The Scale-Symmetric Theory as the Origin of the Standard Model

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Abstract: Here we showed that the Scale-Symmetric Theory (SST) gives rise to the Standard Model (SM) of particle physics. We calculated the SM gauge couplings - we obtained g' = 0.3576, g = 0.6534 (these two gauge couplings lead to an illusion of electroweak unification), and g(s) = 1.2156 +- 0.0036. We as well described the mechanism that leads to the mass of muon. The other SM parameters we calculated in earlier papers. SST is based on 7 parameters only which, contrary to SM, lead also to the 3 masses of neutrinos (they are beyond SM) and to the 4 basic physical constants (i.e. to the reduced Planck constant, to gravitational constant (gravity is beyond SM), to speed of light in "vacuum" and electric charge of electron). We can see that in SST there is 2.7 times less parameters, SST leads to the 19 initial parameters in SM, and SST describes phenomena beyond SM. It leads to conclusion that SST is a more fundamental theory than SM.

1. Introduction

Here we showed that the Scale-Symmetric Theory (SST) gives rise to the Standard Model (SM) of particle physics. We calculated the SM gauge couplings and we described the mechanism that leads to the mass of muon. The other SM parameters we calculated in earlier papers (see the citations in Table 1: [1] – [5]). In Table 1, we compared the SST parameters with the SM 19 initial parameters [6], [7], [8].

In paper [9], we present the initial conditions in the Scale-Symmetric Theory (7 parameters, 5 initial symmetries, and 4 initial formulae). Such initial conditions lead to 5 different levels of Nature and to the atom-like structure of baryons [1] which next lead to the SM 19 initial parameters and to the 7 parameters beyond SM. But most important is the Higgs mechanism which is crucial to understand the similarities and big differences between SST and SM.

In both theories, the Higgs field is added to a quantum field. In SST, the quantum field is the Einstein spacetime (ES) composed of the still undiscovered neutrino-antineutrino pairs – the excited states of ES can behave in a quantum way but its ground state behaves classically [1]. In both theories, the interactions of the Higgs field with the particles the quantum fields consist of cause that the particles acquire their gravitational mass. In SST, the particles have the non-gravitating inertial mass only i.e. they in absence of the Higgs field do not produce the non-gravitating gravitational fields – gravitational fields are the result of interactions of such inertial-only particles with the SST Higgs field. Moreover, without the SST Higgs field, all particles would be unstable.

Table 1. *The SM parameters and SM parameters from SST*

Description	Value in SM	Value in SST
Electron mass	0.5109989461(31) MeV [6]	0.5109989 MeV [1]
Muon mass	105.6583745(24) MeV [6]	105.6563 MeV [1]
Tau mass	1.77686(12) GeV [6]	1.7772 GeV [2]
Up quark mass	$2.2^{+0.6}_{-0.4}$ MeV [6]	2.23 MeV [1]
Down quark mass	$4.7^{+0.5}_{-0.4}$ MeV [6]	4.89 MeV [1]
Strange quark mass	96^{+8}_{-4} MeV [6]	96 ± 8 MeV [3]
Charm quark mass	1.27(3) GeV [6]	1.267 GeV [1]
Bottom quark mass	$4.18^{+0.04}_{-0.03}$ GeV [6]	4.190 GeV [1]
Top quark mass	173.21 ± 1.22 GeV [6]	171.9 GeV [1]
CKM 12-mixing angle	$13.04 \pm 0.05^{\circ}$ [7]	13.164° [4]
CKM 13-mixing angle	$0.201 \pm 0.011^{\circ}$ [7]	0.212° [4]
CKM 23-mixing angle	$2.38 \pm 0.06^{\circ}$ [7]	2.357° [4]
CKM CP-violating phase	~1 [7]	$exp(i\ \delta_{CP}) = 1$ [4]
$U(1)_Y$ gauge coupling g'	0.357 [8]	0.3576 [this paper]
$SU(2)_L$ gauge coupling g	0.652 [8]	0.6534 [this paper]
$SU(3)_C$ gauge coupling $g_S(Z)$	1.221 [8]	1.2156 ± 0.0036 [this paper]
QCD vacuum angle	~0 [8]	0 [5]
Higgs vacuum expectation value	246 GeV [8]	511 GeV ≈ $2(2W + Z) = 2 \cdot 252$ GeV [this paper]
Higgs mass	125.09 ± 0.24 GeV [6]	125.0 GeV [1]

In both theories, the Higgs mechanism occurs whenever the quantum fields have a vacuum expectation value (VEV) but in SST, it concerns only the beginning of the inflation – it means that all gravitational fields were produced during the inflation. Today, "new" masses and their gravitational fields arise only because of local changes in density of the gravitating quantum fields. SST shows that energy of the produced during the inflation VEV condensates was about 511 GeV [10]. This value is close to mass of a pair of following structures ($Z + 2W$) but spin of such structures is unitary so to conserve the spin of the quantum field, there must be a spin-0 pair i.e. $2(Z + 2W) = 504$ GeV, not about 246 GeV, or so, as it is in SM. The VEV has nothing with production of the W and Z bosons but we can see that the ($Z + 2W$) structure can lead to an illusion of electroweak unification via W and Z bosons. In reality, weak interactions are associated with ES condensates while electromagnetic interactions are associated with tori/charges and fermion-antifermion pairs – we cannot unify them within the same mechanism [1]. In SST, masses and lifetimes of the Higgs boson and the Z and W gauge bosons are calculated ab initio – they are not elementary particles [11].

SST shows also that there are not in existence single quarks because there is not in existence a mechanism which stabilizes their fractional electric charges – there are produced only quark-antiquark pairs which are very important to describe dynamics of interactions. Systems composed of single quarks are useless to describe internal structure of particles – we know that, for example, we still within the 3-valence-quarks model cannot calculate spin and precise masses of nucleons from the SM initial conditions.

In SM, at temperatures the electroweak symmetry is unbroken, all elementary particles are massless [8] (more precise: they do not produce gravitational fields but they have non-gravitating inertial mass). At a critical temperature, the Higgs field becomes tachyonic [8]. The symmetry is spontaneously broken by condensation so the Z and W bosons acquire masses [8]. According to SM, the leptons and quarks acquire mass in a different way than the Z and W gauge bosons [8].

In SST, the picture is different. The SST Higgs field is all the time the tachyonic field – it consists of the non-gravitating pieces of space carrying inertial mass only. In SST, the massive Higgs boson (which is an ES condensate so it is not directly associated with Higgs mechanism), charged leptons, quarks, and gauge bosons (they as well are the ES condensates) acquire their masses in the same way i.e. due to local changes in density of the gravitating quantum field (i.e. of the Einstein spacetime – it is due to the quantum entanglement or/and confinement described within SST [1]). Only the neutrinos and binary systems of them acquire their gravitational masses because of the true, classical Higgs mechanism – it is due to the fifth force that follows from smoothness of the SST tachyons the whole Nature is built of (it is very difficult to separate two sheets of glass). In SST, symmetry is broken because of the infinitesimal spin (in comparison with ħ) of the SST tachyons [1].

Initial symmetries in SST differ very much from the initial symmetries in SM but in SST, the SM symmetries are derived from the SST initial conditions [12].

Among a thousand theoretical results calculated within SST, we can find quantities we will use in this paper (all used here quantities are calculated in paper [1] or [11]; in the parentheses, we compare them with experimental central values [6]; here, the symbols of particles denote their masses also): the mass of bare electron $e_{bare}^{+,-}$ = 0.510407 MeV, the mass of muon, $\mu^{+,-}$ = 105.6563 MeV ($m_{muon,exp.}$ = 105.6584 MeV), mass of neutral pion, π^{o} = 134.9767 MeV ($m_{pion(o),exp.}$ = 134.9766 MeV), mass of charged pion, $\pi^{+,-}$ = 139.57041 MeV ($m_{pion(+,-),exp.}$ = 139.57013 MeV), mass of the electric/strong charge of the core of baryons $X^{+,-}$ = 318.2955 MeV, mass of the ES condensate in centre of the core of baryons Y = 424.1245 MeV, mass of boson Z = 91.2 GeV and mass of boson W = 80.4 GeV [11], the fine-structure constant for the electromagnetic interactions: α_{em} = 1/137.036, and the coupling constant for the nuclear strong interactions at $Q = Z$ = 91.2 GeV: $\alpha_S(Z) = 0.1176 \pm 0.0005$.

SST shows that a particle can behave in a quantum way only when its mass density or surface density is close to mass density or surface density of quantum field in which the particle is embedded. Then such particle can disappear in one place and appear in another one, and so on – it leads to the wave function. Surface density of the tori/charges $X^{-,+}$ is about 300,000 times higher than the Einstein spacetime [1] so they behave classically. Such behaviour does not lead to wave function so $X^{-,+}$ cannot interact with DM (it occupies the whole Universe filled with baryonic matter). It concerns as well the S structures composed of 8 photons that can transform into 8 bare electron-positron pairs: $S = 8\gamma = 8(e^+e^-)_{bare} = 16e_{bare}$ = 8.166512 MeV. It follows from the fact that during the inflation, there were produced 4 different ES components [1] – during the inflation the tau-neutrinos [2] were not produced. The 4 different ES components are the carriers of the gluons and photons – they are their rotational energies so there are left-handed and right-handed gluons (we can see that there are 8 different gluons [1]) and photons. But contrary to electromagnetic and weak fields, only nuclear strong fields have internal helicity so they “see” the internal helicities of the ES components. It leads to conclusion that a lightest spin-0 structure, which conserve spin and internal helicity of the nuclear strong field, must consist of 8 different rotating ES components – *then such structure in the nuclear strong field does not interact strongly* but it can interact electromagnetically or weakly.

Notice that inside baryons, the nuclear strong field overlaps with electromagnetic field and both are produced by the torus/charge $X^{-,+}$ inside the core of baryons [1]. Such torus produces the gluon loops, which are responsible for the nuclear strong interactions, and the muons plus S structures that are responsible for the electromagnetic interactions of baryons. The electromagnetic interactions of baryons differ from electromagnetic interactions of charged leptons so we cannot calculate the $U(1)_Y$ gauge coupling g' from following formula $\alpha_{em} = g'^2 / (4\pi)$ – it leads to $g'_{U(1)} = 0.3028$ but such value does not act correctly in SM. Notice as well that coupling constants, α_i, are directly proportional to squared mass [1] so the $U(1)_Y$, $SU(2)_L$ and $SU(3)_C$ gauge couplings should be directly proportional to mass, M_i. Since both types of couplings are dimensionless so gauge couplings can be defined as follows

$$g_i = M_i / M_o , \quad (1)$$

where M_i is the mass of carrier of interaction whereas M_o is a characteristic mass for the nucleon-nucleon collisions (the mass of the source of interactions). In baryons, only the torus/charge is the classical object [9] so there are created the $X^- X^+$ pairs so we can assume that $M_o = X^+ + X^- = 636.591$ MeV.

2. Calculations

The Standard Model is a gauge theory based on the symmetry group:

$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$.

In the non-nuclear electromagnetic interactions, electron (the source) creates electron-positron pair that exchanges quanta with the source [1]. In the nuclear electromagnetic interactions, X^+X^- pair (the source) creates $\mu^+\mu^-$ pair which exchanges pair of the S structures. Such picture of nuclear electromagnetic interactions leads to following value of the $U(1)_Y$ gauge coupling g'

$$g' = [(\mu^+ + S) + (\mu^- + S)] / M_o = 0.3576 . \quad (2)$$

The core of the baryons consists of the spin-1/2 $X^{-,+}$ and the spin-0 central condensate Y. It leads to conclusion that creation of the SS pair near $X^{-,+}$ forces creation of two "holes" in the ES spacetime near the Y which is responsible for the weak interactions – each "hole" carries negative mass equal to $-S$. But nuclear weak interaction behaves in a different way than the nuclear electromagnetic interaction [1] – just the $(Y - S)$ structure exchanges identical structure so only one $(Y - S)$ structure is the carrier of the nuclear weak interactions. Such picture of nuclear weak interactions leads to following value of the $SU(2)_L$ gauge coupling g

$$g = (Y - S) / M_o = 0.6534 . \quad (3)$$

In collisions of nucleons, there instead the $\mu^+\mu^-$ pair can be created an additional X^+X^- pair which exchanges, instead the SS pair, the pair of gluon loops that can transform into neutral pion. In collision of four the $X^{-,+}$ instead two, there can be created $\pi^{+}\pi^{-}$ pair. Such picture of nuclear strong interactions leads to following value of the $SU(3)_C$ gauge coupling $g_S(Z)$

$$g_S(Z)_{\pi(o)} = (\pi^{o} + M_o) / M_o = 1.2120 \,, \qquad (4a)$$

$$g_S(Z)_{\pi(+)\pi(-)} = (\pi^{+} + \pi^{-} + 2\,M_o) / (2\,M_o) = 1.2192 \,. \qquad (4b)$$

Arithmetic mean is $g_S(Z) = 1.2156$. Then formula for field strength $\alpha_S(Z) = g_S(Z)^2/(4\pi)$ leads to the central value of the $\alpha_S(Z) = 0.1176$. In reality, formulae (4a) and (4b) lead to $g_S(Z) = 1.2156 \pm 0.0036$ and to $\alpha_S(Z) = 0.1176 \pm 0.0004$ – the last value is consistent with experimental data [6] and with the value calculated within SST in a different way [1].

Obtained results are very close to the SM gauge couplings (see Table 1).

According to SST, neutral pion consists of two spin-1 gluon loops and a simplest gluon loop consists of two spinning and rotating stable neutrinos [1]. It means that gluon loops have internal helicity. We can assume that the simplest neutral pion emits one energetic neutrino and absorbs a pair of electron and low energy neutrino carrying mass equal to the mass distance between charged pion and neutral pion – we identify it as bound muon

$$\mu^{-}_{bound,1} = 3\,\pi^{o} / 4 + (\pi^{-} - \pi^{o}) = 105.826 \text{ MeV} \,. \qquad (5)$$

Notice as well that mass distance between Y and X^{-} is very close to value obtained in (5)

$$\mu^{-}_{bound,2} = Y - X^{-} = 105.829 \text{ MeV} \,. \qquad (6)$$

Interactions of muons inside baryons and outside them are different so mass of free muons is lower [1]

$$\mu^{-} = 105.6563 \text{ MeV} \,. \qquad (7)$$

We calculated as well lifetime of muon $\tau_{muon} = 2.44 \cdot 10^{-6}$ s [1].

Notice that relation

$$g / (g'^{\,2} + g^{2})^{1/2} = 0.8772 \approx W / Z = 0.8815 \qquad (8)$$

incorrectly suggests that there is an electroweak unification. In reality, electromagnetic interactions are associated with the spin-1/2 tori which create the spin-1 fermion-antifermion pairs while weak interactions are associated with exchanges of the spin-0 ES condensates and "holes" in ES. Descriptions of such interactions are very different [1] so their unification within the same methods is impossible. Generally, the different interactions we can unify only partially due to the phase transitions that follow from the SST initial conditions [1], [9].

3. Summary

Here we showed that the Scale-Symmetric Theory gives rise to the Standard Model of particle physics. Just within SST we calculated all the Standard-Model initial parameters.

We calculated the SM gauge couplings. Values of the $U(1)_Y$ and $SU(2)_L$ gauge couplings lead to an illusion of electroweak unification. In reality, the nuclear electromagnetic interactions are associated with the spin-1/2 tori/charges and creations of the spin-1 fermion-antifermion pairs while weak interactions are associated with exchanges of the spin-0 Einstein-Spacetime condensates and "holes" in the Einstein spacetime. Descriptions of nuclear electromagnetic interactions and weak interactions are very different so their unification within the same methods is impossible. Generally, the different interactions we can unify only partially due to the phase transitions that follow from the SST initial conditions.

We as well described the mechanism that leads to the mass of muon – it follows from internal structure of pions and internal structure of baryons.

Number of initial conditions in SST is much lower than in SM so SST is a more fundamental theory than SM.

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