Solar Neutrino Problem, Atmospheric Neutrino Oscillations, Generations of Leptons and Quarks, and Imaginary Mass of Dark Matter

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Abstract: By combining the quark model and the atom-like structure of baryons described in the Scale-Symmetric Theory (SST) we have described the solar neutrino problem and generations of quarks. According to SST, there is a similarity of shapes and equality of mass ratios of the components of the three fundamental cores, *i.e.* of the core of lightest neutrinos, core of baryons, and the core of the Protoworld that was composed of dark matter. Within such a similarity we described the origin of the large mixing angle $\Theta_{12}/^{o} = 33.089$ and the origin of the mass-squared splitting $\Delta m_{21}^2 = 7.42 \times 10^{-5}\ eV^2$ that define the solar neutrino oscillations. In our description, there appears imaginary mass and activation of the solar neutrino oscillations that can be damped. We showed that survival probability for the solar electron-neutrinos decreases from $\frac{1}{2}$ at low energies of the electron-neutrinos (it is a mean value) to $\frac{1}{3}$ for $\nu_e \geq u + u + d = 9.345\ MeV$. We also described the atmospheric neutrino oscillations. SST leads to a minimum in the curve describing the dependence of the survival probability on neutrino energy for the atmospheric ν_μ-like neutrinos for $\frac{L}{E_\nu} \approx 500\ \frac{km}{GeV}$ – it is consistent with experimental data. From SST follows that there are three generations of leptons and four generations of quarks and that the eight quarks combine into four pairs, *i.e.* d and u, s and c, b and t, and $b' \approx 2.68\ TeV$ and $t' \approx 14.76\ TeV$. We described also the dark-matter (DM) field.

Keywords: Scale-Symmetric Theory, Solar Neutrino Problem, Imaginary Mass, Activation of Neutrino Oscillations, Atmospheric Neutrino Oscillations, Generations of Leptons and Quarks, Fourth Generation of Quarks, Dark-Matter Field.

1. Introduction

Within the Standard Model (SM) neutrinos are massless, so we need a theory beyond the SM to explain their masses.

In this article, we apply the Scale-Symmetric Theory (SST) [1] to solve the solar neutrino problem and to describe the atmospheric neutrino oscillations and phenomena that determine number of generations of leptons and quarks.

In SST appear 5 different fundamental scales [1]: the SST tachyons that are the components of the SST Higgs field and gravitational fields, the closed string composed of $K^2 = (0.7896685548 \times 10^{10})^2$ the SST tachyons (a pair of the closed strings, *i.e.* the spin-1 entanglon, is responsible for the quantum entanglement; the neutrinos are built of the entanglons that are embedded in the Higgs field), the core of the electron-neutrino and muon-neutrino that are the very stable neutrinos (the tau-neutrino consists of three entangled stable neutrinos), the core of baryons, and the core of the Protoworld that was built of dark matter. Shapes of the three last objects are similar (there is a torus and central condensate) and ratios of masses of their components are the same – it causes that we can combine the phenomena in the neutrinos and in baryons. For example, the Compton wavelength of the electrons ($\sim 2.4 \times 10^{-12}\ m$) is an analogue to the effective radius of the Higgs potential for the stable neutrinos ($\sim 4 \times 10^{-32}\ m$), *i.e.* the ratio of these two quantities is close to K^2, and so on.

In various experiments, the ratio of observed number of the solar electron-neutrinos to expected number from the standard solar model (SSM) was between one third and one half [2]. It was the solar neutrino problem. Such a problem was solved via a superposition of defined mass eigenstates in different complex proportions – it leads to the neutrino oscillations, *i.e.* during propagation, the electron-neutrinos change into a mixture of the three neutrino flavours.

The energy dependence of the survival probability of solar neutrinos leads to the so-called large mixing angle (LMA) solution: $sin^2\ \Theta_{12} \approx 0.3$, *i.e.* to the large mixing angle $\Theta_{12}/^o \approx 33$, and to the mass-square splitting $\Delta m_{21}^2 \approx 7.4 \times 10^{-5}\ eV^2$. Here we try to describe the physical meaning of the two physical quantities that define properties of the solar neutrinos. It should lead to phenomena in high-energy nuclear plasma in the core of the Sun.

2. Physical Meaning of the LMA

In SST, the mixing angle that concerns the solar neutrino problem is as follows [3]

$$\Theta_{12}/^o = \frac{8\pi^{\pm}}{E_{\nu}^{in-pion}} = 33.0890\ , \qquad (1)$$

where $E_{\nu}^{in-pion} = 33.7442\ MeV$ is the energy of each neutrino of the 4 entangled neutrinos in the neutral pion.

Why there are 8 charged pions (*i.e.* four $\pi^+\pi^-$ pairs), not only 2?

For entangled pairs, due to the four-object symmetry, we have [3]

$$N_d = 2 \times 4^d\ , \qquad (2)$$

where $d = 0,1,2,4,8,16,32, ...$ are the Titius-Bode (TB) numbers.

On the other hand, there is the SST nuclear plasma composed of the cores of baryons packed to maximum. In such a plasma can be created also other real and virtual particles, so quarks as well [3]. It means that the $\pi^+\pi^-$ pairs are created inside the cores of baryons.

The charged pions consist of following particles

$$\pi^+ \rightarrow e^+ + \nu_e + \nu_{\mu}^{anti} + \nu_{\mu}\ , \qquad (3)$$

$$\pi^- \rightarrow e^- + \nu_e^{anti} + \nu_{\mu} + \nu_{\mu}^{anti}\ . \qquad (4)$$

The very frequent collisions of the charged pions in the SST nuclear plasma cause that the pion wavefunctions collapse in such a way that one of the 4 components takes over whole energy. It means that to obtain a globally neutral object composed of charged pions, such an object must contain 8 charged pions, not only two.

Creations of groups of 8 entangled charged pions that mass is normalized via the energy of one stable neutrino of the four entangled neutrinos in the neutral pion, are crucial to understand correctly the processes that take place inside the plasma core and plasma corona.

3. Physical Meaning of the Mass-Squared Splitting

In [3], we showed that to obtain the mass-squared splitting $\Delta m_{21}^2 = m_2^2 - m_1^2 = 7.42 \times 10^{-5}\ eV^2$, there in the stable neutrinos must be created an imaginary counterpart to $iE_{\nu}^{in-pion} = i33.7442\ MeV$ – it leads to $im_1 = i0.0026102\ eV$.

What is physical meaning of the imaginary mass?

We showed its origin within the fourth fundamental scale but it is also valid for the counterparts in neutrinos.

Imaginary mass follows from a phase $\delta = \frac{\pi}{2}\ rad = 90^o$

$$e^{i\frac{\pi}{2}} = \cos\frac{\pi}{2} + i\ sin\frac{\pi}{2} = i\ . \qquad (5)$$

Imaginary mass should be produced inside the neutral pion created in the SST nuclear plasma. In neutral pion, there are two gluon loops in which the spins of the neutrino-antineutrino pairs rotate in the planes perpendicular to gluon loop [1]. A phase $\delta = 90^o$ means that the spins are forced to be tangent to gluon loop. Such an arrangement of spins is in the dark-matter (DM) loops [1]. We can say that mass of the DM-loops is imaginary and that the DM phase is $\delta_{DM} = 90^o$. Next, such a DM-pion decays to 4 imaginary neutrinos (i.e. spin and velocity are parallel or antiparallel) with the same mass/energy.

We emphasize that in order to change the energy/mass of a gluon loop into a dark-matter loop, the angle between the spins of the loop components and their spin velocities must decrease from 90 degrees to zero or increase to 180 degrees, *i.e.* during the conversion of energy/mass into dark matter the phase is 90 degrees.

We should not confuse the DM-pion with dark pion that is described in [3].

Emphasize that number density of neutrinos in a pion is too low to create new DM-loop [1].

In [3], we showed that the real mass $m_2 = 0.0082071\ eV$ in the stable neutrinos is the counterpart to the $Y^* - X^{\pm} \approx \mu^{\pm}$, where $Y^* = 424.39406\ MeV$ is the excited state of the $Y = 424.12176\ MeV$ spacetime condensate in the core of baryons, whereas $X^{\pm} = 318.29555\ MeV$ is the mass of the electric charge in the core of baryons.

It leads to

$$\Delta m_{21}^2 = m_2^2 - (im_1)^2 = 7.42 \times 10^{-5}\ eV^2\ . \qquad (6)$$

We see that we solved the solar neutrino problem via three phenomena that take place inside the SST nuclear plasma in the core of the Sun. The different neutrino oscillations are activated due to different interactions that concern the third and fourth fundamental scales described in SST. Without described here the three phenomena, and without a process that activates the neutrino oscillations, the description of the solar neutrinos problem is incomplete.

4. Dark-Matter (DM) Field

Each DM-loop is built of K^2 of the non-rotating-spin stable neutrinos. According to SST, the mean number density of the DM-loops (with different sizes of them) in the Universe is $\sim 10^{20}$ per cubic meter [1] – it is the DM field.

Due to the interactions of the DM field with brains, there are created minds which are the DM-solitons composed of the entangled DM-loops. In minds, there are simpler solitons which we will call the subsolitons. We can say that minds are the DM-solitons embedded in the DM field. The different structures/subsolitons are produced by the simultaneously excited in the brains the closed electric currents – in the chosen DM-loops by the electric currents, the spins of the neutrino-antineutrino pairs are parallel to the spins of the electrons in the currents, i.e. the spin polarization creates the DM-subsolitons which are stable structures for a long time.

Identical DM-subsolitons attract each other – there is a war for domination of different DM-subsolitons. Such interactions of the DM-subsolitons lead to consciousness.

From the mean number density of the DM-loops and their invariant mass ($\sim 2 \times 10^{-47}\ kg$) [1] we can calculate the mean density of baryonic matter which is equivalent to one hydrogen atom per ~4.3 cubic meters.

Inside the SST Higgs potential of neutrinos, the field composed of the spin-2 pairs of entanglons overlaps with the classical gravitational field that is the gradient in the SST Higgs field (in such classical field, creations of virtual objects are impossible) – it is the SST quantum gravity [1].

The mutual interactions of DM-loops and DM-loops with the SST spacetime condensates are due to the partial overlap of the SST Higgs potentials of neutrinos. Such quantum gravity leads to creations of the electron-positron pairs by the Y spacetime condensate in baryons [1] and/or to changes of angular momentum of the DM-loops (radii of the DM-loops change) – coupling constant for such weak interactions is $\sim 1.9 \times 10^{-6}$ [4]. The electron-positron pairs are created due to an increase in local number density of the neutrino-antineutrino pairs above the allowed invariant density for the SST spacetime condensates [1].

The DM-loops consist of the neutrino-antineutrino pairs so they also interact gravitationally.

5. Activation of the Oscillations in the Solar Neutrinos

By an analogy to (6), for the cores of baryons we have

$$\Delta m^2_{21,baryon} = (Y^* - X^{\pm})^2 - \left(iE_{\nu}^{in-pion}\right)^2 = 12395.57\ MeV^2\ , \tag{7}$$

$$\Delta m_{21,baryon} = \sqrt{\Delta m^2_{21,baryon}} = 111.335\ MeV\ . \tag{8}$$

Let us denote by $\nu_{e,\beta}$ the energy/mass of the electron-neutrino equal to

$$\nu_{e,\beta} = n - p - e^- = 0.78233\ MeV\ . \tag{9}$$

There are two possibilities to create an object with a mass calculated in (8). The first possibility is as follows

$$\Delta m_{21,baryon,high} = \mu^+ + d^{anti} + \nu_{e,\beta} + (2u^{anti})_{virtual} = 111.331\ MeV\ , \tag{10}$$

where in SST is $d^{anti} = 4.890481\ MeV$ and $Q_{d^{anti}} = +\frac{1}{3}e$ are the mass and electric charge of the down antiquark, respectively [3]. The resultant masses in (8) and (10) are practically the same. The resultant object in (10) is electrically neutral and after the decay of the μ^+ muon we have following three neutrinos: $2\nu_e$ and ν_{μ}^{anti}, *i.e.* the electron-neutrino survival probability is equal to $\frac{2}{3}$.

The second possibility is as follows

$$\Delta m_{21,baryon,high} = \mu^- + d + \nu_{e,\beta} + (2u)_{virtual} = 111.331\ MeV\ . \tag{11}$$

The resultant object in (11) is also electrically neutral and after the decay of the μ^- muon we have following three neutrinos: ν_e^{anti}, ν_{μ} and ν_e, *i.e.* the electron-neutrino survival probability is equal to $\frac{1}{3}$.

At low energy, so also at low energy of the produced electron-neutrinos, there are realized both possibilities so the mean survival probability is $\frac{1}{2}$. When energy of the electron-neutrino increases, due to the $p \rightarrow uud$ transition, the percentage of the object in (11) is higher and higher, so the survival probability decreases and for $\nu_e \geq u + u + d = 9.345\ MeV$ the resultant survival probability is $\frac{1}{3}$.

We see that in SST, the dependence of the survival probability on the electron-neutrino energy is consistent with observational data [2].

The mean survival probability, $P_{ee,o}$, depends on energy of the electron-neutrino, *i.e.* $P_{ee,o} = f(E_{\nu_e})$.

We can define the survival probability as follows

$$P_{ee} = P_{ee,o} \pm \Delta P_{ee,o}\ , \tag{12}$$

where for $E_{\nu_e} \to 0$ we have $P_{ee,o} = 0.5$ whereas for $E_{\nu_e} \geq u + u + d$ we have $P_{ee,o} = \frac{1}{3}$. Then the mean real uncertainties that cannot be eliminated are as follows

$$\pm\Delta P_{ee,o} = \pm(P_{ee,o} - \tfrac{1}{3})\ , \tag{13}$$

i.e. for $E_{\nu_e} \to 0$ we have $\pm\Delta P_{ee,o} \approx \pm 0.167$ whereas for $E_{\nu_e} \geq u + u + d$ we have $\pm\Delta P_{ee,o} = 0$.

Notice that experimental uncertainties are higher for lower energies of the electron-neutrinos [2], so the SST conclusion is correct.

In Figure 1 are collected the SST results for a linear dependence of $P_{ee,o}$ on E_{ν_e} – we can compare it with the figure provided by A. Ianni [2]. Emphasize that other experimental data overlap with the region in Figure 1 that defines the real uncertainties.

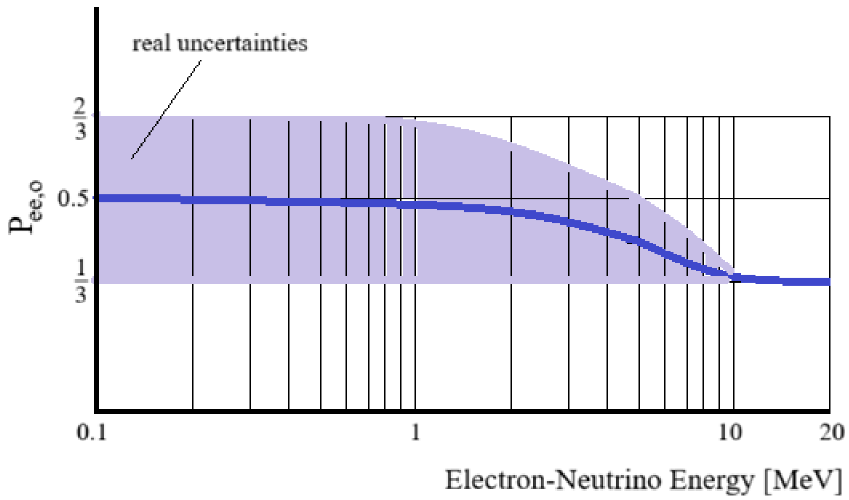

Figure 1. Electron-neutrino survival probability as a function of neutrino energy.

In [3], we showed that sometimes in SST is a resonance because $\Delta m_{ij}^2 = m_i^2 - m_j^2 = (\Delta m_{ij})^2$. Notice that here we have $\Delta m_{21,baryon} = Y^* - X^{\pm} + \alpha_{w(p)} 2\pi^{\pm} = 111.325\ MeV$, where $\alpha_{w(p)} = 0.0187228951$ is the coupling constant for the nuclear weak interactions [1] – this value is very close to the value in (8).

6. Atmospheric Neutrino Oscillations

In [3], we showed that the muon-neutrino can transform via tau-neutrino into electron-neutrino, and vice versa. But probabilities of these two processes are not the same because the

$\nu_\mu^{anti}\nu_\mu$ carriers of elementary photons are more stable because the neutrino and antineutrino differs by both the sign of the weak charge and internal helicity. It causes that the transformation

$$\nu_\mu \to \pi^- \to \nu_e^{anti} , \tag{14}$$

is more probable than the following one

$$\nu_e^{anti} \to \pi^- \to \nu_\mu^{anti} . \tag{15}$$

Instead the transformation in (15) there mainly is realized following transformation

$$\nu_e^{anti} \to \pi^- \to \nu_e^{anti} . \tag{16}$$

Similarly is for the transformations via π^+.

In the $d = 2$ state in the baryons that is the ground state above the Schwarzschild surface for the nuclear strong interactions [1] there can be created pairs of charged relativistic pions. Such creations cause a disappearance of ν_μ-like neutrinos. Mass of such a pair is

$$M_{pair,d=2} = W_{(+),d=2} + W_{(-),d=2} = 363.408\,MeV . \tag{17}$$

The dependence of the survival probability on neutrino energy shows that neutrino energy equal to $E_\nu = 5.17\,MeV$ relates to $\frac{L}{E_\nu} = 35\,\frac{km}{MeV}$ [3]. It means that the energy/mass $M_{pair,d=2}$ relates to $\frac{L}{E_\nu} \approx 500\,\frac{km}{GeV}$. We see that there should appear some minimum in the curve describing the dependence of the survival probability on neutrino energy for $\frac{L}{E_\nu} \approx 500\,\frac{km}{GeV}$. It is consistent with experimental data [5], [6].

Due to the transformations in (14) and (16) and the analogous transformations for positively charged pion, number of ν_μ-like neutrinos in a neutrino flux interacting with hadronic matter decreases – it is due to the decoupling of the carriers of elementary photons ($\nu_\mu^{anti}\nu_\mu$) from the ν_τ-like neutrinos. Creations of the $W_{(+),d=2}W_{(-),d=2}$ pairs intensifies the disappearance of the ν_τ-like neutrinos – when we neglect such creations then a formula for the survival probability of the atmospheric ν_μ-like neutrinos in two-neutrino case (here it is the transition $\nu_\mu \leftrightarrow \nu_\tau$ in atmospheric mixing) looks as follows [5]

$$P(\nu_\mu) = 1 - sin^2\, 2\Theta_{23} sin^2(1.27\Delta m_{32}^2[eV^2]\, \frac{L}{E_\nu} [\frac{km}{GeV}]) , \tag{18}$$

where $\Delta m_{32}^2 = 2.45 \times 10^{-3}\,eV^2$ and $\Theta_{23}/^o = 41.3613$ [3].

From (18), for example, for $L \approx 12{,}800\,km$ (it is the diameter of the Earth) and $E_\nu \approx 1\,GeV$, we obtain $P(\nu_\mu) = 0.596$. This SST value is consistent with the data presented in [6]: number of detected ν_μ-like neutrinos in Kamiokande was 85 (it was published in 1988) whereas expected number was 144, *i.e.* $\frac{85}{144} = 0.590$ – it is the central value.

7. Physical Meaning of the PMNS Mixing Angles

The mixing parameter $\Theta_{13}/^o = 8.27225$ [3] is measured using the stable electron-antineutrinos from nuclear reactors, so we can assume that it appears due to the weak decay of negatively charged muon, *i.e.* there appear two stable neutrinos. The stable neutrinos are produced by the core of baryons because $Y - X^{\pm} \gtrsim \mu^{\pm}$.

In the central part of the Sun, pressure and temperature are very high so weak decays of the Y spacetime condensates should dominate. Since $Y \gtrsim 4\mu^{\pm}$ and due to the four-object symmetry, there appear eight stable neutrinos, *i.e.* value of the solar mixing parameter $\Theta_{solar}/^{o} = \Theta_{12}/^{o} = 33.0890$ must be four times higher than $\Theta_{13}/^{o}$.

The atmospheric neutrinos appear due to the weak decays of charged pions and muons. Due to the four-object symmetry, the characteristic objects should look as follows

$$(\pi^{+} + \pi^{-}) + (\mu^{+} + \mu^{-}) \ . \tag{19}$$

Such objects contain 10 stable neutrinos so value of the atmospheric mixing parameter $\Theta_{atmospheric}/^{o} = \Theta_{23}/^{o} = 41.3613$ must be five times higher than $\Theta_{13}/^{o}$.

8. Generations of Leptons

According to SST the tau-neutrino consists of three stable neutrinos that appear in the decays of charged pions: $\nu_{\tau} \equiv (\nu_{e} \nu_{\mu}^{anti} \nu_{\mu})$ or $\nu_{\tau}^{anti} \equiv (\nu_{e}^{anti} \nu_{\mu} \nu_{\mu}^{anti})$. In π^{o} can be 4 stable neutrinos whereas ν_{τ} is composed of 3 entangled stable neutrinos with the same mass, so energy of such a tau-neutrino is $E_{\nu_{\tau}}^{in-pion} = \frac{3\pi^{o}}{4} = 101.2326\ MeV$.

To show that the tauons favour the tau-neutrinos, we must show that the sum of masses/energies of the tauon and the tau-neutrino is equal to a characteristic mass/energy that frequently appears in experiments.

Energy equivalent to the sum of masses of neutron and proton is

$$E_{np} = n + p = 1877.8375\ MeV \ . \tag{20}$$

Such energy can transform into a pair of tauon and tau-neutrino

$$E_{np} = \tau^{+} + E_{\nu_{\tau}}^{in-pion} \ . \tag{21}$$

From (20) and (21) we have

$$\tau^{\pm} = 1776.60\ MeV \ . \tag{22}$$

This SST result is very close to the experimental value [2]: $\tau^{\pm} = 1776.93(9)\ MeV$.

From [3] follows that due to the internal helicities of neutrinos and electrically charged leptons and sign of the weak charge of neutrinos and sign of the electric charge of the electrically charged leptons, the electron favours the electron-antineutrino and that negatively charged muon favours the muon-antineutrino. On the other hand, in this Paragraph, we showed that the positively charged tauon favours the tau-neutrino, *i.e.* there are three generations of leptons.

The electron does not interact with the electron-neutrino because their internal helicities and signs of electric-weak charges are the same.

9. Generations of Quarks

In [3], we showed that the fractional electric charges of quarks in the three generations of them, *i.e.* $k_{i} = +\frac{2}{3}$ and $-\frac{1}{3}$ are forced by the atom-like structure of baryons described in SST and by the Kasner conditions

$$\Sigma_{i=1}^{3} k_i = 1 , \tag{23}$$

$$\Sigma_{i=1}^{3} k_i^2 = 1 . \tag{24}$$

To show that there are four generations of quarks we must explain what causes that the d-quark favours the u-quark, the s-quark favours the c-quark, the b-quark favours the t-quark, and the b'-quark should prefer the t'-quark.

The u-quark and d-quark are the components of the first quark generation because of the two mass distances of the nucleon components [1]

$$\Delta H = H^{+} - H^{o} = d - u = 2.66332\ MeV , \tag{25}$$

$$\Delta W = W_{(+-),d=1} - W_{(o),d=1} = d + u = 7.11764\ MeV . \tag{26}$$

The s-quark and c-quark are the components of the second quark generation because of the transition from the nuclear strong interactions via the fundamental gluon loops (FGLs; the coupling constant at low energies is $\alpha_s = 1$ [1]) to via the pions (the coupling constant for a mean nucleon is $\alpha_s^{NN.\pi} = 14.40076$ [1])

$$1265(1)\ MeV = s \frac{\alpha_s^{NN.\pi}}{\alpha_s} \approx c \approx 1267\ MeV , \tag{27}$$

where $s \approx 87.85\ MeV$ (it is mass of the s-quark) and $c \approx 1267\ MeV$ (it is mass of the c-quark) [1], [3].

The b-quark and t-quark are the components of the third quark generation because of the coupling at high energies of the peripheral gluon loop (it leads to the mass of the b-quark) and the two most massive components of the core of baryons (it leads to the mass of the t-quark) [1].

The first lepton generation that is composed of the electron and electron-antineutrino is coupled to the quark generation composed of the u-quark and d-quark because in the β-decay of the neutron there appears the first lepton generation. Such a generalized first generation is the fundamental generation because masses of its components are lowest.

In SST, the weak and electric charges are directly proportional to mass of the tori that represent the charges. We see that ordinary pulsation of torus/charge does not change its charge. Generally, absolute value of electric charge of quarks in a generation should be lower for a quark with a lower mass. It is satisfied for the second and third generation but is not valid for the first generation. It follows from the fact that there appears the sum and mass distance between the d and u quarks which combined with the Kasner conditions force the observed anomaly.

In [1], we derived formula for masses of quarks heavier than the s-quark

$$M_{Quark,Glueball}[GeV] = \left(\frac{0.5229558}{m_{Particle,Condensate}[GeV]} + 0.9686785[fm]\right)^{10} . \tag{28}$$

On the other hand, the core of baryons consists of the Y spacetime condensate and the X^{+} torus/electric-charge. From (28) for such particles-objects we obtain the following masses of the SST b'-quark and t'-quark that are the components of the fourth generation of quarks (the b'-quark prefers the t'-quark because they both are created inside the core of baryons)

$$b' = 2.67672\, TeV\ , \tag{29}$$

$$t' = 14.76309\, TeV\ . \tag{30}$$

Within SST we predict existence of a heavier Higgs boson with a mass of $C = 17.11935\, TeV$ [1] and due to the radius → circle transition in oscillations of a condensate with a mass of the t'-quark, there can be produced a mass of $\frac{t'}{2\pi}$, so there are satisfied the following two relationships for masses

$$17.113\, TeV = t' + \frac{t'}{2\pi} \approx C = 17.119\, TeV\ , \tag{31}$$

$$17.440\, TeV = C(1 + \alpha_{w(p)}) = b' + t' = 17.440\, TeV\ , \tag{32}$$

where $\alpha_{w(p)} = 0.0187228951$ is the coupling constant for the nuclear weak interactions [1].

The b' and t' quarks are combined via the two basic components of the core of baryons, *i.e.* via X^+ and Y, whereas formula (32) shows that the b' and t' quarks are combined via the nuclear weak interactions.

The present-day lower bound for a fourth generation of quark masses is $\sim 1.370\, TeV$ [7], so the SST result $m_{b'} = b' \approx 2.68\, TeV$ is consistent with experimental data.

The SST mass of top quark is $t = 171.85\, GeV$ [1], [3]. But in experiments we can obtain a mass that is increased by the electromagnetic mass of the top quark at high energy. Since the coupling constant is $\alpha_{em,high}^{-1} = 127.5425133$ [1], so the corrected mass is

$$t_{high} = t(1 + \alpha_{em,high}) = 173.20\, GeV\ . \tag{33}$$

In [8] appears a theoretical mass of the b'-quark equal to $b' = (2.7 \pm 0.1)\, TeV$ that is consistent with the SST result, but mass of the t'-quark in [8] ($\sim 200\, TeV$) is very different from the SST result. To explain it notice that in SST there is satisfied following approximate formula

$$2.67672\, TeV = b' \approx \frac{\alpha_s^{NN.\pi} + \alpha_s}{\alpha_s} t_{high} = 2.6674\, TeV\ . \tag{34}$$

It probably is the reason that the dispersive determination of mass of the lighter quark in the fourth generation in [8], *i.e.* of the b'-quark, via the intermediate charm-top (ct) channel in the b' case, is correct.

10. Summary

We showed that the solar neutrino oscillations mimic the described here processes that take place in the SST nuclear plasma.

We showed that survival probability for the solar electron-neutrinos decreases from the mean value $\frac{1}{2}$ at low energies of the electron-neutrinos to $\frac{1}{3}$ for $\nu_e \geq u + u + d = 9.345\, MeV$.

SST leads to a minimum in the curve describing the dependence of the survival probability on neutrino energy for the atmospheric ν_μ-like neutrinos for $\frac{L}{E_\nu} \approx 500\ \frac{km}{GeV}$ – it is consistent with experimental data.

From SST follows that there are three generations of leptons and that the six known/discovered quarks combine into three pairs, *i.e.* d and u, s and c, and b and t. The d, s and b quarks are the d-type quarks.

SST suggests that there can be in existence a fourth generation of quarks: $b' = 2.67672\ TeV$ and $t' = 14.76309\ TeV$.

We have shown that due to the Kasner conditions, there can be the transitions of the elementary electric charge to the fractional electric charges of quarks. The quark model is equivalent to the atom-like structure of baryons, but SST is the superior theory, *i.e.* the quark model can be realized only because it emerges from the stable atom-like structure of baryons. In [1], we also showed that there is equivalence of the electroweak description of the anomalous magnetic moment of the electron within the SST and the electromagnetic description within the Quantum Electrodynamics (QED).

Emphasize that within SST we explained the masses of quarks and leptons and numbers of their possible generations (4 and 3, respectively) from first principles.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Kornowski, S. (2024) Foundations of the Scale-Symmetric Theory and the Illusory Total Width of the Off-Shell Higgs Bosons.
Journal of High Energy Physics, Gravitation and Cosmology, **10**, 398 – 437
https://doi.org/10.4236/jhepgc.2024.101028

[2] Navas, S., *et al*. (Particle Data Group) Reviews, Tables & Plots (2024): Neutrino masses, mixing, and oscillations.
Phys. Rev. **D 110**, 030001 (2024) and 2025 update

[3] Kornowski, S. (2026) Flavour-Changing Weak Interactions of Neutrinos and Quarks from SST.
Journal of High Energy Physics, Gravitation and Cosmology, **12**, 782 – 808
https://doi.org/10.4236/jhepgc.2026.122041

[4] Kornowski, S. (2024) The Origin, Properties and Detection of Dark Matter and Dark Energy.
Journal of High Energy Physics, Gravitation and Cosmology, **10**, 749 – 774
https://doi.org/10.4236/jhepgc.2024.102046

[5] Super-Kamiokande Collaboration (2004) Evidence for an Oscillatory Signature in Atmospheric Neutrino Oscillations.
Phys. Rev. Lett. **93**, (2004) 101801
https://doi.org/10.1103/PhysRevLett.93.101801

[6] Kajita, T., (2016) Discovery of atmospheric neutrino oscillations.
Ann. Phys. (Berlin) **528**, 6, 459 – 468 (2016)
https://doi.org/10.1002/andp.201600086

[7] CMS Collaboration (2019) Search for pair production of vectorlike quarks in the fully hadronic final state.
Phys. Rev. D **100**, 072001 (2019)
https://doi.org/10.1103/PhysRevD.100.072001

[8] Hsiang-nan Li (2024) Dispersive determination of fourth generation quark masses.
arXiv:2309.15602 [hep-ph]
https://doi.org/10.48550/arXiv.2309.15602

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