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Flavour-Changing Weak Interactions of Neutrinos and Quarks from SST

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Abstract

According to the Scale-Symmetric Theory (SST), there is a similarity of shapes and equality of mass ratios of the components of the three basic cores, *i.e.* of the core of lightest neutrinos, charged core of baryons, and the core of the Protoworld that was composed of dark matter. From the neutrino-spin rotation, we calculated the masses of the cosmological neutrinos. Two characteristic neutrino oscillations lead to $\Delta m^2_{32,mean} = 2.45 \times 10^{-3}\,\text{eV}^2$ and $\Delta m^2_{21,mean} = 7.42 \times 10^{-5}\,\text{eV}^2$. The $\nu_e \leftrightarrows \nu_\mu$ transitions are possible only via the tau-neutrino. We also described three neutrino oscillation anomalies that follow from $\Delta m^2_{41,mean} = 1.32 \times 10^{-2}\,\text{eV}^2$, $\Delta m^2_{41,mean} = 1.36\,\text{eV}^2$, and $\Delta m^2_{41} = 7.395\,\text{eV}^2$. We show that the dependence of the survival probability on the electron-antineutrino energy in the KamLAND data follows from the atom-like structure of neutrons/baryons and some symmetrical associations of the neutrons. We also calculated mass and range of the dark pion, which are $\pi_{dark} \approx 7 \times 10^{-18}\,\text{MeV}$ and ~181 km, respectively—such a range defines the fundamental range of the neutrinos. We also explained the reactor electron-antineutrino anomaly. The CKM matrix concerns the flavour-changing weak interactions of quarks, so we described both the PMNS neutrino-mixing matrix and the CKM quark-mixing matrix. Within SST, we also formulated a model containing both a unitarity triangle of mixing angles and a unitary SST matrix that lead to the three weak-interaction doublets of scalars, pseudoscalars and fermions. We also described the origin of the up and down quarks in nucleons.

Keywords

Scale-Symmetric Theory, Internal Structure of Neutrinos, Dark Pion in SST, Survival Probability in the KamLAND Data, Masses of Cosmological Neutrinos, Neutrino-Photon Decoupling, PMNS Matrix, Reactor

Electron-Antineutrino Anomaly, CKM Matrix, SST Matrix, Up and Down Quarks in Nucleons, Neutrino Oscillation Anomalies

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 describe the most fundamental problems concerning the neutrinos, *i.e.* the neutrino-mass problem and the neutrino-oscillation problem.

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 $K^2 = \left(0.7896685548 \times 10^{10}\right)^2$ 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 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.

The properties of the tachyons and density of the Higgs field (the 6 initial parameters) combine the first and second scale and lead to the reduced Planck constant $\hbar$, to the speed of light c, and to the gravitational constant G. On the other hand, the saturation of interactions combines the next four scales while the nuclear strong interactions of the core of baryons lead to the atom-like structure of baryons (there is the core composed of the torus/electric-charge, the central spacetime condensate Y that is responsible for the nuclear weak interactions, and there is one or more relativistic pions on quantized orbits outside the core).

In SST, the stable neutrinos acquire their mass as follows. The very dense initial inflation field as a whole was lefthanded. Due to the rotations of the tachyons (they have infinitesimal spin) in the initial inflation field, created during the inflation, the closed strings have the internal helicities defined by the toroidal and poloidal motions. On the other hand, the entanglons (*i.e.* the binary systems of the closed strings) that the neutrinos consist of are embedded in the Higgs field, so the internal helicity of the closed strings and the viscosity of them and tachyons cause stable neutrinos to produce a gradient in the Higgs field, *i.e.* produce the gravitational field. Due to the very high energy densities in entanglons and neutrinos, the symmetry of the left-handedness and right-handedness was not broken. The left-right symmetry was broken at the end of the inflation and is encoded in the matter-antimatter asymmetry, *i.e.* there are many more baryons with the lefthanded internal helicity.

The stable neutrinos cannot change their flavours directly because of the tremendous non-gravitating energy frozen inside them—there is about 119 orders of magnitude more non-gravitating energy than gravitating one [1]. It explains why the zero-point energy of the "vacuum" suggested by quantum field theory does not cause a large cosmological constant.

The four stable neutrinos (*i.e.* the electron-neutrino, muon-neutrino and their antiparticles) differ by orientation of the spins of the entanglons on their torus/weak-charge or/and by the internal helicity. It means that their masses, when their spins do not rotate, are the same. We will show that the experimental mass distance between the electron-neutrino and muon-neutrino follows from the fact that transition between them is possible via the tau-neutrino.

Emphasize that the internal helicity defined by the toroidal-poloidal motions also defines the external helicity of the neutrinos (only of neutrinos) that is defined by spin and particle velocity. Lefthanded internal helicity of neutrinos leads to righthanded external helicity—it is showed in **Figure 1**.

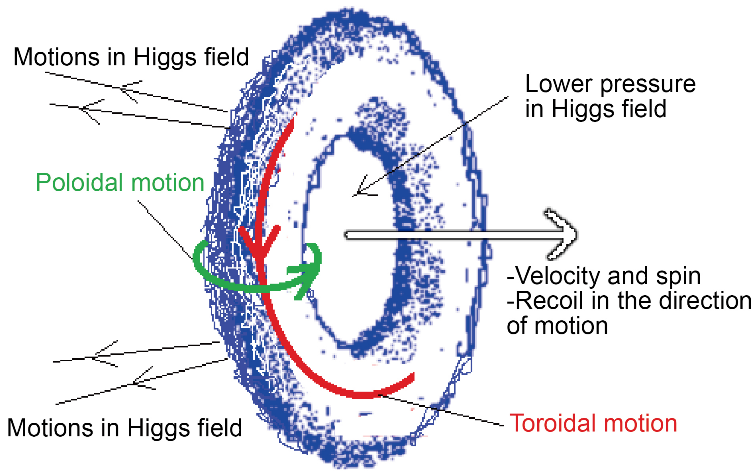

Figure 1. Weak charge of electron-antineutrino with righthanded external helicity and lefthanded internal helicity.

Some properties of selected fermions are presented in **Table 1**. The electron first of all chooses the electron-antineutrino because the internal helicities and electric-weak charges of electron and electron-antineutrino are opposite. Next the electron chooses the muon-neutrino because the interactions of the opposite electric-weak charges dominate over the interactions of the internal helicities. Next the electron chooses the muon-antineutrino because their internal helicities are opposite. Such is the origin of creation of the negatively charged muon and pion. The electron does not interact with the electron-neutrino because their internal helicities and signs of electric-weak charges are the same. We also see that external helicity of neutrinos is always lefthanded whereas of antineutrinos is always righthanded. Our neutrino model is consistent with all experimental data.

Pressure in the Higgs-field region limited by the weak charge of neutrino is a little lower so the tachyons interacting with it more frequently detach from the weak charge on its inner surface. We see that the neutrino recoil in direction of motion follows from the internal helicity of the neutrinos.

Table 1. Properties of selected fermions.

Particle	Internal Helicity	External Helicity	Electric Charge	Weak Charge
ν_e^{anti}	L (left)	R		+
ν_e	R (right)	L		–
ν_μ^{anti}	L	R		–
ν_μ	R	L		+
e^-	R		–	
e^+	L		+	

It is assumed that if neutrinos have masses, the weak eigenstates, ν_α, produced in a weak interaction are linear combinations of the mass eigenstates ν_i

$$\left|\nu_\alpha\right\rangle = \sum_{i=1}^{n} U_{\alpha i}^{*}\left|\nu_i\right\rangle , \tag{1}$$

where $\alpha = e, \mu, \tau$ are the neutrino flavours, $i = 1,2,3$, the n is the number of neutrino species, and U is the mixing matrix [2].

The m_i is the mass of the neutrino mass eigenstate ν_i.

In the Standard Model, for the neutrino mass-squared splitting we have [2]

$$\Delta m_{ij}^2 = m_i^2 - m_j^2 , \tag{2}$$

whereas in SST are obligatory two definitions, *i.e.* the definition in (2) and $\Delta m_{ij}^2 = \left(\Delta m_{ij}\right)^2$, *i.e.* there is a resonance.

2. Dark Pion from SST

In baryons, for the nuclear weak interactions is responsible the $Y = 424.12176\ \text{MeV}$ SST-absolute-spacetime condensate that is composed of the non-rotating-spin-1 neutrino-antineutrino pairs—they are the carriers of the elementary photons, they are the elementary dark photons. Such a condensate is located in the centre of the core of the baryons [1].

In [1], we showed that nature tries to replicate certain behaviors on different scales, so we can assume that the Y condensate consists of K^2 dark pions composed of the elementary dark photons. Then mass of the SST dark pion is

$$\pi_{dark} = \frac{Y}{K^2} = 1.2124668 \times 10^{-47}\ \text{kg} = 6.801440 \times 10^{-18}\ \text{MeV} . \tag{3}$$

Contrary to the neutrino-antineutrino pairs (the neutrinos are entangled) in the neutral pion, in the SST dark pions the spins of the pairs do not rotate, so mass of the dark pion is about 19 orders of magnitude lower than mass of the neutral pion.

Due to the 4-object symmetry and saturation of interactions [1], the number of entangled single objects can be [3]

$$N_d = 4^d , \tag{4}$$

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

For an object composed of entangled binary systems we have

$$N_d = 2 \times 4^d . \tag{5}$$

Neutral pion decays to two photons so for neutrinos in neutral pion we have $d \ge 1$.

Neutral pions that contain more the neutrino-antineutrino pairs are preferred because then energies of the components are lower.

Calculate mass of a dark pion composed of $N_{d=32} = 4^{32}$ the entangled non-rotating-spin neutrino-antineutrino pairs (or of $N_{d=32} = 2 \times 4^{32}$ the entangled non-rotating-spin neutrinos)

$$\pi^*_{dark} = 2 \times 4^{32} m_{Neutrino} = 1.2303709 \times 10^{-47}\ \text{kg} = 6.9018745 \times 10^{-18}\ \text{MeV}, \tag{6}$$

where $m_{Neutrino} = 3.3349269504 \times 10^{-67}\ \text{kg}$ is the mass of the lightest non-rotating-spin neutrino [1].

Notice that the mass of the dark pion built of 2×4^{32} lightest neutrinos is very close to the mass of dark pion calculated in (3). It suggests that $N_{d=32} = 2 \times 4^{32}$ can be the upper limit for number of entangled single objects. For example, each of the two cosmological loops inside the Protoworld was composed of 2×4^{32} the neutron black holes (NBHs) [1] [3]. It follows from the relation

$$\frac{Y}{K^2} \approx 2 \times 4^{32} m_{Neutrino}, \tag{7}$$

i.e. from the fact that nature tries to replicate certain behaviors on different scales.

Assume that range of the dark pion is equal to the de Broglie wavelength

$$\lambda_{de-Broglie,\pi^*_{dark}} = \frac{2\pi\hbar}{c\pi^*_{dark}} = 179.64\ \text{km}, \tag{8}$$

$$\lambda_{de-Broglie,\pi_{dark}} = \frac{2\pi\hbar}{c\pi_{dark}} = 182.29\ \text{km}. \tag{9}$$

Due to the four-object symmetry, population of dark pions with masses 4 times lower than the calculated in (9) should be higher (the dark pion decays into 4 parts)—it leads to a conclusion that the neutrinos should also disappear over distances 4×182.29 km≈729 km. The SST results, *i.e.* ~182 km and ~729 km are consistent with experimental data: KamLAND find that reactor ν_e^{anti} disappear over distances of about 180 km while MINOS observes the disappearance of accelerator ν_μ's at distance of 735 km [2].

Here we showed that the dark mass of energetic neutrinos consists of the Y weak black holes [1] that are built of the dark pions. It looks as a "dark star". In [4], it is shown that the final result of the gravitational collapse is a quantum object, an extremely compact "dark star".

3. The Origin of the KamLAND Survival Probability

Rotating-spin neutrinos, due to viscosity of the SST absolute spacetime [1], force the more ordered motions of the non-rotating-spin neutrino-antineutrino pairs in the absolute spacetime. It decreases the local pressure in the absolute spacetime so the local number density of the neutrino-antineutrino pairs increases—there are created the Y spacetime condensates composed of the entangled dark pions that behave practically as single objects.

Total mass of the dark pions surrounding a rotating-spin neutrino is practically equal to its rotational energy E_ν. But the total mass is a part of the zero-point energy, so its detection is impossible—the same concerns the photons.

From (8) and (9) results that mean range of the rotating-spin neutrinos is about $L_{SST} = 181\ \text{km}$ because such is the mean range of the SST dark pions surrounding them. It is a little greater distance than the reactor baseline $L_o = 180\ \text{km}$ in the KamLAND experiment [5].

Emphasize that number densities, ρ_N, for different energies of neutrinos, E_ν, at the SST distance L_{SST} (so at L_o as well) are different because of both the atom-like structure of baryons and creations of groups of entangled neutrons in the reactor nuclear matter. We should observe some maxima and minima in the following function

$$\rho_N = f\left(\frac{L_{SST}}{E_\nu}\right). \tag{10}$$

Let's calculate the $\frac{L_{SST}}{E_{\nu_e^{anti}}}$ ratios for the extrema in $\rho_N = f\left(\frac{L_{SST}}{E_{\nu_e^{anti}}}\right)$.

From (4) and (5) follows that the β-decays of single neutrons and the β-decays of groups of entangled 2, 4 and 8 neutrons are most probable. Assume that created electrons in such β-decays are the virtual particles so the whole decay energy is absorbed by the groups of entangled electron-antineutrinos. There can appear the collapse of the wavefunctions that describe such groups, *i.e.* one of the electron-antineutrino in a group absorbs whole energy of the group. It causes that there appear electron-antineutrinos with following energies

$$E_{\nu_e^{anti}} = 1.293, 2.59, 5.17 \text{ and } 10.34\ \text{MeV}. \tag{11}$$

We see that we should observe some maxima for

$$\left(\frac{L_{SST}}{E_{\nu_e^{anti}}}\right)_{max} \approx 18, 35, 70 \text{ and } 140\,\frac{\text{km}}{\text{MeV}}. \tag{12}$$

The maxima 35 km/MeV and 70 km/MeV are very well observed in the Kam-LAND data [5]. It is for pairs and quadrupoles of neutrons in nuclear matter (quadrupoles are most abundant).

The minima appear for the restorations of the negatively charged relativistic pions in neutrons, *i.e.* for $W_{(o),d=1} \rightarrow W_{(-),d=1}$.

We have

$$W_{(-),d=1} \equiv W_{(o),d=1} + e^- + \nu_e^{anti}. \tag{13}$$

When the electron is virtual then the energy absorbed by the ν_e^{anti} is

$W_{(o),d=1} - W_{(-),d=1} = -7.1176\ \text{MeV}$ [1]. When absorbed energy is equally distributed between e^- and ν_e^{anti} then the energy absorbed by the ν_e^{anti} is $\frac{-7.1176}{2} = -3.5588\ \text{MeV}$.

We see that we should observe only two minima for

$$\left(\frac{L_{SST}}{E_{\nu_e^{anti}}}\right)_{min} \approx 25 \text{ and } 51 \frac{\text{km}}{\text{MeV}}. \quad (14)$$

The minimum for 51 km/MeV is observed in the KamLAND data [5].

SST shows that the minimum ~25 km/MeV should be deeper.

In [5], the P_{ee} is the ν_e^{anti} survival probability. From a global analysis of neutrino oscillation data involving solar, accelerator, and reactor neutrinos, we have [5]

$$P_{ee} = 0.551 \pm 0.015. \quad (15)$$

On the other hand, here we showed that there are the two dominating processes, *i.e.* the β-decays that increase the mean amplitude in the function $\rho_N = f\left(\frac{L_{SST}}{E_{\nu_e^{anti}}}\right)$ and the reconstructions of the $W_{(-),d=1}$ relativistic pions that decrease the mean amplitude. We can assume that in the first processes, the mean amplitude, $A_{o,1}$, is the ratio of the possible maximum energy of the electron-antineutrino when the electron is a real particle to such an energy when the electron is virtual

$$A_{o,1} = \frac{n - p - e^-}{n - p} = 0.6049. \quad (16)$$

In the second processes, similar phenomena for the electron lead to

$$A_{o,2} = \frac{-3.5588}{-7.1176} = 0.5000. \quad (17)$$

From (16) and (17) we obtain the SST mean amplitude

$$A_o = \frac{A_{o,1} + A_{o,2}}{2} = 0.55245 \pm 0.05245 \approx 0.552. \quad (18)$$

The A_o in SST relates to the mean survival probability P_{ee}.

Generally, the simplest neutral pion consists of 4 energetic neutrinos each carrying energy equal to $E_\nu^{in-pion} = 33.744\ \text{MeV}$. We can use this energy to define the deviations from the mean amplitude because the β-decays and the reconstructions of the $W_{(-),d=1}$ relativistic pions concern the pion inside the neutron

$$\pm \Delta A_\nu = \frac{\pm E_{\nu_e^{anti}}}{E_\nu^{in-pion}} = \frac{\pm E_{\nu_e^{anti}}}{33.744\ \text{MeV}}. \quad (19)$$

The total amplitude is defined as follows

$$A_{total} = A_o \pm \Delta A_\nu = 0.552 \pm \frac{E_{\nu_e^{anti}}}{33.744\ \text{MeV}}. \quad (20)$$

The A_{total} relates to the total survival probability in the KamLAND experiment.

To compare the SST results with the KamLAND data we can calculate the amplitudes for the three clear extrema, *i.e.* for $\pm E_{\nu_e^{anti}} = 5.17\ \text{MeV}, -3.56\ \text{MeV}$ and 2.59 MeV (they relate to $\frac{L_{SST}}{E_{\nu_e^{anti}}} \approx 35\frac{\text{km}}{\text{MeV}}, 51\frac{\text{km}}{\text{MeV}}$ and $70\frac{\text{km}}{\text{MeV}}$)

$$A_{total,max}\left(35\frac{\text{km}}{\text{MeV}}\right) = 0.552 + \frac{5.17\ \text{MeV}}{33.744\ \text{MeV}} \approx 0.71, \quad (21)$$

$$A_{total,min}\left(51\frac{\text{km}}{\text{MeV}}\right) = 0.552 - \frac{3.56\ \text{MeV}}{33.744\ \text{MeV}} \approx 0.45, \quad (22)$$

$$A_{total,max}\left(70\frac{\text{km}}{\text{MeV}}\right) = 0.552 + \frac{2.59\ \text{MeV}}{33.744\ \text{MeV}} \approx 0.63. \quad (23)$$

The SST results and the KamLAND data are presented in **Figure 2**.

We see that our results are consistent with the experimental data [5] [6].

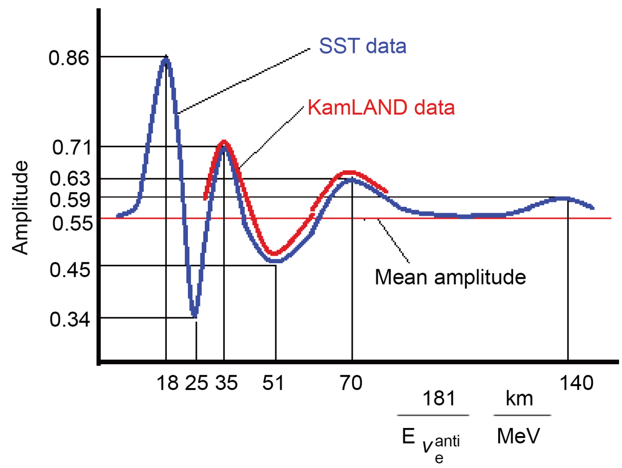

Figure 2. Amplitude versus electron-antineutrino energy from SST.

4. Masses of Neutrinos

According to SST, the tremendous non-gravitating energy inside the four lightest neutrinos (*i.e.* the electron-neutrino, muon-neutrino and their antiparticles) causes that they are the very stable particles [1], *i.e.* they cannot change their flavours directly.

The charged pions can decay as follows

$$\pi^+ \to e^+ + \nu_e + \nu_\mu^{anti} + \nu_\mu, \quad (24)$$

$$\pi^- \to e^- + \nu_e^{anti} + \nu_\mu + \nu_\mu^{anti}. \quad (25)$$

There is a possibility that the three neutrinos that appear in the decays of charged pions will be entangled and will carry half-integral spin. We claim that such objects composed of three entangled stable neutrinos are the tau-neutrinos

$$\nu_\tau \equiv \nu_e\left(\nu_\mu^{anti}\nu_\mu\right) \equiv \nu_\mu\left(\nu_\mu^{anti}\nu_e\right) \leftrightarrows \nu_e\left(\text{or } \nu_\mu\right) + \gamma_{carrier}, \quad (26)$$

$$\nu_\tau^{anti} \equiv \nu_e^{anti}\left(\nu_\mu\nu_\mu^{anti}\right) \equiv \nu_\mu^{anti}\left(\nu_\mu\nu_e^{anti}\right) \leftrightarrows \nu_e^{anti}\left(\text{or } \nu_\mu^{anti}\right) + \gamma_{carrier}, \quad (27)$$

where $\gamma_{carrier}$ is the neutrino-antineutrino pair that is a carrier of the elementary photon (they are the dark photons that are a part of the zero-point energy)—when the spin-1 rotates then it is the elementary photon. We see that there is possible the decoupling of a carrier of photon from the tau-neutrino and tau-antineutrino. It means that, for example, the electron-neutrino can transform into the tau-neutrino and next, due to the neutrino-photon decoupling, the tau-neutrino can transform into the muon-neutrino, and so on. Emphasize that such transformations are not some neutrino oscillations inside the neutrinos. We should change the nomenclature: here instead the neutrino oscillations we have the neutrino-photon decoupling (or coupling). Of course, there are some oscillations of the cores of neutrinos, for example, they lead to the Higgs potential that increases the effective radius of the neutrinos (the SST quantum gravity) but in such processes, the neutrinos do not change their flavour [1]. There are also the two characteristic neutrino oscillations that lead to the Δm_{32}^2 and Δm_{21}^2.

Notice that the carriers of the elementary photons/gluons must contain neutrino and antineutrino and must have opposite internal helicities. It leads to four different carriers that as a whole, due to the spin-1 rotation, can be externally lefthanded or righthanded, *i.e.* we have 8 different states that are activated in fields with internal helicity—we see that in the nuclear strong fields which contrary to the electromagnetic fields have internal helicity, we have 8 different spin-1 Types of gluons. The 8 Types of gluons force 3 colors of quarks: there is the left-helicity (LH) color, right-helicity (RH) color, and spin-rotation (SR) color—they are the red, green and blue colors of quarks. In anticolors, charges are converted to their opposite charges.

Let's calculate the maximum mass, $M_{\nu,rotation}$, of cosmological neutrino that follows from its spin rotation—it is in the form of the Y spacetime condensates, so in the form of the dark-pions as well

$$M_{\nu,rotation,max} = \frac{h\nu}{c^2} = \frac{2\pi\hbar}{2\pi r_{neutrino}\mathrm{c}} = 3.14511\times10^{-8}\ \mathrm{kg}, \quad (28)$$

where $r_{neutrino} = 1.118455577\times10^{-35}\ \mathrm{m}$ is the radius of the core of the stable neutrino [1]. The effective neutrino radius that follows from the Higgs potential is ~3510.2 times higher [1].

The mass of non-rotating-spin lightest neutrino is [1]

$$m_{Neutrino} = 3.3349269504\times10^{-67}\ \mathrm{kg}. \quad (29)$$

Masses of the cosmological neutrinos are defined by the following interval

$$m_{Neutrino} \le M_\nu \le M_{\nu,rotation,max}. \quad (30)$$

In SST, the arithmetic mean is for simultaneous interactions of a mass (then effective coupling constant is a sum of coupling constants) while for not simultaneous ones we must apply the geometric mean because then effective coupling constant is a product of successive coupling constants [1]. The masses of neutrinos concerning their rotational energies decrease asymptotically to the minimum mass, so the real mean geometric mass of the lightest cosmological neutrino is (it is the real mass of the electron-neutrino and muon-neutrino; mass of tau-neutrino is three times higher)

$$m_{\nu_e}^{real} = m_{\nu_\mu}^{real} = \frac{m_{\nu_\tau}^{real}}{3} = \left(M_{\nu,rotation} m_{Neutrino}\right)^{\frac{1}{2}} = 1.024145\times10^{-37}\ \text{kg} = 0.057450\ \text{eV}. \quad (31)$$

From (31) follows that the sum of the real masses of the three cosmological neutrinos with different flavours is

$$\Sigma m_{\nu}^{real} = 5\times0.057450\ \text{eV} = 0.28725\ \text{eV}. \quad (32)$$

In neutrino experiments, we do not measure their masses that follow from (31) but the masses emitted by them during their interactions. SST shows that in the interacting neutrinos there are produced the counterparts of the objects that appear in the interacting cores of baryons [1]. The effective mass of the interacting core of baryons is the sum of the mass of the created spacetime condensate $Y^* = 424.39406\ \text{MeV}$ and the mass of the torus/electric-charge $X^{\pm} = 318.29555\ \text{MeV}$ [1]. On the other hand, in a stable neutrino there is a spacetime condensate and the torus/weak-charge both composed of the entanglons. The mass $Y^* + X^{\pm}$ is a counterpart of the mass $m_{\nu_e}^{real} = 0.05745\ \text{eV}$.

The neutrino-photon coupling-decoupling concerns the transformation of the electron-neutrino into muon-neutrino, or vice versa (it concerns the antineutrinos as well) via the tau-neutrino. In the core of baryons, a photon can create the X^+X^- pair, so for some counterpart we obtain

$$\Delta m_{32}^2 = \left(m_{\nu_e}^{real}\frac{2X^{\pm}}{Y^* + X^{\pm}}\right)^2 = 2.425\times10^{-3}\ \text{eV}^2. \quad (33)$$

The second solution that results from (2) is as follows. The electron-neutrino can emit a counterpart to Y^* (it leads to $m_3 = m_{\nu_e}^{real}$ and $m_2 = 0.0328286\ \text{eV}$) or to $X^{\pm}$ (it leads to $m_3 = m_{\nu_e}^{real}$ and $m_2 = 0.0246214\ \text{eV}$). The first scenario leads to $\Delta m_{32}^2 = m_3^2 - m_2^2 = 2.2228\times10^{-3}\ \text{eV}^2$ whereas the second one to $\Delta m_{32}^2 = m_3^2 - m_2^2 = 2.6943\times10^{-3}\ \text{eV}^2$. The mean value is $\Delta m_{32,mean}^2 = 2.459\times10^{-3}\ \text{eV}^2$ that is very close to the result in (33)—the mean value of the three results is $\Delta m_{32,mean*}^2 = 2.45\times10^{-3}\ \text{eV}^2$. We can say that there is a resonance between the SST results.

Interacting core of baryons can also produce a quanta with an energy that is a sum of the mass distance $Y^* - X^{\pm}$ and the weak mass of the $\pi^+\pi^-$ pair (the coupling constant is $\alpha_{w(p)} = 0.0187229$ [1]), so for some counterpart in a stable neutrino we obtain

$$\Delta m_{21}^2 = \left(m_{\nu_e}^{real}\frac{Y^* - X^{\pm} + \alpha_{w(p)}2\pi^{\pm}}{Y^* + X^{\pm}}\right)^2 = 7.416\times10^{-5}\ \text{eV}^2. \quad (34)$$

The second solution that results from (2) is as follows. The electron-neutrino can emit a counterpart to $Y^* - X^\pm$ (it leads to $m_2 = 0.0082071\ \text{eV}$) or an imaginary counterpart to $iE_\nu^{in-pion} = i33.7442\ \text{MeV}$ (it leads to $im_1 = i0.0026102\ \text{eV}$). It leads to $\Delta m_{21}^2 = m_2^2 + m_1^2 = 7.417\times10^{-5}\ \text{eV}^2$. This second SST result is very close to the result in (34)—the mean value is $\Delta m_{21,mean}^2 = 7.42\times10^{-5}\ \text{eV}^2$. We can say that there is a resonance between the SST results.

Notice that decoupling of the carrier of the elementary photon from the tau-neutrino causes that the tau-neutrino behaves as the electron-neutrino or muon-neutrino, so then we have only two different flavours of neutrinos

$$\Sigma m_\nu^{real}\left(\text{neutrino-photon decoupling}\right) = 2\times0.057450\ \text{eV} = 0.1149\ \text{eV}. \quad (35)$$

5. The Mixing Angles for Neutrinos and PMNS Matrix

Mixing angles are the angles between two sets of orthogonal basis vectors. The choice of angles (parameterization) is based on convention, *i.e.* is not unique.

Define some mixing angle, $\Theta_{13}/^\circ$, for a stable neutrino emitted by the $\pi^+\pi^-$ pair that appears in Formula (34), and normalize it via the mass $E_\nu^{in-pion} = 33.7442\ \text{MeV}$ that appears in Formula (19)

$$\Theta_{13}/^\circ = \frac{2\pi^\pm}{E_\nu^{in-pion}} = 8.27225. \quad (36)$$

In the $\mu^+\mu^-$ pair, there are 4 stable neutrinos (the 4-fermion symmetry) so we have

$$\Theta_{12}/^\circ = 4\Theta_{13}/^\circ = 33.0890. \quad (37)$$

The real total mass of the 3 neutrino flavours is 5 times higher than mass of a stable neutrino and there are 5 stable neutrinos (see (32)). Moreover, in the $\pi^+\mu^-$ pair, there are 5 stable neutrinos so we have

$$\Theta_{23}/^\circ = 5\Theta_{13}/^\circ = 41.3613. \quad (38)$$

In the $\pi^+\pi^-$ pair, there are 6 stable neutrinos, so we have

$$\Theta_{23}/^\circ = 6\Theta_{13}/^\circ = 49.6335. \quad (39)$$

Emphasize that the neutrino mixing angles can change their values because of the nuclear weak interactions of the $\pi^+\pi^-$ pairs that appear in (36)-(39). It means that we should take into account such interactions when we interpret experimental results. For example, the weak mass of the charged pion is $\alpha_{w(p)}\pi^\pm = 2.61316\ \text{MeV}$, where $\alpha_{w(p)} = 0.0187229$ is the coupling constant for the nuclear weak interactions [1]. Then we obtain $\Theta_{12}/^\circ = 33.708539$ and $\sin^2\Theta_{12} = 0.3080$.

In such a way we should interpret the neutrino mixing angles.

The SST results in (36)-(39) are consistent with experimental data [6].

When we also take into account the mixing angle in (39) then Formula (1) has not a physical meaning (then for mass of the muon-neutrino we obtain value about 50% too high), so it suggests that probability of the angle $\Theta_{23}/^\circ = 49.6335$ is very low.

We assume that in the neutrino oscillations there is obligatory the CP conservation

$$\delta_{CP}/^\circ = 180. \tag{40}$$

Notice that $\cos\left(-180^\circ\right) = -1$.

In SST, the Pontecorvo-Maki-Nakagava-Sakata (PMNS) matrix is unitary.

Table 2. The PMNS-SST matrix for neutrinos.

0.8291066	0.5402609	−0.1438770
−0.3301044	0.6807401	0.6539298
0.4512356	−0.4946830	0.7427485

From (36), (37), (38) and (40) we obtain the PMNS-SST mixing matrix for neutrinos—see **Table 2**.

To obtain the real masses of neutrinos we must assume that the masses m_1, m_2 and m_3, *i.e.* the masses of the neutrino mass eigenstates ν_i that appear in Formula (1), are as follows

$$m_1 = 2m_{\nu_e}^{real} = 0.115 \text{ eV}, \tag{41}$$

$$m_2 = -0.4287 m_{\nu_e}^{real} = -0.02463 \text{ eV}, \tag{42}$$

$$m_3 = 3m_{\nu_e}^{real} = 0.172 \text{ eV}. \tag{43}$$

The m_1 relates to two stable neutrinos as it is in the muon $\mu^\pm$.

The m_2 is the virtual mass of the weak charge, *i.e.* it is a counterpart of $-X^\pm$.

The m_3 relates to three stable neutrinos as it is in the charged pion $\pi^\pm$.

We see that the masses m_1, m_2 and m_3 are not associated with the Δm_{32}^2 and Δm_{21}^2.

From the PMNS-SST mixing matrix for neutrinos and from (41)-(43), within the PMNS formalism we can calculate the real masses of neutrinos

$$m_{\nu_e}^{real,PMNS} = 0.0573 \text{ eV}, \tag{44}$$

$$m_{\nu_\mu}^{real,PMNS} = 0.0577 \text{ eV}, \tag{45}$$

$$m_{\nu_\tau}^{real,PMNS} = 0.192 \text{ eV}. \tag{46}$$

The results in (44)-(46) are very close to the SST results in (31).

For the weak correction for the $\pi^+\pi^-$ pair we obtain

$$\Theta_{13}/^\circ = \frac{2\pi^\pm\left(1+\alpha_{w(p)}\right)}{E_\nu^{in-pion}} = 8.427135, \tag{47}$$

$$\Theta_{12}/^\circ = 4\Theta_{13}/^\circ = 33.708539, \tag{48}$$

$$\Theta_{23}/^\circ = 5\Theta_{13}/^\circ = 42.135674. \tag{49}$$

From (47)-(49) we obtain the second PMNS-SST mixing matrix for neutrinos (see Table 3).

Table 3. The second PMNS-SST matrix.

0.8228897	0.5489764	−0.1465515
−0.3297520	0.6714454	0.6636449
0.4627268	−0.4977810	0.7335517

From the second PMNS-SST mixing matrix for neutrinos and from (41)-(43), we obtain the second solution that is very close to the first solution but the results are a little worse

$$m_{\nu_e}^{real,PMNS} = 0.0559\ \text{eV}\,, \tag{50}$$

$$m_{\nu_\mu}^{real,PMNS} = 0.0597\ \text{eV}\,, \tag{51}$$

$$m_{\nu_\tau}^{real,PMNS} = 0.192\ \text{eV}\,. \tag{52}$$

6. The Reactor Electron-Antineutrino Anomaly

We showed that production of the electron-antineutrinos in reactors concern the decays of the $W_{(-),d=1}$ charged relativistic pions inside the neutron nuclear strong field. It means that number of such weak decays can be changed because of a change in coupling constant for the nuclear strong interactions. The ratio $\frac{\alpha_s^{NN,\pi}}{\alpha_s^{NN,\pi} + \alpha_s}$ represents the transition from the nuclear strong interactions via the pions (the strong coupling constant is $\alpha_s^{NN,\pi} = 14.40076$) and via the fundamental gluon loops (at low energies the strong coupling constant is $\alpha_s = 1$) to the strong interactions only via pions outside the strong field [1]. We see that when the β-decays of the negative relativistic pions take place outside the neutron strong field then number of such decays is lower

$$\frac{N_{observed}}{N_{expected}} = \frac{\alpha_s^{NN,\pi}}{\alpha_s^{NN,\pi} + \alpha_s} = 0.935\,. \tag{53}$$

It solves the reactor electron-antineutrino anomaly. Our result is consistent with the experimental data [7].

7. CKM Quark-Mixing Matrix and SST Mixing Matrix

The Cabibbo-Kobayashi-Maskawa (CKM) matrix is a unitary matrix that concerns the flavour-changing weak interactions of quarks so there also should appear the energetic neutrinos with the energy equal to $E_\nu^{in-pion} = 33.744\ \text{MeV}$, energy equal to $n - p = 1.29333\ \text{MeV}$, and neutrinos from the $W_{(-),d=1} \rightarrow W_{(o),d=1}$ transition: their maximum energy is $\Delta W_{d=1} = W_{(-),d=1} - W_{(o),d=1} = 7.11764\ \text{MeV}$.

Mass of the bottom quark follows from the peripheral interactions of the baryons [1]. The first mixing angle we define as the ratio of the mass of the bottom quark, $m_b = 4190.33\ \text{MeV}$, to the mass of the source of the nuclear strong interactions and electromagnetic interactions ($X^{\pm} = 318.29555\ \text{MeV}$ [1])

$$\Theta_{12}/^{\circ} = \frac{m_b}{X^{\pm}} = 13.1649. \tag{54}$$

The second mixing angle is the ratio of the mass of the fundamental gluon loop $m_{FGL} = 67.54441313\ \text{MeV}$ [1] to $X^{\pm}$

$$\Theta_{13}/^{\circ} = \frac{m_{FGL}}{X^{\pm}} = 0.2122066. \tag{55}$$

The third mixing angle is the ratio of the mass of the boson that creates the Titius-Bode states for the strong-electroweak interactions,
$M_{TB} = 750.2957682\ \text{MeV}$ [1], to $X^{\pm}$

$$\Theta_{23}/^{\circ} = \frac{M_{TB}}{X^{\pm}} = 2.3572298. \tag{56}$$

We see that the mass $X^{\pm}$ normalizes the quark mixing angles.

In such a way we should interpret the quark mixing angles.

The SST results in (54)-(56) are consistent with experimental data [6].

We assume that in the quark weak interactions there is obligatory the CP conservation

$$\delta_{CP}/^{\circ} = 0. \tag{57}$$

Notice that $\cos\left(-0^{\circ}\right) = 1$.

What is the difference between the $\delta_{CP} = 180^{\circ}$ in the PMNS matrix and the $\delta_{CP} = 0^{\circ}$ in the CKM matrix? In SST, a charge (*i.e.* weak, electromagnetic, dark-matter charge) is a torus with an internal helicity and with all spins of its components directed towards the inside of the torus or all of them directed towards the outside of the torus. From **Table 1** follows that flavour of a stable neutrino we can change by changing only weak charge or only internal helicity, *i.e.* $\delta_{CP} = 180^{\circ}$. To change flavour of a quark in a V_{ij}, we must change simultaneously both electric charge (the spins must be inverted) and internal helicity, *i.e.*
$\delta_{CP} = 180^{\circ} + 180^{\circ} = 360^{\circ} = 0^{\circ}$.

Why the stable neutrinos have the 4 different states that leads to $\delta_{CP} = 180^{\circ}$ whereas the quarks and electrically charged leptons have only 2 different states (*i.e.* particle and its antiparticle) that leads to $\delta_{CP} = 0^{\circ}$? From SST follows that the neutrinos are embedded in the Higgs field (Hf) whereas the quarks and electrically charged leptons are embedded in the SST absolute spacetime (SST-As) which density is about 4×10^{42} higher than the Higgs field [1]. It means that viscosity of the SST-As is much, much higher than Hf. It also causes that at low energy, gravitational interactions are much weaker than electromagnetic interactions. Then on the tori of the quarks and electrically charged leptons, there appears a spin-helicity (internal) coupling. Such a coupling causes that when the spins of a torus components are directed towards the outside of the torus then there is preferred the right internal helicity whereas when they are directed towards the inside then there is preferred the left internal helicity—in such a way behaves the ball that is kicked in such a way that it starts spinning.

Emphasize that in SST, the matter-antimatter symmetry was broken at the end of the SST inflation because of the external left helicity of the initial inflation field, *i.e.* there between the angular velocity and velocity was the angle equal to 180˚. The matter-antimatter asymmetry does not concern the PMNS matrix or CKM matrix. It could be possible when the total internal helicity of the SST spacetime (*i.e.* of the Hf plus SST-As) was not equal to zero. But it is zero because the excessive left-handedness is encoded in the baryons. Emphasize that the nuclear strong field has helicity not equal to zero.

From (54)-(57) we obtain the CKM-SST mixing matrix for quarks—see **Table 4**.

Table 4. The CKM-SST mixing matrix for quarks.

0.973712	0.2277529	0.0037037	V_{ud}	V_{us}	V_{ub}
−0.22771034	0.9728599	0.0411295	V_{cd}	V_{cs}	V_{cb}
0.0057642	−0.0408917	0.999147	V_{td}	V_{ts}	V_{tb}

The SST result for V_{td} is about 33% lower than the Standard Model (SM) result. Current experimental results are too imprecise to determine which model is correct.

The up-down quark-mixing element of the CKM matrix is $V_{ud} = 0.97367(32)$ [8]. We see that the SST result, $V_{ud,SST} = 0.97371$, is very close to the central value of the result presented in [8]. On the other hand, the element V_{ud} depends on both Θ_{12} and Θ_{13}—it suggests that the SST definitions of the Θ_{12} and Θ_{13} can be correct. Notice that the SST definitions of Θ_{12} and Θ_{13} contain the mass of the bottom quark and the mass of the fundamental gluon loop, respectively, and they are normalized via the mass of the electric charge inside the core of baryons.

The fit result for the magnitude of V_{tb} is (it is from [6]: 12. CKM Quark-Mixing Matrix): $V_{tb} = 0.999118^{+0.000029}_{-0.000034}$—this result is consistent with the SST result. On the other hand, the element V_{tb} depends on both Θ_{23} and Θ_{13}.

The up-bottom quark-mixing element of the CKM matrix from $B \to \pi l \nu$ is $V_{ub} = 0.00370 \pm 0.00010(\exp) \pm 0.00012(th)$ [9]—it depends only on Θ_{13} and it is consistent with the SST result.

We see that the V_{ud} from [8], V_{tb} from [6] and V_{ub} from [9] plus the condition of unitarity of the matrix lead to the CKM-SST matrix.

In the right vector in (1) (it is a vector of the mass eigenstates of the down-type quarks), there appear the masses of the down quark, strange quark and bottom quark. In SST, the mass of the s-quark is equal to half the mass of the relativistic neutral pion in the $d = 2$ state that is responsible for the structures of the hyperons: $m_s = 87.85483\ \text{MeV}$, whereas the mass of the *b*-quark is $m_b = 4190.33\ \text{MeV}$ [1].

The masses of the three involved quarks in the right vector in (1) and the CKM-

SST mixing matrix for quarks lead to the masses in the left vector in (1) (there are the weak-interaction doublet partners of down-type quarks)

$$m'_d = 40.29\text{ MeV} \approx m_d + E_\nu^{in-pion} + (n-p) = 39.93\text{ MeV}, \quad (58)$$

$$m'_s = 256.70\text{ MeV} \approx 3m_s - \Delta W_{d=1} = 256.45\text{ MeV}, \quad (59)$$

$$m'_b = 4183.2\text{ MeV} = m_b - \Delta W_{d=1} = 4183.2\text{ MeV}. \quad (60)$$

In (58), there appear the β-decay and the weak decay of the neutral pion.

In (59), there can appear the transition from the heaviest hyperon Ω^- that contains three strange quarks to the lightest hyperon Λ that contains one strange quark.

In (59) and (60), there appear the weak decays of the relativistic charged pion $W_{(-),d=1}$.

The experimental mass of the strange quark is $m_{s,exp} = 93.5(8)\text{ MeV}$ [5]. It differs from the SST results. It is because in the atom-like structure of baryons, in the $d = 2$ state there appears symmetrical decay of the virtual mass/energy $\frac{M_{TB}}{2} = 375.147884\text{ MeV}$ [1]. Such a mass can also decay to a pair of the ss^{anti} pairs, *i.e.* to a quadrupole

$$\frac{M_{TB}}{2} \to 2\left(ss^{anti}\right). \quad (61)$$

From (61) we have

$$s = m_s^* = 93.78697\text{ MeV}. \quad (62)$$

The SST mass $m_s^* = 93.787\text{ MeV}$ can mimic the experimental value $m_{s,exp} = 93.5(8)\text{ MeV}$.

The mass of top quark calculated within the SST is $m_t = 171.85\text{ GeV}$ [1] whereas the experimental value is $m_{t,exp} = 172.56(31)\text{ GeV}$. It follows from the fact that at high energies such a quark can absorb its electromagnetic mass, *i.e.* $\alpha_{em,high} m_t$, where $\alpha_{em,high} = \frac{1}{127.54251}$ is the fine-structure constant at high energy [1]. Then the SST mean value is

$$m_{t,mean} = \frac{m_t + m_t\left(1+\alpha_{em,high}\right)}{2} = 172.52\text{ GeV}. \quad (63)$$

This SST result is consistent with experimental value [6].

The Wolfenstein parameterization of the CKM matrix leads to the unitarity triangle with three angles/phases [6]

$$\beta = \Phi_1 = \arg\left(\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right), \quad (64)$$

$$\alpha = \Phi_2 = \arg\left(\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right), \quad (65)$$

$$\delta = \gamma = \Phi_3 = \arg\left(\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right). \quad (66)$$

Experimental data lead to [6]: $\sin 2\beta = 0.709 \pm 0.011$, *i.e.* $\beta/^{\circ} = 22.58 \pm 0.35$, $\alpha/^{\circ} = 84.1^{+4.5}_{-3.8}$ and $\delta/^{\circ} = 65.7 \pm 3.0$. We see that the sum of the central values is $172.4^{\circ} < 180^{\circ}$. We claim that in SST, the three angles are associated with the components of the core of baryons, *i.e.* with $X^{\pm}$ and Y, and with the muon $\mu^{\pm}$ plus $\Delta\pi = \pi^{\pm} - \pi^{o}$ produced by the core (they are the objects from decay of the charged pion). The Θ_{12}, Θ_{13} and Θ_{23} in the CKM-SST are normalized via $X^{\pm}$ but the CKM matrix is associated with the d-type quarks (they appear in the right vector in (1)), so we can define three angles normalized by mass of the d-quark that in SST is equal to half the mass distance between the two states of neutron: $m_d = 4.890481\ \text{MeV}$ [1]

$$\beta_{SST}/^{\circ} = \frac{\mu^{\pm} + \Delta\pi}{m_d} = 22.5442 \quad (\textit{i.e.}\ \sin 2\beta_{SST} = 0.7082\ ), \tag{67}$$

$$\alpha_{SST}/^{\circ} = \frac{Y}{m_d} = 86.7239\,, \tag{68}$$

$$\delta_{SST}/^{\circ} = \frac{X^{\pm}}{m_d} = 65.0847\,, \tag{69}$$

We see that the SST angles are consistent with the experimental values presented in [6] and are very close to the experimental central values.

The sum of the three SST angles is

$$\beta_{SST}/^{\circ} + \alpha_{SST}/^{\circ} + \delta_{SST}/^{\circ} = 174.35 < 180\,. \tag{70}$$

When in (67), instead the $\mu^{\pm} + \Delta\pi$ there is the charged pion $\pi^{\pm}$ then we obtain $\beta_{\pi,SST}/^{\circ} = \frac{\pi^{\pm}}{m_d} = 28.5392$ and then the sum is

$$\beta_{\pi,SST}/^{\circ} + \alpha_{SST}/^{\circ} + \delta_{SST}/^{\circ} = \frac{\pi^{\pm} + Y + X^{\pm}}{m_d} = 180.35 \approx 180\,, \tag{71}$$

so we can say about the SST unitarity triangle for $\pi^{\pm}$, Y, and $X^{\pm}$ normalized via m_d.

We should not confuse the phases in (64)-(66) or in (67)-(69) with the CP phase $\delta_{CP}/^{\circ} = 0$ in (57).

Within SST we can define the three mixing angles in such a way to obtain from them the unitarity triangle

$$\Theta_{13,SST}/^{\circ} = \frac{\pi^{\pm}}{m_d} = 28.5392\,, \tag{72}$$

$$\Theta_{12,SST}/^{\circ} = \frac{X^{\pm}}{m_d} = 65.0847\,, \tag{73}$$

$$\Theta_{23,SST}/^{\circ} = \frac{Y}{m_d} = 86.7239\,. \tag{74}$$

The relativistic charged pion, the $X^{\pm}$ and Y are the three fundamental objects in the neutron while the $2m_d$ is the mass distance between the two states of the neutron [1]—we see that the SST mixing angles are closely related to the internal structure of the neutron which undergoes β-decay.

For scalars, pseudoscalars and electrically charged fermions we have

$$\delta_{CP} / ^\circ = 0 . \tag{75}$$

From (72)-(75) we obtain the SST unitary mixing matrix (see Table 5).

The SST mixing matrix and Formula (1) lead to

*the doublet scalars $s's \equiv \pi^+\pi^-$ and Y;

*the doublet pseudoscalars $p'p \equiv -\pi^o$ (virtual) and π^o;

*the doublet fermions $f'f \equiv X^\pm$ and $E_\nu^{in-pion}$.

Table 5. The SST mixing matrix.

0.3700887	0.7967308	0.4777599	$V_{s's}$	$V_{s'p}$	$V_{s'f}$
−0.2527698	−0.4085124	0.8770548	$V_{p's}$	$V_{p'p}$	$V_{p'f}$
0.8939473	−0.4453513	0.0502036	$V_{f's}$	$V_{f'p}$	$V_{f'f}$

The calculated from (1) masses of the weak eigenstates differ from the real values less than 1 part in $\frac{1}{\alpha_{w(p)}} \approx 53$ parts, where $\alpha_{w(p)}$ is the coupling constant for the nuclear weak interactions [1].

From Table 5 we obtain that probability of the $Y \to \pi^+\pi^-$ transition is $P_{s's} = V_{s's}^2 = 0.137$. From Table 5, it follows that there is preferred the decay of Y into $X^+\mu^-$.

Notice that instead of saying about the scalar, pseudoscalar and fermion in the mass eigenstate vector (Y, π^o, $E_\nu^{in-pion}$) we can say about the oscillations of the Y scalar because the diameter → circle oscillations lead to $\frac{Y}{\pi} \approx 135.00\ \text{MeV} \approx \pi^o$ while the next 4-object-symmetry decays lead to $\frac{Y}{4\pi} \approx 33.75\ \text{MeV} \approx E_\nu^{in-pion}$. It means that there instead the vector (Y, π^o, $E_\nu^{in-pion}$) we have the vector composed of the scalars (Y, $\frac{Y}{\pi}$, $\frac{Y}{4\pi}$).

The Cabibbo angle, Θ_c, was introduced to preserve the universality of the weak interaction (for example, the β-decay Fermi constant of the strange Λ baryon was a few times smaller). The Cabibbo angle in the CKM-SST matrix is (see Table 4)

$$\tan\Theta_c = \frac{|V_{us}|}{|V_{ud}|} = \frac{0.2277529}{0.973712} = 0.2339017 , \tag{76}$$

$$\Theta_c / ^\circ = 13.1649 = \Theta_{12} / ^\circ = \frac{m_b}{X^\pm} . \tag{77}$$

The Cabibbo angle leads to the relative probability that strange and down quarks decay into up quark.

By analogy to the Cabibbo angle we can define the Cabibbo-SST angle for the SST matrix. From Table 5 we have

$$\tan\Theta_{c,SST} = \frac{V_{s'p}}{V_{s's}} = \frac{0.7967308}{0.3700887} = 2.1528104, \tag{78}$$

$$\Theta_{c,SST}/^{\circ} = 65.0847 = \Theta_{12,SST}/^{\circ} = \frac{X^{\pm}}{m_d}, \tag{79}$$

$$\Theta_{c,SST}[\text{rad}] = 1.13594. \tag{80}$$

This angle leads to the relative probability that neutral pion (pseudoscalar) and scalar Y decay into the $\pi^+\pi^-$ pair.

Notice that there appear some angle resonances

$$65.0847 = \Theta_{c,SST}/^{\circ} = \Theta_{12,SST}/^{\circ} \approx \delta/^{\circ} = \gamma/^{\circ} = 65.7 \pm 3.0. \tag{81}$$

Emphasize that we should not confuse the angle $\delta/^{\circ} = \gamma/^{\circ} = 65.7 \pm 3.0$ with the CP phase $\delta_{CP}/^{\circ} = 0$ that appears in (57) and (75).

From (77) and (79) we obtain

$$\Theta_c/^{\circ} \times \Theta_{c,SST}/^{\circ} = \frac{m_b}{m_d}, \tag{82}$$

where m_b and m_d are the masses of the bottom and down quarks, respectively, so the CKM-SST and SST matrices are combined via masses of such two quarks.

The factor $f = \frac{\alpha_{w(p)}}{\alpha_{em}} = 2.56571$ means that there is a transition from the electromagnetic interactions to the nuclear weak interactions and that then involved mass increases f times [1]. When we use the SST matrix then the mass eigenstate vector (b, s, d), *i.e.* the d-type quarks arranged from heaviest to lightest, leads to the following weak eigenstate vector

$$\left(\sim 2X^{\pm}f, \sim -Yf, \sim 2H^{\pm}f\right), \tag{83}$$

where $H^{\pm} = 727.4392$ MeV is the mass of the charged core of baryons [1]. The mass distances between doublet partner and corresponding to it the right side in (1) is smaller than 1 part in 140 parts.

There is obligatory the following equation that relates the mass of the bottom quark to mass of the electric charge in the core of baryons

$$m_b = 2X^{\pm}f^2 = 4190.6 \text{ MeV}. \tag{84}$$

8. The Origin of the Up and Down Quarks in Nucleons, Other Quarks, and the Quark-Gluon Plasma (QGP)

We define the mass distance between the charged core of baryons and neutral one [1] as the mass distance between the down and up quarks

$$\Delta H = H^{+} - H^{o} = d - u = 2.66332 \text{ MeV}. \tag{85}$$

We define the mass distance between the relativistic charged pion in the $d = 1$ state and neutral one [1] as the sum of masses of the down and up quarks

$$\Delta W = W_{(+-),d=1} - W_{(o),d=1} = d + u = 7.11764 \text{ MeV}. \tag{86}$$

From (85) and (86) we obtain

$$d = m_d = 4.89048 \text{ MeV}, \tag{87}$$

$$u = m_u = 2.22716 \text{ MeV}. \tag{88}$$

The transition between the two states of neutron [1] creates the quark field that is a part of the zero-point energy—there appear the quarks with positive mass and 'holes' in spacetime with negative mass. When we neglect the virtual spacetime holes then we obtain

$$\begin{aligned} &H^{+}W_{(-),d=1} - H^{o}W_{(o),d=1} = \Delta H + \Delta W \\ &= d - u + d + u = d + u(hole) + d + u \rightarrow ddu. \end{aligned} \tag{89}$$

The transition between the two states of proton leads to [1]

$$\begin{aligned} &H^{o}W_{(+),d=1} - H^{+}W_{(o),d=1} = -\Delta H + \Delta W \\ &= -d + u + d + u = d(hole) + u + d + u \rightarrow uud. \end{aligned} \tag{90}$$

When we neglect the atom-like structure of baryons, as it is in the quark model, then from (89) and (90) we obtain the electric charges of the up and down quarks

$$Q_u = +\frac{2}{3}e, \tag{91}$$

$$Q_d = -\frac{1}{3}e. \tag{92}$$

We also have

$$n_1 - n_2 = dd^{anti}, \tag{93}$$

$$p_1 - p_2 = uu^{anti}, \tag{94}$$

where n_1, n_2, p_1 and p_2 are the mass states of the nucleons.

Our conclusions are as follows.

*In interactions/collisions of nucleons, we can measure the mass distances between the characteristic masses of the nucleon components that follow from the atom-like structure of baryons.

*The new description via quarks replicates the total electric charges of the nucleons—such an adaptation symmetry forces quarks to have fractional electric charges, which is achieved through appropriate radii of the tori/electric-charges of the quarks. The elementary torus/electric-charge in the core of baryons has the equatorial radius equal to $A = 0.6974425$ fm [1], so the electric charge equal to $+\frac{2}{3}e$ has the equatorial radius equal to $\frac{2A}{3}$ whereas the charge $-\frac{1}{3}e$ has the equatorial radius equal to $\frac{A}{3}$. The electric tori interact with photons so their mass/energy is not determined by torus equatorial radius.

*It is impossible to describe properties of hadrons only via quarks, gluons and electroweak interactions—we need also the atom-like structure of baryons.

*Due to (93) and (94), there can appear a virtual field composed of the quark-antiquark pairs that is a part of the zero-point energy.

*The proton is the only baryon that is the stable particle because of its lowest mass and because it is the strong black hole [1]. In SST, the lower-mass state of the proton consists of three objects $\left(W_{(o),d=1}, Y, X^{+}\right)$ so it leads to the electric-charge eigenstate vector $\boldsymbol{k}_i = (0,0,+1)$. The quark model of proton (u,u,d) leads to the following electric-charge eigenstate vector $\boldsymbol{k}_i = \left(+\frac{2}{3},+\frac{2}{3},-\frac{1}{3}\right)$. On the other hand, the Kasner metric is an exact solution to Einstein's equations of gravitation in an anisotropic space free from the matter when the following Kasner conditions for the 4D spacetime are satisfied [10]

$$\sum_{i=1}^{3} k_i = 1\,, \tag{95}$$

$$\sum_{i=1}^{3} k_i^2 = 1\,. \tag{96}$$

The two extreme solutions that follow from (95) and (96) are $(0,0,+1)$ and $\left(+\frac{2}{3},+\frac{2}{3},-\frac{1}{3}\right)$, so they overlap with the SST/quark electric-charge eigenstate vectors for proton.

To obtain within SST the correct masses of nucleons, we must assume that the quark field is a result of the mass/electric-charge oscillations of the nucleons and that the created quark field is associated with the zero-point energy. Moreover, the oscillations of both the virtual electroweak field [1] and the virtual quark field of nucleons cause that information about the internal structure of the nucleons leaks outside the nucleons—it is very important in cosmology [11] and in the SST chaos theory.

We can interpret the Kasner conditions as an real-virtual oscillation between the two extreme states of the electric-charge eigenstate vectors defined by both the real SST-model and the virtual quark-model, *i.e.* the exchanged elementary real electric charge in the SST model forces creation of the three virtual fractional electric charges in the quark model, and vice versa.

We showed that in SST, the Kasner conditions concern electric charges (not masses) and concern the zero-point energy field so we can say about the Kasner anisotropic space "free from the matter". In collisions/interactions of the nucleons, the quark field can behave as a real field.

We see that we can partially unify the general relativity (GR) and the standard model (SM) via the Kasner conditions.

In [1] we calculated masses of the three heaviest quarks whereas in this article we calculated masses of the three lightest quarks and the second solution for t-quark. The SST results and the experimental data from [6] are collected in **Table 6**.

SST shows that the base of the QGP is a superfluid composed of the cores of baryons. In the plasma core, there is destroyed the atom-like structure of baryons outside the cores of baryons. On the other hand, only mass of the t-quark follows from the structure of the baryonic core [1]. It means that the other quarks are produced only in the plasma corona, *i.e.* outside the plasma core. In this article we showed that there are 8 Types of gluons.

Table 6. Masses of quarks from SST and [6].

Quark	Effective Mass from SST MeV	Mass from SST Second Solution MeV	Experimental Mass from [6] MeV
u	2.22716		2.16 (7)
d	4.89048		4.70 (7)
s	87.85483	93.78697	93.5 (8)
c	1267.15		1273.0 (4.6)
b	4190.33		4183 (7)
t	171,850	172,520	172,560 (310)

9. Neutrino Oscillation Anomalies

In the Standard Model of particle physics, we have three distinct neutrino flavours. But several anomalous observations suggest that there should be an additional neutrino state [12]. Here we show that the anomalies can be explained within presented here the SST model of neutrinos.

Some neutrino-flavour change corresponds to a mass-squared splitting of $\Delta m_{41}^2 \gtrsim 10^{-2}\,\text{eV}^2$ [12], which is much greater than the measured Δm_{32}^2 and Δm_{21}^2 in (33) and (34), respectively. On the other hand, the mass distance between the tau-neutrino and electron-neutrino (the $\nu_e \leftrightarrows \nu_\mu$ oscillations are possible only via the tau-neutrino) leads to

$$\Delta m_{\nu_\tau \nu_e}^{real} = 0.1149\,\text{eV}\,, \tag{97}$$

$$\Delta m_{41}^2 = \left(\Delta m_{\nu_\tau \nu_e}^{real}\right)^2 = 1.320 \times 10^{-2}\,\text{eV}^2\,. \tag{98}$$

The second solution that results from (2) is as follows. The sum of the rest masses of neutrinos in the muon is $m_4 = m_{\nu_e^{anti}}^{real} + m_{\nu_\mu}^{real} = 0.1149\,\text{eV}$. The decay of the muon leads to $m_1 = 0\,\text{eV}$ in the electron, so we have $\Delta m_{41}^2 = m_4^2 - m_1^2 = 1.320 \times 10^{-2}\,\text{eV}^2$. It is the mean value because this result and result in (98) are the same, *i.e.* $\Delta m_{41,mean}^2 = 1.32 \times 10^{-2}\,\text{eV}^2$ that is consistent with the data in [12].

The interplay between oscillation of intrinsic ν_μ and ν_e components in a beam leads to $\Delta m_{41}^2 = 1.2$ or $1.4\,\text{eV}^2$ [12]. Its origin is as follows.

The derived relationship between the center-of-mass energy $\sqrt{s_{NN}}$ and the characteristic masses created in the SST nuclear matter, M, is as follows [13]

$$\frac{\sqrt{s_{NN}}}{M} = C_M = 20.7825\,. \tag{99}$$

We obtain such a formula for the ratio $\frac{v}{c}$ in the formula for the relativistic mass equal to $\frac{1}{1+a_e}$, where $a_e = 0.0011596522$ is the anomalous magnetic moment of the electron. We obtain it by calculating the relativistic mass of the electron when the wavefunction of the bare electron propagates with the maximum speed c. Then we have [1]: $\frac{m_{e,bare}}{m_e} = \frac{v}{c} = \frac{1}{1+a_e}$, where m_e is the rest mass of the electron while $m_{e,bare}$ is the rest mass of the bare electron. Next from the Einstein's formula for the relativistic mass we obtain that the relativistic mass of the electron is C_M times higher than its rest mass.

We can apply the factor C_M also to the neutrinos. Then we obtain

$$M_{\nu_e} = C_M m_{\nu_e}^{real} = 1.1940 \text{ eV}, \tag{100}$$

$$\Delta M = M_{\nu_e} - m_{\nu_e}^{real} = 1.1365 \text{ eV}, \tag{101}$$

$$\Delta m_{41}^2 = \Delta M^2 = 1.292 \text{ eV}^2. \tag{102}$$

The second solution that results from (2) is as follows: $m_4 = M_{\nu_e} = 1.1940 \text{ eV}$ and $m_1 = m_{\nu_e}^{real} = 0.057450 \text{ eV}$. It leads to $\Delta m_{41}^2 = m_4^2 - m_1^2 = 1.422 \text{ eV}^2$. The mean value of this result and the result in (102) is $\Delta m_{41,mean}^2 = 1.36 \text{ eV}^2$ that is consistent with the data in [12].

The value in (102), *i.e.* $\Delta m_{41}^2 = 1.29 \text{ eV}^2$ appears in [14].

Let's consider a neutrino counterpart to $4Y^* = 1697.576 \text{ MeV}$ for 4 different entangled stable neutrinos that mass increased C_M times (see (99)). Then we have

$$m_4 = m_{\nu_e}^{real} \frac{4Y^*}{Y^* + X^{\pm}} C_M = 2.729 \text{ eV}, \tag{103}$$

$$m_1 = 4 m_{\nu_e}^{real} = 0.2298 \text{ eV}, \tag{104}$$

$$\Delta m_{41}^2 = m_4^2 - m_1^2 = 7.395 \text{ eV}^2. \tag{105}$$

The value in (103) and (105) are consistent with the results presented in [15]: $m_4 = 2.70 \pm 0.22 \text{ eV}$ and $\Delta m_{41}^2 = 7.3 \pm 1.17 \text{ eV}^2$, respectively.

10. Summary

SST shows that the neutrinos are the Dirac fermions.

Here within SST, we showed that due to the cloud of the dark pions surrounding the energetic neutrinos, they should disappear over distances of ~182 km and ~729 km.

Due to the spin rotation, masses of neutrinos can change from ~3 × 10^{-67} kg to masses close to the Planck mass but they are a part of the zero-point energy.

We described two oscillations of neutrinos that lead to $\Delta m_{32,mean}^2 = 2.45 \times 10^{-3} \text{ eV}^2$ and $\Delta m_{21,mean}^2 = 7.42 \times 10^{-5} \text{ eV}^2$. We showed that they follow from the SST structure and weak interactions of the core of the stable neutrinos. Emphasize that they are not associated with the mass eigenstates. We also described three Standard-Model anomalies that follow from following mass-squared splitting equal to $\Delta m_{41,mean}^2 = 1.32 \times 10^{-2} \text{ eV}^2$, $\Delta m_{41,mean}^2 = 1.36 \text{ eV}^2$, and $\Delta m_{41}^2 = 7.395 \text{ eV}^2$—SST shows that sterile neutrinos are not needed.

The cores of neutrinos pulsate that lead to the Higgs potential that increases the effective radius of the neutrinos (the SST quantum gravity), but in such processes, the neutrinos do not change their flavour [1]—such pulsations activate the neutrino oscillations.

We explained the dependence of the survival probability on the electron-antineutrino energy in the KamLAND data via the atom-like structure of baryons. There are two dominant phenomena, *i.e.* the *β*-decays and the reconstructions of the $W_{(-),d=1}$ charged relativistic pions.

We showed that the experimental results for masses of cosmological neutrinos lead to the radius of the neutrino core and vice versa.

We showed that there can be the neutrino-photon decoupling (or coupling). In such processes, the flavours of neutrinos can change.

We also solved the reactor electron-antineutrino anomaly that follows from a change in the strong coupling.

We used the SST to show how we should correctly interpret the PMNS formalism. The mixing angles relate to two symmetries, *i.e.* to the four-fermion symmetry and to the saturation-of-interaction symmetry for the three neutrinos with different flavours. On the other hand, the internal structure of the stable neutrinos leads to the CP phase $\delta_{CP}/^\circ = 180$. But we can show that there exists an alternative set of mixing angles (the choice of angles is based on convention). We have:

$\Theta_{13}/^\circ = \frac{2\pi^\pm}{E_\nu^{in-pion}} = 8.272$, $\Theta_{12}/^\circ = \frac{\Lambda}{E_\nu^{in-pion}} = 33.063$,

$\Theta_{23}/^\circ = \frac{\mu_{B,ch,upper,T=0}}{E_\nu^{in-pion}} = 41.99$, and $\Theta_{23}/^\circ = \frac{\Omega^-}{E_\nu^{in-pion}} = 49.56$, where

$\Lambda = 1115.683(6)$ MeV and $\Omega^- = 1672.45(29)$ MeV are the masses of the lightest and the heaviest hyperons [6], and $\mu_{B,ch,upper,T=0} = 1417$ MeV is the upper limit for the characteristic baryonic chemical potential for emission of the relativistic pion $W_{(-),d=1}$ by neutron at $T = 0$ [13]. Such a set of mixing angles practically does not differ from the original set.

Via the mixing angles Θ_{ij} and the SST squared masses Δm_{ij}^2 we can solve all problems concerning the neutrino oscillations [6]. Emissions of the weak charge-anticharge pair lead to Δm_{32}^2 while the four-neutrino symmetry (it appears in the $\mu^+\mu^-$ pairs) leads to Θ_{12} (the so-called large mixing angle (LMA) solution). The Δm_{32}^2 and Θ_{12}, lead to the energy dependence of the survival probability of solar neutrinos [6].

Within the CKM-SST matrix presented here, we can determine probability of changing flavour of quarks in weak decays.

We present here also the SST model based on both the unitarity triangle from the mixing angles and the unitary matrix that lead to the weak eigenstate vector and mass eigenstate vector both composed of scalar, pseudoscalar and fermion. We showed that the mass eigenstate vector can be composed of only scalars as well.

SST shows that masses of quarks are very important at high energy collisions/interactions but at low energies there dominates the atom-like structure of baryons. Here we described the origin of the up and down quarks and their compositions in the nucleons. We introduced the masses of the up and down quarks as half the mass distance between the two states in proton and two states in neutron, respectively—we obtained $m_u = 2.22716\text{ MeV}$ and $m_d = 4.89048\text{ MeV}$. It is not true that we can from the quark-gluon field calculate the basic quantities concerning the nucleons at low energies, *i.e.* their exact masses, magnetic moments and spin.

To investigate the weak interactions we need a model that preserves probability amplitudes. We can do it via unitary matrices which preserve both probability amplitudes and norms/lengths of vectors. Euclidian norm, $\|x\|$, of the left and right vectors in (1), for a vector $\boldsymbol{x} = (x_1, x_2, x_3)$, is $\|x\| = \sqrt{x_1^2 + x_2^2 + x_3^2}$. Emphasize that our selection of the mass eigenstates in (1) must lead to a vector composed of the weak eigenstates that have physical meaning—only then we can investigate the weak interactions via unitary matrices. We can choose, for example, the total masses of the real neutrinos in muon and in charged pion and the mass of the weak charge—it leads via the PMNS-SST matrix to the real masses of the neutrinos. We can choose, for example, the masses of the d-type quarks, *i.e.* masses of quarks that have the electric charge equal to $-e/3$, or we can choose the three fundamental oscillatory states of the spacetime condensate Y, and so on.

We showed that we can partially unify the General Relativity (GR) and the Standard Model (SM) via the Kasner conditions. We cannot fully unify GR and SM because the gravitational fields concern the Higgs field whereas the SM interactions concern the SST absolute spacetime that is composed of the neutrino-antineutrino pairs. The gravitational fields, because of the strong viscous forces between the Higgs field and the binary systems of closed strings the neutrinos consist of, are curved whereas the SM fields are practically flat. This causes that in GR time is relativistic whereas in SM is absolute. There is the elementary invariant gravitational field produced by the non-rotating-spin stable neutrinos. Of course, some parts of the absolute spacetime can flow but we should not call them the gravitational waves because gravitational waves are some superluminal flows in pure Higgs field—such superluminal flows were possible during the SST inflation.

Notice also that the Higgs potentials of the neutrinos in the SST absolute spacetime are in direct contact (on the torus/electric-charge in the core of baryons, the neutrino Higgs potentials practically fully overlap) whereas the tachyons in the Higgs field are not in direct contact but there are direct collisions of them—it causes that there are four stable neutrinos with the same mass (*i.e.* electron-neutrino, muon-neutrino and their antiparticles) whereas the electrically charged fermions have only two states with the same rest mass (*i.e.* particle and its antiparticle).

SST shows that the CP violation in the weak interactions follows from the fact that we neglect the poloidal motions on the tori/charges of the weakly decaying fermions or systems of entangled fermions. The poloidal motions cause that there appear small directional asymmetries in the weak decays of the spacetime condensates (for example, of the Y condensates) when they take place near the centers of the cores of fermions. In reality, the left-handedness of the toroidal-poloidal motions in fermions (for example in neutron, proton, positron, positively charged muon, and so on) and the right-handedness of the antifermions do not lead to the matter-antimatter asymmetry.

The poloidal motions are damped outside the core of baryons in the plane of its equator so the CP violation does not appear in the nuclear strong interactions. It follows from the fact that both the toroidal speed on the equator of the core of baryons and the resultant speed of the neutrino-antineutrino pairs are equal to the speed of light in "vacuum" c. On the other hand, the toroidal speed on the torus/charge is lower when distance from axis of rotation is smaller—it forces an increase in the poloidal speed. The small directional asymmetry in the weak interactions is a result of the poloidal motions and viscosity of the SST absolute spacetime.

The small directional asymmetry in weak decays of fermion and its antifermion is symmetrical so it does not lead to the observed matter-antimatter asymmetry. In SST, the observed matter-antimatter asymmetry is a result of the external left-handedness of the initial inflation field that today is encoded in the internal left-handedness of the baryons that dominates. Notice that the electrons are internally righthanded but their mass is about 1836 times lower than protons so their handedness does not dominate in our Universe.

We see that we must distinguish the violation of symmetry of the initial inflation field that led to the observed matter-antimatter asymmetry, from the small directional asymmetries in the weak decays/interactions that do not force the matter-antimatter asymmetry.

The Scale-Symmetric Theory is a superior theory to the Quantum Chromodynamics (QCD) because within SST we have described the origin and physical meaning of the fundamental quantities used in QCD and more broadly in the Standard Model.

We showed that the SST internal structure of neutrinos leads to only three different flavours. According to SST, no sterile neutrino exists. The observed neutrino oscillations (also the Standard-Model anomalies) follow from the internal structure and dynamics of neutrinos described in SST. For the large neutrino mass-squared splitting $\Delta m_{ij}^2 > 1\,\text{eV}^2$ is responsible the increase in neutrino energy/mass defined by the distinguished factor $C_M = 20.7825$—it is the result of the weak interactions of the neutrinos with relativistic particles.

In this article appear many resonances that concern the mixing angles and the neutrino mass-squared splitting that define the neutrino oscillations. Such resonances cause that we can better understand the main features of the flavour-changing weak interactions of neutrinos and quarks. Due to the unitary matrices that follow from the mixing angles, we can analyse selected weak decays and neutrino oscillations—we showed that it leads to the internal structure and dynamics of the leptons and hadrons described in SST.

Conflicts of Interest

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

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