The Quark Theory of the Electron and the Vacuum

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Abstract: Paul Dirac introduced the Quantum Theory of the Electron in 1928 that led him to the discovery of antimatter in general and in particular to the discovery of the electron antiparticle, the positron. We propose a new quark theory of the electron and the vacuum. We propose that the electron is a non-elementary non-point like particle comprised of two quarks and two antiquarks and having a tetrahedron structure. We further assume that electrons perform rapid quark flavor exchange reactions with pion tetraquark tetrahedrons comprised of the valence quarks and antiquarks, $u\ , d\ , \tilde{u}\ , \tilde{d}$ that form the vacuum pion tetrahedron fabric. Motion of the electron tetraquark tetrahedron on the vacuum pion tetraquark tetrahedron fabric is performed by quark flavor exchange reactions of $u\ and\ d$ quarks via gluons by tunneling through a double well potential between the electron tetrahedron and the vacuum pion tetrahedrons that transform the electron tetraquark tetrahedron to a pion tetraquark tetrahedron and vice versa. We assume that the quark flavor exchanges occur with Dirac's equation extremely high zitterbewegung frequency and hence a single electron cannot be isolated since it forms a delocalized electron cloud with the vacuum pion tetraquark tetrahedrons fabric. Extremely high precision measurements of the electron mass at the earth's trajectory perihelion and aphelion may prove the quark theory of the electron and the vacuum, the existence of the vacuum pion tetraquark tetrahedron fabric and its density dependence on gravity.

Keywords: Antimatter, Quantum vacuum, Pion tetrahedrons, QED, QCD.

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1. Problems with the Quantum Electron Theory

Dirac proposed a relativistic wave equation using a Spinoric 4*4 wave equation and found a new set of negative energy solutions he interpreted as antimatter states[1]. Dirac thought that since the positive electron solutions would decay to negative energy states there must be an infinite number of invisible negative energy electrons that occupy the negative states and prevent the decay of positive energy electrons according to Pauli exclusion principle[2]. Dirac thought that electrons may not be point like particles and proposed a charged spherical shell electron model with an internal oscillation and self-energy[3]. Dirac thought that since the electron interacts always with the vacuum electron-positron virtual pairs, the electron is never bare in contrast to Feynman's QED[4], where bare electrons propagate in free space in zero order and then interact in a perturbation theroy with other particles. Dirac thought that better understanding of the vacuum structure is needed to understand QED[5].

The questions we address in this paper are:

1. Are electrons non-elementary non-point like not a single particle made of quarks and antiquarks?
2. Is the quantum vacuum filled with massive pion tetrahedrons comprised of 50% quarks and 50% antiquarks?
3. Does electrons motion occur via u and d quark flavor exchanges by tunneling reactions through a double well potential between electrons and the vacuum pion tetrahedrons in a first electron chiral state, and exchanges of $\tilde{u}$ and $\tilde{d}$ antiquark flavors in a second electron chiral state?

2. The Vacuum Pion Tetraquark Tetrahedron Fabric

We assume that the quantum vacuum is filled with pion tetrahedron tetraquark fabric[6-10]. We note that the vacuum pion tetrahedrons are not ordinary matter since they are composed of 50% antiquarks that annihilate the other 50% quarks, however, we assume that the pion tetraquark tetrahedrons still have a small mass and internal rotation and vibration energy and since the quarks are charged the pion tetrahedrons may have internal electric dipoles. We assume that in each site in the vacuum fabric there is a single tetraquark tetrahedron, $u\tilde{d}d\widetilde{u}$, composed of two valence quarks, d and u, and their antiquark pairs, $\tilde{d}$and $\tilde{u}$. Two pion tetraquark tetrahedron enantiomers may exist obtained by exchanging the position of two quarks at the tetrahedron vertices as shown below in line with Dirac Weyl massless chiral spinors and the ground state of the QCD vaccum[11-17].

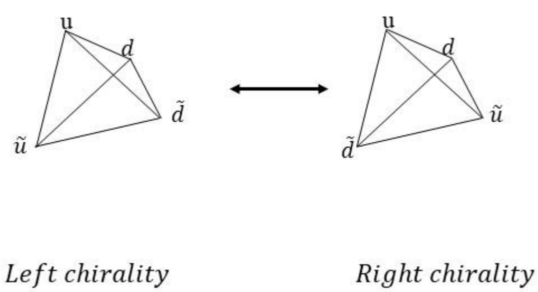

Figure 1 illustrates the two pion tetrahedron enantiomers where the $\tilde{u}$ and $\tilde{d}$ antiquarks exchange positions.

We assume that the pion tetrahedron fabric may be a simple cubic lattice in free space. However, in the vicinity of a massive body, the pion tetrahedron fabric may have higher density and a spherical symmetry with a cell size that changes according to gravity or charge, e.g. the distance from the massive body. The size of the pion tetraquark tetrahedron edge may be less than a femtometer, while the pion tetrahedron fabric lattice length in outer space far from any massive body may be much larger, for example about $5.0 * 10^{-8}$ meter. In extreme gravitational field, in the vicinity of a black hole for example, the pion tetrahedron lattice cell size may become extremely small, similar to the pion tetrahedron edge size of about $0.5 * 10^{-15}$ meter. However, far away from any galaxy in cosmic voids[18-20], the pion tetraquark tetrahedron fabric may be extremely diluted with larger lattice cell.

3. The Electron Tetraquark Tetrahedron and the Double Well Potential Model

We assume that electrons are non-elementary non-point like particles comprised of tetraquarks having two configurations, a right chiral (spin), $\tilde{u}\, du\tilde{u}$, and a left chiral (spin), $\tilde{u}\, dd\tilde{d}$. Adding an electron to the pion tetrahedron fabric occurs by a quark flavor exchanges in a fabric site transforming a pion tetrahedron with one of the two chiral electron tetraquark tetrahedrons. Motion of the electron tetraquark tetrahedron on the pion tetrahedron fabric occurs via tunneling through a double well potential[21] that represents an exchange of quark flavors via gluon exchanges between the electron tetraquark tetrahedron and the pion tetraquark tetrahedron on adjacent fabric sites that transform the electron tetrahedron to a pion tetrahedron and vice versa. The $u\ and\ d$ quark flavors are exchanged by gluons as shown in figure 2 and equations 1 below for the left chiral state.

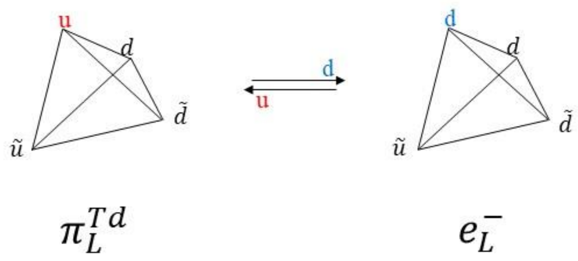

Figure 2 illustrates an electron and a pion tetrahedron where two quark flavors are exchanged (u and d).

$$\tilde{u}d\tilde{d}u\ (\pi^{Td})_i\ +\ \tilde{u}d\tilde{d}d\ (e^L)_j \rightarrow\ \tilde{u}d\tilde{d}d\ (e^L)_i\ +\ \tilde{u}d\tilde{d}u\ (\pi^{Td})_j \tag{1}$$

In the case of the right chiral electron the $\tilde{u}$ *and* $\tilde{d}$ antiquarks exchange their flavor via gluon exchanges, and the quark flavor exchange reaction equation is

$$\tilde{u}d\tilde{d}u\ (\pi^{Td})_i\ +\ \tilde{u}d\tilde{u}u\ (e^R)_j \rightarrow\ \tilde{u}d\tilde{u}u\ (e^R)_i\ +\ \tilde{u}d\tilde{u}u\ (\pi^{Td})_j \tag{2}$$

Since the quark flavor exchange reactions are symmetric, e.g., the reactants on the left-hand-side and the products on the right-hand-side are identical, the usage of the double well potential Hamiltonian is justified[21].

$$\hat{H} = \frac{\hat{P}^2}{2m} + m\,\lambda\ (x^2\ -\ a^2)^2 \tag{3}$$

We assume for the double well potential model that the mass m is the electron rest mass, a is the pion tetrahedron lattice cell size and the double well potential parameter λ determines the potential barrier height, $V_0 = m\,\lambda\, a^4$. Based on Dirac equation zitterbewegung force free trembling motion, we assume that the potential barrier height $V_0 = \hbar\boldsymbol{\omega} = 2m_e c^2$, and hence the frequency $\omega = \frac{2m_e c^2}{\hbar}$ is Dirac's equation zitterbewegung[22-23]. Accordingly, the zero-order ground state energy inside the well $E_0 = \frac{1}{2}\hbar\boldsymbol{\omega} = m_e c^2 = 5.11 * 10^6\ eV$ is equal to the electron rest mass energy.

Figure 3 below illustrates the double well potential model for the electron and pion tetrahedron quark flavor exchange reaction in lattice sites i and j in the ground state. The quark flavor exchange reaction and the double well potential exists between all adjacent lattice sites and the electron motion on the vacuum fabric is via quantum tunneling of gluons through the potential barrier V_0, which is twice the electron rest mass energy at least and represents the threshold for electron-positron pair production. Note that the electron tetraquarks on both sides of the double well is identical and hence the electron chiral configuration (a $\widetilde{u}\,dd\widetilde{d}$ or a $\widetilde{u}\,du\widetilde{u}$) is conserved, the two chiral states are not mixed by the rapid quark flavor exchanges that occur with the extremely high zitterbewegung frequency.

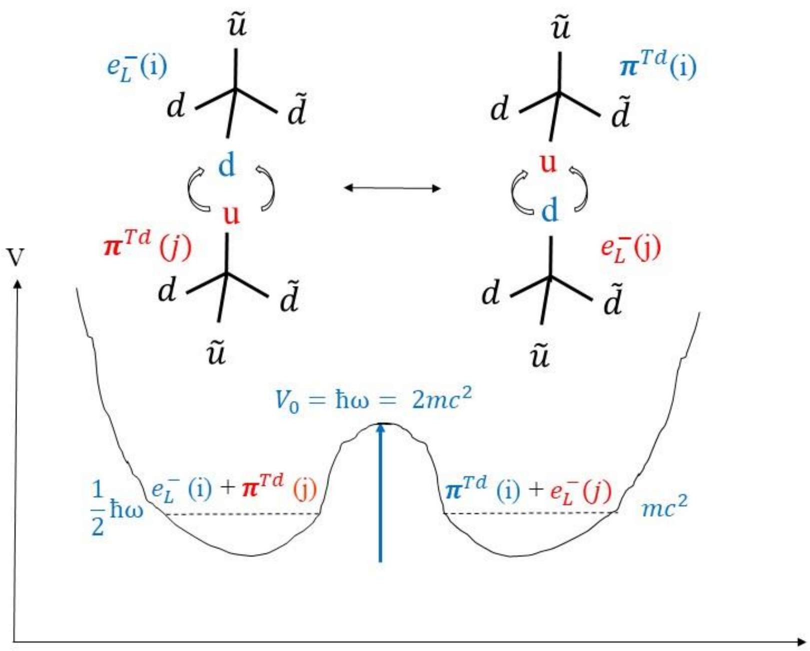

Figure 3 illustrates the double well potential model for the electron and pion tetrahedron quark flavor exchange reactions via gluons in lattice sites i and j. Note that the potential barrier V_0 is twice the electron rest mass energy and represents the threshold for electron-positron pair production.

The tunneling probability, T, from the first to the second potential well in the ground state through the potential barrier V_0 is[21]

$$T = e^{-\frac{8\, ma^3\sqrt{2\lambda}}{3\hbar}} = e^{-\frac{32V_0}{3\hbar\omega}} \tag{4}$$

ω is the ground state frequency in each well separately given by the double well model parameters by

$$\omega = \frac{2\pi}{\tau} = \sqrt{8\,\lambda\, a^2} \tag{5}$$

We assume that the barrier height potential V_0 may vary in space according to the gravitational field for example and that $2m_e c^2$ is its absolute minimal value very far from any massive body and that the value of V_0 determines the average electron velocity of the electron in the vacuum pion tetrahedron fabric. The velocity of the electron tetrahedron from site i to j due to the flavor exchange wave may be estimated by the distance between the sites, a, divided by the time period, τ, and multiplied by the double well tunneling probability in the ground state T.

$$v_e = \frac{a}{\tau}\mathrm{T} = \frac{a\omega}{2\pi} e^{-\frac{32V_0}{3\hbar\omega}} \quad \frac{m}{sec} \tag{6}$$

Assuming that the minimal possible value of V_0 is $\hbar\boldsymbol{\omega}$ and that the electron velocity in this case is maximal and equal to the speed of light c, we get the following expression for the electron tunneling velocity from site to site that show that the product, $a\omega$, is constant.

$$\frac{a\omega}{2\pi} = c\, e^{\frac{32}{3}} \quad \frac{m}{sec} \tag{7}$$

With $V_0 > \hbar\boldsymbol{\omega}$ the electron velocity divided by the speed of light c on the pion tetraquark tetrahedron fabric is

$$\frac{v_e}{c} = e^{-\frac{32}{3}(\frac{V_0}{\hbar\omega} - 1)} \tag{8}$$

We note that the electron does not follow a classical trajectory, the quark flavors exchanges between the pion tetrahedron sites occur by quantum tunneling through a potential barrier and the rapid tunneling motion of the electron creates a delocalized electron and pion tetrahedron cloud. We may assume that in some extremely small internal Compton length range around the electron tetraquark tetrahedron site, $V_0 = \hbar\boldsymbol{\omega}$, and the quark flavor exchange reactions occur at the speed of light as in semi-classical electron models[22--23]. Out of this small internal region that may be in a shape of a ring or a torus, $V_0 > \hbar\boldsymbol{\omega}$, the quark flavor exchange reactions and the electron speed is smaller than the speed of light. The pion tetrahedron quarks in each fabric site may rotate or vibrate as electromagnetic wave excitations since quarks are electrically charged.

The double well potential with $\frac{V_0}{\hbar\omega} = 1.0$ and with $\frac{V_0}{\hbar\omega} = 2.0$ are shown below. With a larger potential barrier V_0 the two wells are steeper, the tunneling probability through the barriers is smaller, the quark flavor exchanges via gluons are slower and the electron ground state wavefunction is more localized inside the well.

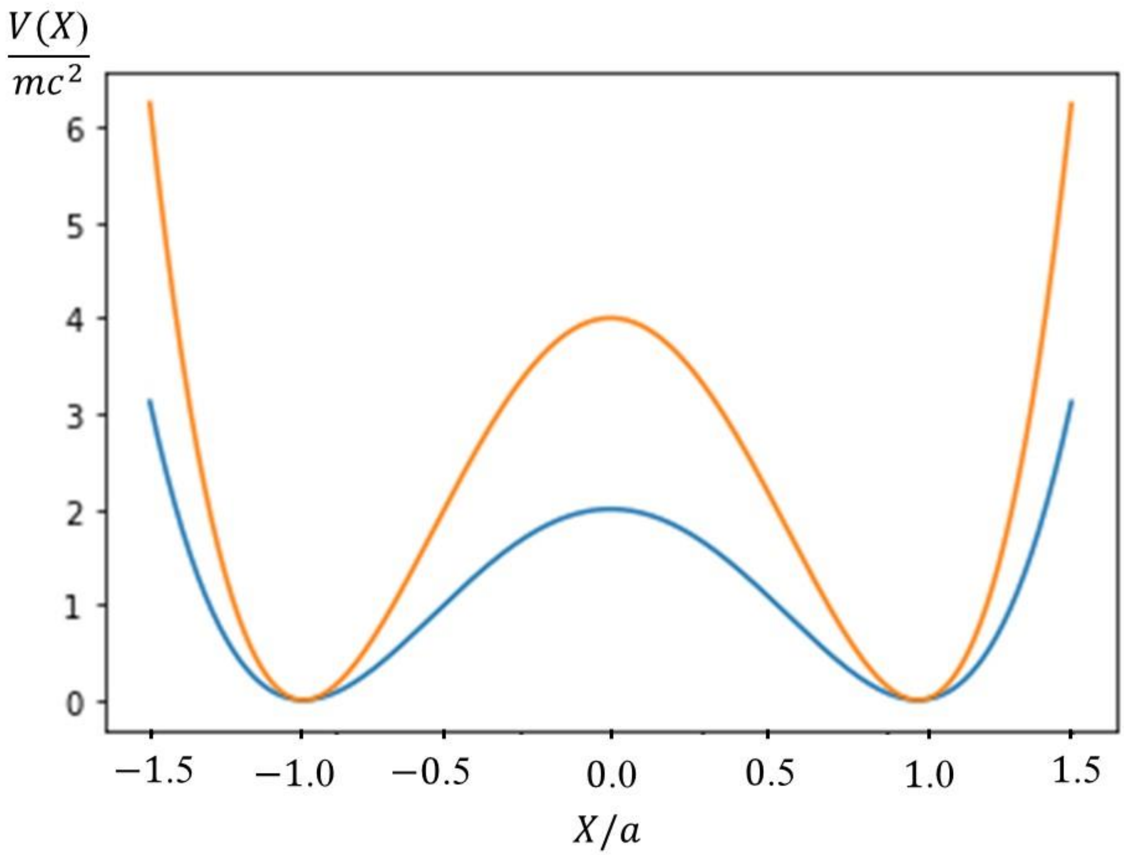

Figure 4 illustrates the double well potential with two values of the barrier height $V_0 = 2m_ec^2$ and $V_0 = 4m_ec^2$ with a = $5.2045 * 10^{-8}\ m$.

We assume that the product, $\omega\, a$, is a constant (see equation 7 above)

$$\omega\, a = 2\pi c e^{\left(\frac{32}{3}\right)} = 8.0811 * 10^{13}\ \frac{m}{sec} \tag{9}$$

Using the zitterbewegung frequency for ω in the Compton region where the potential barrier height is assumed minimal, $V_0 = \hbar\boldsymbol{\omega}$, we can estimate the pion tetrahedron lattice cell length in free space far from any massive body

$$a = \frac{8.0811*10^{13}}{\omega} = \frac{\hbar\, 8.0811*10^{13}}{2m_e c^2}\ \text{meter} \tag{10}$$

$$a = \frac{8.0811*10^{13}}{1.5527*10^{21}} = 5.2045 * 10^{-8}\ \text{meter} \tag{11}$$

We note that in free space where $V_0 = \hbar\boldsymbol{\omega}$ and the zitterbewegung frequency $\omega = \frac{2m_e c^2}{\hbar}$, the barrier height is $V_0 = 2m_e c^2$, which is the threshold for production of an electron-positron pair. The double well potential model parameter λ is given by

$$\lambda = \frac{V_0}{m_e\, a^4} = \frac{2\, c^2}{a^4} = 2.4498 * 10^{46}\, \frac{1}{m^2 sec^2} \tag{12}$$

With the double well potential model, the first order correction $E_0^{(1)}$ to the double well potential ground state energy of $E_0^{(0)} = \frac{1}{2}\hbar\boldsymbol{\omega}$ depends on the value of the width parameter a and is[21]

$$E_0^{(1)} = \frac{3\hbar^2}{32 m_e a^2} = 2.637 * 10^{-6}\ eV \tag{13}$$

We propose to measure the electron mass in the perihelion and aphelion points of earth's elliptic trajectory with extremely high precision[24]. We assume that the vacuum pion tetrahedron density changes due to the gravitational field variability at the extreme points of the perihelion and aphelion points[6]. If the product $\omega\, a$ remains constant as assumed and the vacuum pion tetrahedron density changes due to gravity, the fabric cell size a changes and the zitterbewegung frequency will have to change to keep the product constant ($\omega\, a = 8.0811 * 10^{13}$, $\omega = \frac{2m_e c^2}{\hbar}$). Extremely high precision measurements of the electron mass in the earth's trajectory around the sun perihelion and aphelion points, may prove the quark theory of the electron and the vacuum, the existence of the vacuum pion tetraquark tetrahedron fabric and its density dependence on gravity.

4. The Positron Tetraquark Tetrahedron

The positrons tetraquark tetrahedrons have a positive charge $u\,\tilde{d}$ quarks instead of the negative charge $\tilde{u}\,d$ quarks of the electron tetraquark tetrahedrons as shown below in figures 6 (a-b) for the electrons on the left and figures 6 (c-d) for the positrons on the right. Two positron configurations may exist with right and left chirality as shown below in figures 6 (c-d) on the right.

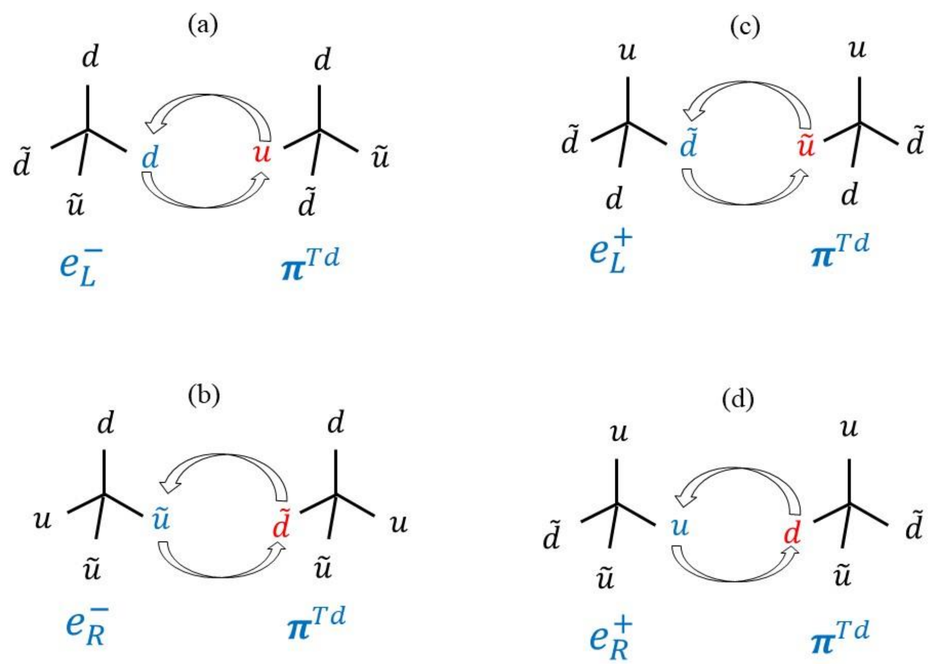

Figure 5 illustrates electron tetraquark tetrahedrons (a) and (b) and positron tetraquark tetrahedrons (c) and (d) exchanging quarks with pion tetraquark tetrahedrons with symmetric reactions such that the electrons and positrons transform to pion tetrahedrons and vice versa in each exchange reaction conserving the charge and chiral state.

5. Electron-Positron Annihilation

Electron-positron tetraquark tetrahedron annihilation on the pion tetraquark tetrahedron fabric may be due to a collision of an electron tetraquark tetrahedron and a positron tetraquark tetrahedron that form two pion tetraquark tetrahedrons that become part of the quantum vacuum pion tetrahedron fabric as shown in equation 14.

$$\tilde{u}d\tilde{d}d(\,e_L^-) + \,u\tilde{d}\tilde{u}u(\,e_R^+) \;\rightarrow\; \tilde{u}du\tilde{d}(\pi^{Td}\,) + \;\tilde{d}d\tilde{u}u\,(\pi^{Td}\,) \qquad (14)$$

Hence if an electron tetrahedron in site i on the fabric collide with a positron on site j on the fabric the outcome is that in both sites i and j after the collision there remain two pion tetraquark tetrahedrons. The electron and positron charges and spins are annihilated, and the extra energy of the electron and positron may be transferred to the vacuum pion tetraquark tetrahedron fabric as electromagnetic wave excitations.

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6. Summary

We propose a quark theory of the electron and the vacuum where the electron is not an elementary point like and not a single particle. The electron is comprised of quarks and antiquarks, and it forms with the vacuum pion tetraquark tetrahedrons fabric a delocalized electron cloud. We propose that the quantum vacuum has a structure formed by massive pion tetraquark tetrahedrons fabric with varying density where the massive pion tetraquark tetrahedrons are made of 50% matter and 50% antimatter and hence the fabric is not a regular matter. We propose that the electron motion occurs via u and d quark flavor exchange tunneling reactions between electron tetraquark tetrahedrons and pion tetraquark tetrahedrons of the vacuum fabric through a double well potential in a first electron chiral state, and the exchanges of $\tilde{u}$ and $\tilde{d}$ antiquark flavors in the second electron chiral state. Extremely high precision measurements of the electron mass[24] in earth’s trajectory perihelion and aphelion may prove the quark theory of the electron and the vacuum, the existence of the vacuum pion tetraquark tetrahedron fabric and its density dependence on gravity.

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