THE POSSIBLE ROLE OF SALAM'S EFFECT IN FUNDAMENTAL INTERACTIONS UNIFICATION

R.G. Ragachurin

Institute of Nuclear Physics, Tashkent, Uzbekistan

1 SALAM’S RANGE

The effect of the rest mass compensation (Salam’s effect [1]) can play an important role in the unification of the fundamental interactions if one adresses to the field equation of the energy conservation. According to [2], this equation is

$$\frac{\partial}{\partial t} \left\{ \int W dv + E_r \right\} = - \oint \vec{f} d\vec{s},$$

where $W$ is the density of the field energy, $E_r$ is the relativistic kinetic energy of particles, $\vec{f}$ is Pointing’s vector, $dv$ and $d\vec{s}$ are the elements of volume and surface respectively.

One of the important features of Salam’s effect is connected with the formation of a potential barrier around the particle whose rest mass is spent on the barrier formation. This barrier is important for the consideration of stationary solutions of equation (1), when in the left hand side the time derivative from the sum should be zero. This condition is satisfied if the surface integral in the right hand side is equal to zero too that is possible in the case when ingoing and outgoing energy fluxes are equal in the absolute quantity. The ingoing flux is arising from an external field and outgoing - from Salam’s barrier. Due to their equality the stationary interaction of a particle with an external field becomes possible. Thus, one of Salam’s effect features is connected with the maintenance of this stationary condition.

The influence of the effect can be performed in some range which is determined by variations of the external field and the relativistic kinetic energy $E_r$. The presence of the range borders is caused by the limited rest mass of the particle. One of the borders arises at zero influence of the external field (the particle infinitely far from a field source) and minimum possible relativistic kinetic energy $E_r$ (rest energy). There is no necessity for the barrier formation in this case. The second border arises in the case when all rest mass is spent on the maintenance of the stationary condition and further increase of the external field and relativistic kinetic energy

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$E_r$ cannot result in the formation of the stationary states. The range of the effect action is defined as Salam’s range.

## 2 RELATIVITY AND GEOMETRIZATION PRINCIPLE

The choice of the geometrization principle plays the important role too. The choice is defined by the presence of the relativistic kinetic energy $E_r$ in equation (1),

$$E_r = mv^2[1 - (v/c)^2]^{-1/2},$$

where $m$ is the rest mass of the particle, $v$ is its speed and $c$ is the speed of light in vacuum.

The expansion of the relativistic kinetic energy $E_r$ in McLoren’s series on speed $v = 0$ is

$$E_r = mc^2 + (1/2)m v^2 + (3/8)m v^4/c^2 + (5/16)m v^6/c^4 + ... \quad (3)$$

There are only terms with even degrees of the ratio $(v^2/c^2)^n$ in the equation (3). The absence of the odd terms is connected with the equality of relevant derivatives in McLoren’s series to zero.

The interesting feature of the equation (3) is connected with the second term which defines the nonrelativistic kinetic energy $E_k$. Higher degrees terms also have physical meaning of an energy but differ from the nonrelativistic energy $E_k$. Their presence allows to use the potential geometrization principle according to which changes of the field potential energy should be equal to changes of the nonrelativistic kinetic energy $E_k$. Then the sum

$$E_{r3} = (3/8)m v^4/c^2 + (5/16)m v^6/c^4 + ... \quad (4)$$

has the important physical meaning. Our task is to show that the sum (4) defines the energy of the gravitational interaction under special circumstances to be specified.

## 3 THE EFFECTIVE VOLUME OF SALAM’S BARRIER

The role of Salam’s barrier effective volume (which is defined by the effective radius $r_{eff}$ in the spherical approximation) is important at the consideration of the stationary solutions of the equation (1).

Let us assume, that the interaction of the particle with the field is executed inside Salam’s range. Then the left hand side of the equation (1) must be zero or

$$\int Wdv + E_r = \text{Const.} \quad (5)$$
It is necessary to consider interaction conditions at the case of the particle infinitely far from a source of the field, minimal possible value of the relativistic kinetic energy $E_r$ and zero considered volume. If the distance of the particle from the field source is determined by the generalized coordinate $R$, the minimal value of the relativistic kinetic energy $E_r$ - by $mc^2$ (the rest energy), then it follows from the expression (5) that at the infinity $R_\infty$ and at zero volume

$$Const = mc^2$$

and therefore

$$\int Wdv + E_r = mc^2. \quad (6)$$

The equation (6) is defined as the stationary one which area of the solutions is inside Salam’s range. It is assumed that the variations of the nonrelativistic kinetic energy $E_k$ are only connected with the central interaction and do not depend on the integration volume.

It follows from the equation (6) that

$$E_r = mc^2 \quad (7)$$

at the coordinate $R_\infty$ and the zero volume. The last is the first border of Salam’s range.

Let the volume increases at the same value of the coordinate $R_\infty$. The contribution to the space integral from the central interaction remains is being equal to zero in this case. However, this integral increases due to the non-central interaction. The area of the field which is included in the space integral is defined as the effective volume of Salam’s barrier. The increase of the effective volume (increase of $r_{eff}$) should be accompanied by the equivalent decrease of the relativistic kinetic energy $E_r$ for the execution of the equation (6). The limit is reached in the case when all rest mass is transformed into the energy of the barrier. This case defines the second border of the range.

The limiting states of the particle are represented by points $a$ and $b$ in the figure 1. The energy stationary states are presented there at various coordinates $R$ and $r_{eff}$. The longitudinal variations are defined by $R$, and the lateral ones- by $r_{eff}$. The smooth curve represents the field energy variations which are connected to the potential energy $E_p$ with the negative sign. The field energy has a positive value, and the potential energy $E_p$ has the negative value in the connected systems. Therefore, the value $-E_p$ defines the field energy variations corresponding to the variations of the nonrelativistic kinetic energy $E_k$ in the connected systems. The connected systems are considered below.

The limiting states $a$ and $b$ are defined by the conditions

$$\left\{ \begin{array}{l} E_r = mc^2, \\
\int Wdv = 0, \\
 r_{eff} = 0; \end{array} \right. \quad (8a)$$

and

$$\left\{ \begin{array}{l} E_r = 0, \\
\int Wdv = mc^2, \\
r_{eff} = r_{effm}, \end{array} \right. \quad (8b)$$
where the value $r_{effm}$ corresponds to the transformation of all rest mass into the barrier energy.

The borders of the range, similar to (8), exist at any value of the coordinate $R$. Particular values $E_r$, $\int W dv$ and $r_{eff}$ vary in dependence on the sum of the series (3) but the physical meaning of the borders is the same. The type (8a) borders define the maximal mass for the concrete $R$, and the type (8b) borders - a state in which this mass is completely transformed into the energy of the barrier.

The above mentioned discussion shows that the influence of Salam’s effect results in the additional coordinate $r_{eff}$ account. The coordinate $r_{eff}$ is connected to the energy lateral variations as against to the generalized coordinate $R$ which determines longitudinal ones.

4 THE PHYSICAL MEANING OF THE POTENTIAL ENERGY

The energies $\int W dv$ and $E_k$ grow with the decrease $R < R_\infty$. The integrated field energy grows due to the density $W$ increase. All terms of the series (3) with higher degrees should grow too because of the nonrelativistic kinetic energy $E_k$ increase. Therefore, the particle has to spend the whole rest mass for the increase effects compensation because the series (3) and (4) are infinite ones. As result, the exclusion of these series terms arises because of limiting $m$. The sequence of the terms exception is essential during this process.

The process of the exclusion is illustrated in the figure 1 by any state corresponding to the coordinate $R_o$. The various segments define the variations of the energy connecting to the different members of the equation (6).

The segment $R_o a'$ is equal (relative to the value $R_\infty$) to the variation of the field energy due to the central interaction. It should be equal to the variation of the nonrelativistic kinetic energy $E_k$ due to the geometrization principle action. This part is connected with the contribution of the space integral into the equation (6) and defines the scalar part of the interaction. This part should be taken into account twice due to independent entry of the space integral and the relativistic kinetic energy $E_r$ (due to the second term of the expansion (3)). The repeated account is represented by the segment $b'c$ which should be equal to the segment $R_o a'$ on energy value but differs from it on the physical meaning. The difference is connected with the fact that the quantity $R_o a'$ is defined by the variation of the longitudinal coordinate $R$, and the quantity $b'c$ - by the variation of the lateral coordinate $r_{eff}$. This part is connected with the vector interaction.

The particle should compensate the variations which are caused by the terms of the infinite series (4) in addition to the compensation of the energy variations which are connected to segments $R_o a'$ and $b'c$. But, according to the equation (6), it only has an energy part which is equal to the segment $a'b'$. The necessity of the exclusion of the terms quantity arises there.

The part of the interaction connected with the sum of the series (4) is defined as the tensor part of the interaction.

The division of the interaction on the scalar, vector and tensor parts is connected with distinction in their functional role.

The scalar part is connected to the change of the field energy relative to the coordinate $R_\infty$. 

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and consequently defines that event which have taken place during decrease of the coordinate
$R$ before appearance of the particle in the considered point of the space ($R_o$ is in the figure 1).

The vector part is connected to the lateral changes of the effective radius $r_{eff}$. Analogously
to the scalar part, it is connected with the event which has happened before appearance in the
considered point. However, it limits Salam’s range on the part of the smaller values of the rest
mass on the contrary to the scalar part.

The functional role of the tensor part is connected with the cross changes of the effective
radius $r_{eff}$. The meaning of its allocation in the separate part is connected with its potential
influence. One can easily see that the following expression

$$mv^2 = mc^2 - E_{r3},$$

(9)
is true for any value of the coordinate $R$.

It follows from the expression (9) that the increase of the quantity $mv^2$ occurs due to the
decrease of the tensor part $E_{r3}$. Therefore, the quantity $E_{pl}$ defined from the equality

$$E_{pl} = -E_{r3}$$

(10)
is responsible in fact for the potential energy of the field. In any space point $R_o$ this energy
has the meaning of the energy stock which will be transformed into the nonrelativistic kinetic
energy at the decrease $R < R_o$. Thus, the functional division of the interaction on three parts
in the lateral direction leads to the division of the space in the longitudinal one.

The action of the potential energy $E_{pl}$ has an unexplicit character. It leads to the compensa-
tion of all members of the series (4). Therefore, the particle has only the scalar and vector
explicit components of the energy.

All terms of the energy $E_{r3}$ increase at the decrease $R < R_\infty$. Therefore, the summary
decrease of this energy [which is necessary for the increase of the energy $mv^2$ in the expression
(8)] can be executed only due to the decrease (relative to $R_\infty$) of the terms quantity in the series
(4). The process of the decrease is connected with the formal part of the series (3). This series
is obtained as a result of the expansion in McLoren’s series which is connected to the definition
of the derivatives $f(0), f'(0), f''(0)$ and etc. One can easily see that the double mechanism of
the series terms exclusion arises at the calculations of the derivatives $f^{2k}(0)$. It is connected
with the fact that the series (3) is power series in which the terms are located on the growing
degrees of $(v^2/c^2)^n$. When $k < n$, the terms in $f^{2k}(0)$ are excluded on the part of the small
degrees (because all of them are equal to zero) due to this property. When $k > n$, the terms
are excluded on the part of the high degrees due to the presence of the terms $\sim v^{2k}$. In result,
there is only one term (for which $k = n$) in $f^{2k}(0)$. The action of this double mechanism results
in the strict order of a position of the series terms in the segment $a'b'$ - the first segment has
to represent the first term of the series (4), the second one - the second term and so one. This
feature is represented by the points 1 and 2 at the coordinate $R_o$ in the figure 1. The segment
$a'1$ represents the first term of the series (4), 12 - the second one and so on.

One can see that the whole segment $a'b'$ represents the discrete sum of the segments with
the strictly certain length for each term and with the strict order of the position of all terms.
This order can not be changed without the special external influence on the closed system (for
example, to present a segment \(a'1\) as the sum of the several terms with higher degrees). The strict order of the position leads to the integer number of the derivatives which enter into the segment \(a'b'\). The stationary equation (6) is satisfied only in this case.

One can wait that the process of the decrease of the terms of the series (4) is connected with the curvature of the space representation of the Salam’s barrier due to the strict order and integer number of the derivatives. Then, the first stationary state is connected with the exclusion of the first derivative (relative to \(R_\infty\)), the second one - with the second derivative and so on.

### 5 A CYCLE OF GAUGE TRANSFORMATIONS

Some results presented here after can be obtained with the analysis of the parallel displacement of the unit vector (first considered by Weyl [3]). However, our results definitely show that the length of the vector is meaningful. The correlation between pseudo-euclidean and riemannian spaces (first mentioned in works [4-7]) has the important meaning too. Besides, the model gives the clear physical understanding of the phenomenon.

In the model the length of the vector is connected to the quantity of the derivatives which are excluded from the series (4) at the transition between two adjacent stationary states. The curvature characteristics of Salam’s barrier and the variation of the angular momentum do not depend on the length of the vector. However, the functional completeness of the stationary states is violated at such transition.

The model gauge transformations are based on the representation of one cycle. This cycle is connected with the transition from scalar to tensor spaces and back. The model gauge transformations are similar to Weyl’s ones.

The understanding of the physical meaning of the rest mass is necessary for the elucidation of the role of the model gauge cycle. One has to come back to consideration of the borders of Salam’s range at the coordinate \(R_\infty\) (the section 3). This consideration shows that the meaning of the field compressed in some curvilinear volume can be attributed to the rest energy. The rest mass defines the energy compression in the lateral direction at \(R_\infty\). Such object is retained in the stationary state by the equality of the external field energy to internal one in its volume.

At the decrease \(R < R_\infty\) the volumes of the Salam’s barriers are decreased. Therefore, the part of the internal energy become free due to the volumes decrease. According to the previous section, this part must be defined by the corresponding derivative of the series (4). The energy of this part, which is defined by the lateral coordinate \(r_{eff}\), is transformed into the energy of variation of the longitudinal coordinate \(R\) (nonrelativistic kinetic energy \(E_k\)) at one gauge cycle. Three various space areas (scalar, vector and tensor ones) correlate at such cycle. The scalar area is represented by symbol I, the vector - by symbol II and the tensor - by symbol III in the figure 1.

The model cycle is defined by one elementary segment which is excluded in the process of the decrease of the terms quantity of the series (4). One elementary lateral segment is transformed in a longitudinal one with help of such cycle. The scale of such transformation is defined by the functional dependence \(-E_p(R)\). The consequential recurrence of such cycles leads
to the strict sequence of the longitudinal elementary segments $\Delta R_i$ due to the strict sequence of the lateral ones. In this sequence each segment in the scale $-E_p(R)$ reproduces the appropriate term of the series (4).

The considered mechanism has the important property - the curve $-E_p$ plays a role of a string connecting all possible stationary states inside Salam’s range.

Some common conclusions can be received by the consideration of one elementary cycle. Such cycle is represented by the dush line $a R_o a' 1 d'$ in the figure 1. This line is formed as a result of three transitions. The first transition occurs from the point $a$ which is located on the curve $-E_p$ (the border between the scalar and tensor areas) to a point $R_o$. The second transition occurs from the point $R_o$ to the state $1$ and is connected with motion from the scalar to the tensor area. At last, the third transition occurs from the point $1$ to the point $d'$ before the crossing with the curve $-E_p$. One can see that the first transition images on the longitudinal direction in the scale $-E_p$ an interval $\Delta R$ corresponding to the second term of the series (3) - $mv^2/2$. The second transition reproduces before the crossing with the curve $-E_p$ value $mv^2/2$, and after crossing up to the point $1$ - the value of the first term of the series (4). At last, the third transition images this term on the axis $R$ in the appropriate scale. One can see that the consecutive recurrence of the gauge cycles results in consecutive projection of all terms of the series (4).

All gauge cycles have three topological features which are important for the further discussion:
1. All gauge cycles are formed with help of three transition connected with three movements between scalar and tensor areas;
2. Considered values have the phase shift on an angle $\pi$ at the tensor area (For example, the rest mass has a maximal value at the bottom border; the spacing of the segments which define the value of the nonrelativistic kinetic energy $E_k$ [relative to the segments which define the corresponding variation of the coordinate $R$] has the phase shift on the same angle relative to the scalar area etc.]. An input from the scalar area to tensor one on the lateral part of the cycle and then the output on the longitudinal part can be treated as rotation of the system on an angle $2\pi$ due to this feature;
3. The point of the crossing with the curve $-E_p$ defines the beginning or end of an elementary segment on any transition. The states which are located on the edges of the transition (for example, $R_o$ and $1$ in the figure 1) can be considered as the states having the common point on the curve $-E_p$ due to this property.

6 THE ROLE OF THE MASSIVE PARTICLE UNLOCAL STRUCTURE IN TWO-PARTICLES INTERACTION

Three common properties which were considered in the previous section are important in the consideration of two-particles interaction. Such consideration requires explicit dependence of
According to [2],
\[ W = \frac{E^2 + H^2}{8\pi} , \]
where \( E \) and \( H \) are the intensity of electrical and magnetic fields, respectively.

The magnetic field is assumed to be zero in our research, and \( E \) is defined by Coulomb interaction of two particles with electrical charge \( \pm e \) (hydrogen atom)
\[ E = \pm e/R^2 . \]

The expressions (11) and (12) are used in the volume integral of the equation (6). The integration will be carried out on the effective volume of Salam’s barrier which is defined by the effective radius \( r_{\text{eff}} \). The account of the independence of the coordinates \( R \) and \( r_{\text{eff}} \) results in
\[ (m - m_{\text{cc}})c^2 = (1/6)(r_{\text{eff}}/R)^3 e^2 / R . \]

The right hand side of the last equation grows up due to account of the central interaction. The term \( m_{\text{cc}} \) in the left hand side of (13) is the varying quantity and implicitly characterizes the rest mass which has been left at the particle after the compensation of the central and non-central interactions.

The expression (13) shows that the location of a state with respect to the curve \( e^2 / R \) (in the considered system it represents the curve -\( E_p \)) is defined by the ratio \( r_{\text{eff}}/R \). The double physical meaning is attributed to this value in the model. On the one hand, it is connected with the curvature of the spatial representation of Salam’s barrier. On the other hand, it characterizes the distribution of the barrier along the generalized coordinate \( R \) (interaction radius) and consequently can be connected with the wave function in its probability interpretation. The gauge transformations arise in this aspect as a result of the periodic recurrence of the states with the same value of the ratio \( r_{\text{eff}}/R \). The characteristic properties of the variations of this quantity along the gauge cycles are considered below for the confirmation of this statement.

It was mentioned in the section 6 that one cycle begins and ends by the states which are located on the curve -\( E_p \). It is
\[ -E_p = e^2 / R . \]
in the considered system. It follows from the expressions (13) and (14) that the beginning and end of the cycle correspond to the same value
\[ r_{\text{eff}}/R = 6^{1/3} \]

The numerical values of the ratio \( r_{\text{eff}}/R \) in other states can be determined with the account of the properties 1-3 of the section 6. The states which are located bellow \( e^2 / R \) are marked by the subscript \( e \) (\( r_e / R \)), and the states higher - by the subscript \( p \) (\( r_p / R \)). The system from two equations arises in this case
\[ \begin{cases} (m - m_{\text{cc}})c^2 = (1/6)(r_e/R)^3 e^2 / R ; \\
(M - M_{\text{cc}})c^2 = (1/6)(r_p/R)^3 e^2 / R . \end{cases} \]
The division of the second equation on the first one results in the expression

\[
\frac{M - M_{cc}}{m - m_{cc}} = \frac{(r_p/R)^3}{(r_e/R)^3},
\]

(17)

which connects the effective values of the rest masses to the appropriate values of the ratios \(r_e/R\) and \(r_p/R\). The expression (17) defines the ratio of the rest masses \(M/m\) in the limiting borders of Salam’s range.

Two cycles \(aR_o\) and \(d'd'd''f\) represent the first and second cycles of the gauge transformations in the figure 1.

The state \(R_o\) in the first cycle is located on the longitudinal axis that is zero value of barrier volume should be attributed to it. However, it is necessary to note that it is connected with the conventional location of the quantity \(e^2/R\) on infinity. Actually the nonvanishing value of this quantity should be attributed to this state.

The values \(r_e/R\) and \(r_p/R\) are not arbitrary. The connection between them is defined by the condition of the location of the point \(a'\) on the curve \(e^2/R\). This point corresponds to the termination of the term \(mv^2/2\) in the series (3) and the beginning of the term \((3/8)mv^4/c^2\) in the series (4). The point \(a'\) is the common point of these two segments in this aspect.

It follows from the first and second equation (16) that the common point should satisfy to the condition

\[
r_e/R = r_p/R = 6^{1/3}.
\]

(18)

By multiplying of the first equation (16) into the coordinate \(r_p\), one can get equation connecting the ratios \(r_e/R\) and \(r_p/R\) for any state

\[
(r_e/R)^3r_p/R = A,
\]

(19)

where

\[
A \equiv \frac{6(m - m_{cc})c^2r_p}{e^2}.
\]

(20)

One can see from the equation (19) that the condition of the equality

\[
r_e/R = r_p/R
\]

is satisfied for different values of \(A\) but the condition (18) is satisfied only in one case when the common point belong also to the curve \(e^2/R\). In other cases the common point lays above or below this curve. It follows from here that the considered values are connected among themselves by the relation

\[
(r_e/R)^3(r_p/R) = 6^{4/3}.
\]

(21)

One has to note that any state has two points of the crossing with the curve \(e^2/R\) - in the longitudinal and lateral directions. The parity (21) connects events both in one cycle (lateral transitions) and in consecutive cycles (longitudinal transitions) due to this fact. Analogous relation for the longitudinal transitions is

\[
(r/R_o)^3(r/R_p) = 6^{4/3},
\]

(22)

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where $R_e$ refer to area I and $R_p$ - to area II in the figure 1.

It follows from (21) and (22) that

$$\begin{cases}
  r_e/R = r/R_e; \\
  r_p/R = r/R_p
\end{cases} \quad (23)$$

for all gauge cycles. Two layers are formed in Salam’s range side by side with the layer $-E_p$ due to the relation (23). One of them defines the movement of the particle $p$ in the range and the other - of the particle $e$. These layers are distinguished by the various values of $r/R$.

One can define the values $r_e/R$ and $r_p/R$ at the unlocal representation of the barrier of the particle which is placed in the layer $r_p/R$. Such representation is based on the distinction of the physical properties of three layers forming the gauge cycle. The distinction arises at the point particle approximation.

The location of the point particle in the layer $-E_p$ is connected with the geometrization principle. Since the terms quantity of the series (4) defines the variation of the nonrelativistic kinetic energy $E_k$ relative to $R_\infty$, the beginning and end of any transition have to belong to the curve $-E_p$. In the considered system $r_e/R + r_p/R$ both particles are not located on $-E_p$. Therefore, the geometrization principle can not be satisfied at the transitions of the point particle between layers $r_e$ and $r_p$. At the same time, the location in this layers has the property which is important too. This property can be defined at the unlocal consideration which is connected with the model role of the electrical charge.

The role of the charge is connected with the transformation of the lateral segments into the longitudinal ones. The scale of this transformation is defined by the quantity $-E_p$ depending on the value of the charge. Therefore, the charge defines the compression of the field energy on the longitudinal direction on the contrary to the rest mass which defines the compression of the energy on the lateral one.

The definition of the charge role allows to define such transitions at which both the geometrization principle and property of the layers $r_e/R$ and $r_p/R$ are valid. The satisfaction of the both properties can be completed in this case when the particle has the part of the whole charge $+e$ in the state $r_p/R$. Then the state $r_e/R + r_p/R$ can be considered as the interaction of the particle which has the charge $-e$ with another particle having fractional charge. If the value of the fractional charge is agreed with the structure of the gauge cycle in the longitudinal direction, the whole charge $+e$ corresponds to one gauge cycle. Therefore, the interaction of two point particles with charges $\pm e$ can be considered as the interaction of the particle which localized at the beginning of the cycle with another particle which is located at the end of one. Such unlocal representation arises due to the space structure of the Salam’s barrier. This structure has been agreed with gauge cycle one. Therefore, the summary structure of the transition between adjacent states is the superposition of the gauge cycle and the structure corresponding to the transitions between the layers $r_e/R$ and $r_p/R$. The quantity of such transitions in one gauge cycle has to correspond to the whole charge $+e$. Then the fractional charge $q$ can be represented as

$$q = +e/l \quad (24)$$

due to the functional role of the charge ($l$ is the transitions quantity in one cycle). The last
relation represents average charge connecting to quantity of the transitions between the layers \( r_e/R \) and \( r_p/R \) in one cycle.

The transitions quantity \( l \) takes the integer values. The case of three transitions is of special interest. It is connected with quantity of the transitions which is equal to three according to the results of the previous section. If the quantity of the transitions between the layers \( r_e/R \) and \( r_p/R \) is also equal to three, then the sequence of the stationary states has the harmonic character connecting with the periodical reiteration of the all values of \( r/R \) in one cycle.

Two states \( R_o \) and \( d''b'' \) represent two adjacent states of the system \( r_e/R + r_p/R \) in the figure 1. The state \( R_o \) corresponds to \( r_e/R \) and the state 1 - to \( r_p/R \) in the first gauge cycle. Analogously, the state \( d'' \) corresponds to \( r_e/R \) and the state \( b'' \) - to \( r_p/R \) in the second one. One can see from the figure 1 that the quantity of the gauge transitions (connected with the crossing of the curve \( -E_p \)) between these states is equal to two \((R_o, 1 \rightarrow 1d'' \rightarrow d''b'')\). According to the results of the previous section, such quantity is equivalent to the rotation of the system on the angle \( 2\pi \). The double transition can not lead to the harmonic sequence. It has to be equal to three \((l = 3)\) in order to satisfy to this condition. However, it is impossible to pass from the space with index \( e \) (or \( p \)) to the space with the same index with help of three transitions between layers \( r_e/R \) and \( r_p/R \). This property is connected with the general property of the spinor objects - the rotation of the system on an angle \( 2\pi \) does not lead to the initial state [8]. The additional rotation on the same angle \( 2\pi \) is necessary due to this reason. The additional rotation on the same angle means the transition to the position of the end of the second gauge cycle. Finally, one can see that the system \( r_e/R + r_p/R \) comes into the initial state with help of two gauge cycles. Therefore, the value of \( l \) in the relation (24) is equal to six and the mean charge

\[
q = +e/6.
\]  

Thus, the system \( r_e/R + r_p/R \) can be treated as the interaction of the particle \(-e\) with the particle \(+e/6\) in the aspect of the gauge cycles. Then, the state of the first particle has to be decreased into six time in comparison with the state predicted by the curve \(-E_p\). Then, it follows from the first equation of the system (16) that

\[
\frac{r_e}{R} = 1.
\]  

By using of the last expression in the equation (21), one can obtain

\[
\frac{r_p}{R} = 6^{4/3}.
\]  

It is necessary to pay attention to the physical meaning of the relation (26). The interaction area is a sphere with the radius \( R \) at the central interaction. Then, the equality of the radii \( R \) and \( r \) means that the influence of the external field is compensated by Salam’s barrier in the interaction area. Therefore, the surface integral in the equation (1) is equal to zero and the stationary equation (6) is satisfied. If the quantity \( l \) is not equal to six, the value of \( r_e/R \) is changed. Then the influence of the external field is not compensated by Salam’s barrier and the equation (6) is not satisfied. Thus, the harmonic sequence of the stationary states, which is connected with the periodical reiteration of the all values of \( r/R \) in one gauge cycle, can be executed at one value \( l = 6 \).
The relation (27) has the important meaning together with (26). The mutual action of these relations allows to understand the role of the unlocal interaction of two particles. It is connected with two conditions of the gauge cycles - the geometrization principle and the necessity of the compensation of the external field influence in the interaction area. The first one is executed at location of the point particle on the curve $-E_p$. The second one is satisfied in the case of the location of such particle in the system $r_e/R + r_p/R$. The mutual execution of these conditions is possible only if Salam’s barrier of the particle $p$ is unlocal. At such representation it possesses the both necessary conditions. One can see that this fact is connected with dualistic representation ”wave-corpuscle” of the elementary particle.

The unlocal structure of the barrier defines the internal area of the coordinate $R$ in any stationary state. The interaction of the fractional electrical charge with charge $-e$ is essential in this area. Therefore, it corresponds to the strong interaction. Thus, the whole area of the coordinate $R$ variations is divided into three parts in two-particles interaction. The external part corresponds to the variation of the nonrelativistic kinetic energy $E_k$ (relative to $R_\infty$) in the right hand side from the fixed value $R_i$. The spacing of the double gauge cycles is important in this part. The second part is connected with the quantity (relative to $R_\infty$) of the terms of the series (4) at $R_i$. It defines the energy stock which will be transformed into $E_k$ when the coordinate $R$ decreases relative to $R_i$ in the one-particle approximation. The space of the transformation defines the third part of the area. The last one is the area of the strong interaction in the two-particles approximation.

The quantity of the terms of the series (4) decreases as $R$ decreases. The limit is the case when the quantity of the terms is equal to zero and the whole stock of the potential energy of the series (4) is exhausted. This limit is represented by the state $R_e$ in the figure 1. The presence of this limit is important property of the model. Its calculated value is about 5 Fm which is in agreement with the radius of nucleus. Since the point particle $p$ is located at the end of the gauge cycle and the particle $e$ - at its beginning, zero value of the quantity of the terms for the particle $p$ corresponds to unity value for the particle $e$. This property leads to unity value of the main quantum number for the particle $e$ in the end.

In fact the limiting state corresponds to the core of nucleus. Since the particle $p$ is located at the end of any gauge cycle, the core is presented in any one. The value of the coordinate $R$ (corresponding to the core) decreases as $R$ decreases. Thus any state defines two volumes of Salam’s barrier. The first one, corresponding to the location of the particle $e$, defines the maximal volume. The second one, corresponding to the localization of the particle $p$, defines the minimal volume. Therefore, the process of the coordinate $R$ decrease can be considered as consecutive process of the transitions between maximal and minimal values of Salam’s barrier.

The unlocal structure of the Salam’s barrier leads to variation of the mass in the lateral direction analogously to the longitudinal variation of the charge. Such variation is connected with the correction factor in the relation (17). The value of this factor is connected with the variation of the angular momentum.

It follows from the (16)

$$
\begin{align*}
(m - m_{cc})cR &= (1/6)(r_e/R)^3e^2/c; \\
(M - M_{cc})cR &= (1/6)(r_p/R)^3e^2/c,
\end{align*}
$$

(28)
which shows that the angular moments \((m - m_{cc})cR\) and \((M - M_{cc})cR\) do not depend on the value \(R\) and are constant in the all range of changes of \(R\). The variation of these moments \(\Delta P\) only occurs with transition between layers \(r_e/R\) and \(r_p/R\). It is necessary to distinguish the transitions between full gauge cycles (which correspond to two gauge cycles and full charge \(+e\)) and the transitions in the inner area of the gauge cycles (which correspond to fractional charge \(q\)).

The interior transitions are connected with the variation of the charge in the longitudinal direction and with the quantity of the ratio \((M - M_{cc})/(m - m_{cc})\) in the lateral one. Since the values of \(r_e/R\) and \(r_p/R\) do not change in whole Salam’s range, the variation \(\Delta P\) at one transition between layers is constant and the total variation \(\Delta P_l\) at \(l\) transitions is

\[
\Delta P_l = l\Delta P. \tag{29}
\]

The total quantity of the number interior transitions \(l\) correspond to net charge \(+e\). Then the relation (29) shows that \(\Delta P\) is compared to the some value of the elementary fractional charge which is repeated in all interior transitions at the longitudinal direction. The some elementary value of the ratio \((M - M_{cc})e/(m - m_{cc})\) (which is repeated at the lateral direction) is present analogously to the fractional charge. Then the summary variation \((M - M_{cc})/(m - m_{cc})\) is

\[
(M - M_{cc})/(m - m_{cc}) = l(M - M_{cc})e/(m - m_{cc}). \tag{30}
\]

If one does not take into account the unlocal structure of Salam’s barrier, the quantity of the transitions between states \(r_e/R + r_p\) in full gauge cycle (two gauge cycles) is equal to four. In this case

\[
(M - M_{cc})/(m - m_{cc}) = 4(M - M_{cc})/(m - m_{cc}), \tag{31}
\]

where \((M - M_{cc})/(m - m_{cc})\) corresponds to the value which is predicted by the relation (17).

It follows from (30) and (31)

\[
(M - M_{cc})/(m - m_{cc}) = (l/4)(M - M_{cc})e/(m - m_{cc}). \tag{32}
\]

The relation (32) shows that the correction factor in the ratio (17) is equal to \(l/4\) and this one is

\[
(M - M_{cc})/(m - m_{cc}) = (l/4)(r_p/R)^2/(r_e/R)^3. \tag{33}
\]

The substitution of \(l = 6\), the values (26) and (27) into the last relation leads to

\[
(M - M_{cc})/(m - m_{cc}) = 1944 \tag{34}
\]

which will be satisfactory coordinated with the ratio of proton and electron rest masses. The agreement can be even better if one takes into account that the difference \(\sim 50\) MeV can be treated as total mass defect which can be spent on connection energy between nucleons.

Since the quantity (34) corresponds to the only value of \(l\) satisfying to (26) and (27), the ratio of masses (34) defines the only particle \(p\) which can form the stationary pair with the particle \(e\). If the ratio is different from (34), the geometrization principle is satisfied but the condition (26) is violated. Therefore, such pairs can only form the quasi-stationary states which have not the harmonic reiteration (for example, the systems \(\mu^+ + e^-\) and \(e^+ + e^-\)).
The important confirmation of the model correctness gives numerical definition of the variation of the angular momentum $\Delta P$ at one transition between layers $r_e/R$ and $r_p/R$. It is equal to

$$\Delta P = \frac{1}{6}[(r_p/R)^3 - (r_e/R)^3]e^2/c$$  \hspace{1cm} (35)$$

according to relation (28). Inserting of the numbers of fundamental constants $e = 4.803 \cdot 10^{-10} CGSE$, $c = 2.998 \cdot 10^{10} cm/sec$, the relations (26) and (27) into the last expression gives

$$\Delta P = 1.661 \cdot 10^{-27} erg/sec.$$  \hspace{1cm} (36)$$

The last value coincides accurate up to second sign after point with

$$\Delta P = (\pi/2)\hbar,$$  \hspace{1cm} (37)$$

where $\hbar$ is Plank’s constant ($\hbar = 1.054 \cdot 10^{-27} erg/sec$). If one takes into account that two gauge cycles correspond to four transitions between the layers (26) and (27) in the external area of $R$ variations, then the summary variation $\Delta P_{gc}$ is

$$\Delta P_{gc} = 2\pi\hbar$$  \hspace{1cm} (38)$$

in this area. The last expression shows good agreement not only in value of $\hbar$, but also in angular correlations.

It is necessary to underline that the equality (38) takes place for the stationary pair of the particles with the ratio of the rest masses being in agreement with the relation (34).

The important confirmation of model correctness gives also numerical definition of the rest mass variation at transition between the adjacent pairs of the gauge cycles. It is necessary to take into account the correction factor $l/4$ in the expression (33) in such procedure. The constant of the gravitational interaction arises at the definition.

One can obtain with help of the expressions (21) and (22) the variation of the coordinate $R$ corresponding to two gauge cycles

$$R_k = \frac{(r_p/R)^6}{(r_e/R)^6}R_{k+2},$$  \hspace{1cm} (39)$$

where

$$R_{k+2} < R_k < R_\infty$$  \hspace{1cm} (40)$$

and $R_k \to R_{k+2}$ means the transition at two gauge cycles.

The first equation (16) leads to the expression

$$(m - m_{cc})k^2 = (1/6)(4/l)(r_e/R)^3e^2/R_k,$$  \hspace{1cm} (41)$$

for the state $k$ (with account of the correction factor $l/4$ in the expression (33)) relative to the state $k + 2$. The substitution of the relation (39) into the expression (41) with account of the equality (26) gives

$$(m - m_{cc})k^2 = \frac{\gamma e^2}{R_{k+2}},$$  \hspace{1cm} (42)$$
where
\[ \gamma = \frac{1}{6 \cdot 1.5 \cdot 6^8} = 6.61 \cdot 10^{-8}. \] (43)

The value (43) coincides accurate up to second sign after point with the constant of the gravitational interaction. It defines value \((m-m_{cc})k c^2\) with decreasing \(R\) on value corresponding to two gauge cycles. The coincidence shows that the potential stock of the energy \(E_{pl}\) at any space point can be considered as the stock of the energy of the gravitational interaction. According to relations (4) and (10), it is defined by
\[ E_{pl} = -(3/8)m v^4/c^2 - (5/16)m v^6/c^4 - \ldots \] (44)

Such definition means that the relation (9) corresponds to
\[ m v^2 = m c^2 + E_{pl}, \] (45)
which shows that the growth of the double quantity \(E_k\) occurs due to the decrease of the potential energy \(E_{pl}\) of the gravitational interaction.

Thus, the interaction with the potential energy \(E_{pl}\) defines three fundamental interactions - gravitational, electromagnetic and strong ones. It divides the whole area of the variations of the coordinate \(R\) changes into three parts. The external part (in the right hand side from the considered value \(R_1\)) corresponds to the electromagnetic interaction. It is connected with the variation of the nonrelativistic kinetic energy of the particle \(e\) in the longitudinal direction. The second part corresponds to the stock of the gravitational energy in the lateral direction. The third part corresponds to the internal area of Salam’s barrier of the particle \(p\). The interaction of the fractional electrical charge with charge \(-e\) is significant in this area. Therefore, it corresponds to the strong interaction.

It is necessary to underline, that the value (43) is obtained by use of the value of \(r_e/R = 1\) in the relation (41). The last one, only, corresponds to the interaction of the particle \(e\) with the particle \(p\), rest mass of which is determined by the ratio (34). If the rest mass of the one is different (the quasi-stationary pairs), the value of \(\gamma\) differs from the experimental value of the constant of the gravitational interaction. It means, that the experimental value of the gravitational constant corresponds to the gravitational field which is formed in the interaction of the electron with the proton. This conclusion can be of large interest. When quasi-stationary particles (which can form the quasi-stationary pairs with the electrons) hit earthly atmosphere (for example, the positrons at the higher sun activity) the areas of local infringements of the gravitational field with accompanying physical effects can arise. These areas can serve as the sources of the gravitational waves.

It is also necessary to underline another role of the particle \(e\). The interaction with it defines the stationary and quasi-stationary pairs of the particles for Salam’s range which is defined by the rest mass of the particle \(e\). These pairs differ by values of the quantum number \(l\) which is defined with the quantity of the transitions between layers \(r_c/R\) and \(r_p/R\). The possibility of the classification of the elementary particles, belonging to such range, arises there.
1. The gauge model of the fundamental interactions unification is offered. The model takes into account the influence of the effect of the rest mass compensation (Salam’s effect) in the field equation of the energy conservation. The stationary solutions of this equation are considered. The condition of the stationarity is ensured by the Salam’s barrier which is formed due to the transformation of the rest mass of the particle into its energy. The barrier compensates the influence of the external field in the considered volume. The formal condition of the compensation is the equality of the radii $R$ and $r$ in the spherical approximation. The radius $R$ defines the area of the interaction. This area is a sphere at the central interaction. The radius $r$ defines the effective volume of Salam’s barrier which compensates the influence of the external field. The condition of the equality of the radii is the first from two considered conditions.

2. The second condition is connected with the expansion of the relativistic kinetic energy into McLoren’s series. The nonrelativistic kinetic energy $E_k$ is the second term of this expansion. The geometrization principle (variations of the field potential energy should be equal to variations of the $E_k$) is used for the separation of the influence of $E_k$ from the influence of the sum of the terms of $E_{r3}$ with higher degrees. The execution of the geometrization principle is the second condition of the model. It is shown, that the action of Salam’s effect results in the separation of the influence of the coordinates $R$ and $r$. The influence of $R$ is connected with the longitudinal direction and the influence of $r$ - with the lateral one. The sum $E_{r3}$ defines, at the lateral one, the stock of the field energy which is transformed into $E_k$ at the decrease of $R$ at the longitudinal one. The area of the variations of $R$ is divided into three parts due to this property. These parts are connected with the arrangement of the considered value of $R_i$ relative to $R_\infty$. The first part is connected with the value of $E_k$ relative to $R_\infty$. It is formed due to the decrease of the terms quantity (relative to $R_\infty$) in $E_{r3}$. The second part corresponds to the quantity of this terms remaining in $E_{r3}$ (relative to $R_\infty$) in the lateral direction. The third part corresponds to the transformation of the remaining quantity of the terms into $E_k$ in the process of the decrease $R < R_i$.

3. Three parts of the variation of $R$ lead to the gauge cycle consisting of three gauge transitions. Two of them correspond to the longitudinal segments defining the transformation of $E_{r3}$ to $E_k$ in the right and left hand sides from $R_i$. The third transition corresponds to the quantity of the transformed parts of $E_{r3}$ in the lateral direction. The quantities of the gauge transitions are connected with three functional dependences from the generalized coordinate $R$. The first one represents the dependence of the field energy $-E_p$ which is equal to the potential energy on the absolute quantity, but has different sign in the connected systems. According to the geometrization principle, it defines the beginning and end of the gauge cycle. The second and third dependences are similar to the curve $-E_p$ and differ from it by the similarity coefficient. They define beginning and end of the lateral segment corresponding to the transformed parts of $E_{r3}$.

4. Three mentioned above curves differ from each other by the similarity coefficient. It is shown, that this one is defined by the ratio $r/R$ at Coulomb interaction of two particles with electrical charge $\pm e$. The double physical meaning is attributed to this ratio in the model. On the one hand, it is connected with the curvature of the spatial representation of Salam’s
barrier. On the other hand, it characterizes the distribution of the barrier along the generalized coordinate $R$ (interaction radius) and consequently can be connected with the wave function in its probability interpretation. The gauge transformations arise in this aspect as a result of the periodic recurrence of the states with the same values of the ratio $r/R$. Three dependences which were discussed above correspond to three layers with different values of $r/R$.

5. The character of the reiteration of all values of $r/R$ is important at the transitions between adjacent gauge cycles. The beginning and end of the gauge cycle always correspond to the same value of $r/R = 6^{1/3}$. This value corresponds to the curve $-E_p$ and is connected with the second condition of the model (execution of the geometrization principle). The quantities $r_e/R$ and $r_p/R$, corresponding to two other functional dependences of the gauge cycle, are connected with the first condition of the model (the necessity of the compensation of the external field influence by the Salam’s barrier in the area of the interaction). These quantities are connected with the internal structure of the gauge cycle. The beginning and end of the cycle are connected with each other by three gauge transitions. At the same time, the quantity of such transitions is equal to two at transitions between adjacent states $r_e/R + r_p/R$. Therefore, such transition can not be harmonic. The quantity of the gauge transitions have also to be equal to three at the transitions between adjacent states $r_e/R + r_p/R$. Then, the sequence of the stationary states have the harmonic character. The variation of the quantity of the gauge transitions in the interior of the gauge cycle divides the area of the coordinate $R$ variation into the internal and external parts. The variations of the angular momentum $[m - m_{cc}]cR$ and $[(M - M_{cc})cR]$ correspond to whole charge $+e$ at the interaction $\pm e$ in the external area. The variations of these momenta correspond to the interaction of the charge $-e$ with fractional charge $+e/l$ in the internal area ($l$ - the quantity of the gauge transitions between adjacent states $r_e/R + r_p/R$). The variations of the charge occur on the longitudinal direction. The variations of the ratio $(M - M_{cc})/(m - m_{cc})$ occur on the lateral one. The variations of this ratio and of the charge correspond to the complex structure of Salam’s barrier around the particle which is become localized in the layer $p$.

It is shown that the harmonic reiteration of all values $r/R$ (in one gauge cycle) corresponds to values of $r_e/R = 1$ and $r_p/R = 6^{4/3}$. The first relation shows that Salam’s barrier compensates the influence of the external field in the area of the interaction (the sphere with the radius $R$) of the particle $e$ (which become localized in the layer $r_e/R$) with the particle $p$ (which become localized in the layer $r_p/R$). Therefore, the first condition of the model is only executed in case of the harmonic reiteration of all values of $r/R$. If the reiteration at transitions between adjacent states $r_e/R + r_p/R$ is not harmonic, this condition is broken.

The whole charge $+e$ of the particle $p$ corresponds to execution of both conditions in case of the harmonic reiteration. The states of the particle $-e$ are stationary at the interaction with the whole charge $+e$ (external area of the gauge cycle) due to this property. The external area corresponds to the electromagnetic interaction. As the internal area of the gauge cycle corresponds to the interaction of the charge $-e$ with fractional charge $+e/l$, this one corresponds to the strong interaction.

The agreement between calculated values of the angular momentum and the ratio of the rest masses of the proton and electron with their experimental values confirms the important role of two gauge conditions in the unification of the fundamental interactions.
6. The potential energy $E_{pl}$ defined by the relations (44) plays the special role in the unification mechanism. The agreement of the numerical definition of the variation of the rest mass at the transition between adjacent stationary states with the constant of the gravitational interaction shows that this energy has the meaning of the potential energy of the gravitational interaction.

The energy $E_{pl}$ divides the whole space of the variations of the coordinate $R$ to external and internal parts at any value of $R_i$. The electromagnetic interaction is predominant in the external part. The internal part is the area of the strong interaction. The gravitational interaction raises the electromagnetic and strong interactions in this aspect.

The energy $E_{pl}$ has the important property in the model. Since the quantity of the terms in the series (4) decrease at the consecutive decrease of the coordinate $R$, the lower limit (of the stationary interaction of the particle $-e$ with the particle $+e$) exists. This formal limit corresponds to one term (relative to $R_\infty$) in the series (4).

The preliminary results of this work are submitted in [9-11].

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