation in the frameworks of both theories.

5.1. Gravitation and SM

Let us consider at first, what is the relationship between the Higgs mechanism and the gravitational field.

From SM theory follows that the rest mass of particles is an effect produced by the Higgs field (or Higgs vacuum), which is universally everywhere and time independent. Not the Higgs boson which has a lifetime of perhaps 10^{-25} sec and is an excitation of the Higgs field. The Higgs boson has its own mass because of its nonlinear self-interaction.

The Higgs mechanism is what permits quarks, leptons and weak bosons to have rest mass in a way which does not violate gauge invariance. This does not mean mass in general, since mass can arise from other sources. The mass of nucleons, for example, comes almost entirely from the kinetic energy of the gluons within it, not the rest mass of the quarks.

The quarks contribute no more than 2% from the 939 MeV mass of nucleon. Thus, hadrons, such as the proton and neutron, represent matter of a novel kind. In contrast to macroscopic matter, the mass of a nucleon is not equal to the sum of its constituent masses - quarks; it is, basically, a confinement energy of gluons!

The mass of electrons in atoms is negligible compared to the mass of the nucleosn. Thus the mass of material bodies, mainly - more than 98% - is determined by energy-mass of gluons. From this follows that the Higgs mechanism is not connected at all to gravity.

5.2. Gravitation and NTEP

In NTEP, a picture of mass generation and mass behavior is consistent and complete. Here in contrast to the SM, there is no need to use the method of trials and errors (see above a note from (Quigg, 2007)) . In NTEP all the space is occupied by the electromagnetic vacuum excitations, which are virtual and real massless photons and massive elementary particles.

Photons themselves have no mass, but they have energy. Therefore, any set of photons, encased in a confined space, has a mass corresponding to the total energy of the photons . All elementary particles except for photons acquire the rest mass, due to self-action of EM fields of these particles, by the mechanism, which is described in NTEP. In this scheme it is assumed that the wave field of the particle, due to self-action, is closed in a limited space. This ensures the existence of a universal formula of Einstein for the rest mass.

Stability or metastability (i.e., temporal stability) of the particles is provided by a permanent or temporary equilibrium of the forces of interaction of the particle fields. Since energy and other characteristics of the fields at the same time must be precisely defined, the same definition should have the rest mass of the particle. In this regard, each particle has a certain characteristic value of the mass.

Since all of the elementary particles arise from the rotation transformation of their own fields, all the particles have constant or alternate electromagnetic currents, or, as integral values, charges. These currents and charges provide the appearance of various forces: electromagnetic, weak and strong. All of these interactions occur through electromagnetic interaction, i.e., they can be described by the same unified theory.

As shown already in classical electrodynamics, the motion of charged particles through an EM vacuum, is associated with their deformation and emergence of resistance forces of vacuum . The mass of the particles, tend to grow at a velocity according to the Lorentz transformation. This means that at constant velocity a particle conditionally acquires an additional mass, associated with the speed. If body accelerates, this additional mass continuously increases in depending on the velocity. All this is confirmed by experiment with a high degree of accuracy. This picture overlaps with the picture that emerges in the SM

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