A Non-Uniform Pion Tetrahedron Condensate

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Abstract: We propose that the QCD vacuum pion tetrahedron condensate density should vary in space and should drop in the Kennan, Barger and Cowie (KBC) void for example in analogy to earth's atmospheric density drop with elevation from earth. We propose to calculate the non-uniform pion tetrahedron condensate density and propose a formula for the gravitation acceleration based on the non-uniform pion tetrahedron condensate. The MOND acceleration change at the galaxies' edges may be due to the pion tetrahedron condensate density drop. Gravity may be due to the underlying microscopic attraction between quarks and antiquarks which are part of the vacuum pion tetrahedron condensate. The major difference between classical and quantum mechanics may be due to the antimatter discovered by Dirac that may be part of the vacuum Aether. The central roles of antimatter and the non-uniform QCD vacuum that contains antimatter were not anticipated by general relativity and quantum mechanics. Their roles are not fully understood still and the discovery of the KBC giant voids and the possibility of a non-uniform pion tetrahedron condensate need further study.

Keywords: QCD vacuum condensate, KBC Void, Antimatter, MOND Theory, Aether Superfluid and Pion Tetrahedron condensate.

1. Non-Uniform Universe – the KBC Giant Voids

Kennan, Barger and Cowie (KBC)[1] found that galaxy counts and measurements of the luminosity density in the near infrared indicate the possibility that the local universe may be under-dense on scales of several hundred megaparsecs. The presence of a largescale under-density in the local universe could introduce significant biases into the interpretation of cosmological observables and into the inferred effects of dark energy on the expansion rate.

According to Banik[2,3], we live in a giant void in space, an area with below average density that could inflate local measurements through outflows of matter from the void. Outflows would arise when denser regions surrounding a void pull it apart – they'd exert a bigger gravitational pull than the lower density matter inside the void. We are near the center of a huge void about a billion light years in radius and with density about 20% below the average for the universe. The Cosmic Microwave Background (CMB) suggests that matter should be uniformly spread out. However, directly counting the number of galaxies in different regions suggests that we are in a local void contradicting the CMB uniform and isotropic universe. Such a huge deep void was not expected in the standard model and is controversial. If the universe is not uniform and isotropic, what about its underlying QCD vacuum quark condensate, is it also non-uniform?

2. Non-Uniform QCD Vacuum Quark Condensate

Brodsky et al[4,5] presented a new perspective on the nature of quark and gluon condensates in quantum chromodynamics where the QCD condensates are restricted to the interiors of hadrons. According to Brodsky these condensates arise due to the interactions of confined quarks and gluons leaving the external QCD vacuum empty, devoid of vacuum condensates that fill space-time. Lee[6] argues in favor of the non-vanishing QCD vacuum quark condensate and refutes the notion of Brodsky in-hadron only quark and gluon condensates. Halle et al presented equations that reveal effects of modified gravity and dark matter with a non-uniform dark energy fluid[7].

Buballa and Carignano studied an inhomogeneous chiral condensate, which is constant in vacuum and may become spatially modulated at moderately high densities where in the traditional picture of the QCD phase diagram a first-order chiral phase transition occurs[8].

We propose that the QCD vacuum pion tetrahedron condensate[9] exist and furthermore that its density in space is non-uniform and anisotropic and for example should drop in the KBC giant voids in analogy to earth's atmospheric density drop[10]. We propose to calculate the non-uniform and anisotropic pion tetrahedron condensate density and to calculate the gravitation acceleration from the non-uniform pion tetrahedron condensate density. In the extreme MOND limit at the galaxies' edges with r >> λ, the gravitational acceleration is given by $\frac{GM}{\lambda r}$ [11] and not $\frac{GM}{r^2}$.

3. Non-Uniform Pion Tetrahedron Condensate

In 1983 Milgrom proposed the Modified Newtonian Dynamics theory, MOND[12-15], explaining the observed rotational curves of galaxies without adding dark matter, which Kroupa et al suggest does not exist[16]. MOND is a phenomenological theory and does not provide a microscopic mechanism explaining the crossover to the extremely low accelerations limit far from the galaxy center. Milgrom proposed a new acceleration constant $a_0 = 1.2 * 10^{-10}$ cm/sec^2 that fits well the observed galaxy rotation curves. The MOND gravitational force and acceleration in the far limit where a << a_0 is -

$$F = m\,\frac{a^2}{a_0} \tag{1}$$

In a previous paper[9] we assumed that the QCD vacuum pion tetrahedron condensate drops like the atmospheric density due to gravity as shown in the figure 1 below on the left side. We proposed that similar to ideal gas kinetic theory, the pressure difference on a virtual box top and bottom surfaces that contains an infitisimal volume of the pion tetrahedron condensate is due to the difference in collision number at the top and the bottom surfaces due to the non-uniform pion tetrahedron condensate density induced by massive stars or galaxies, where M is the star mass, r is the distance to the star, and ρ is the pion tetrahedron condensate density, A and dr are the surface area and height of the virtual integration box -

$$p_{up}A - p_{bottom}A = -\frac{\rho AdhGM}{r^2} \quad (3)$$

Assuming an ideal gas state equation ($PV = nk_BT$) for the pion tetrahedron condensate ρ with particle mass m_π–

$$\rho = \frac{m_\pi n}{V} = \frac{m_\pi p}{k_BT} \quad (4)$$

The differential equation for the non-uniform condensate pressure is -

$$\frac{dp}{p} = -\frac{G\ m_\pi M}{k_BT\ r^2}dr \quad (5)$$

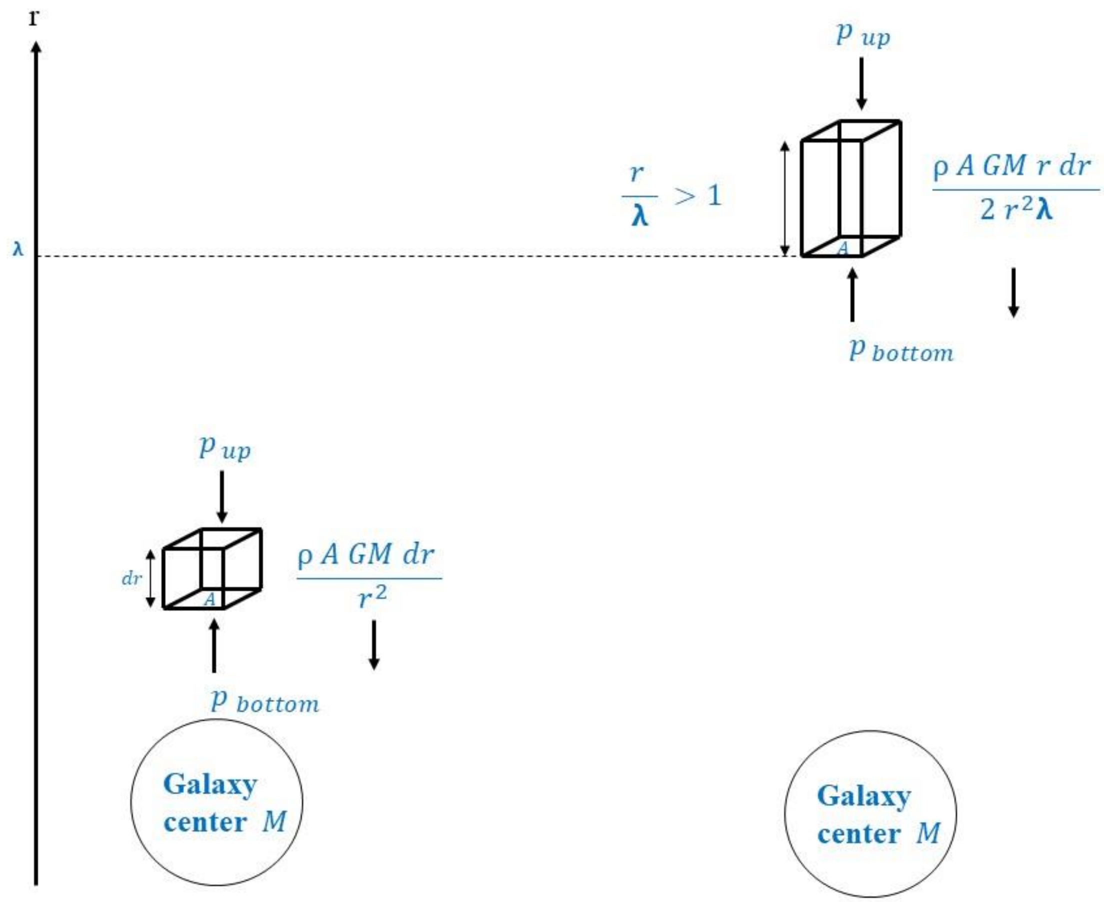

Figure 1 illustrates on the left-hand-side the pressure difference on a virtual box of area A and height dr that contains the pion tetrahedron condensate close to the galaxy center and on the right-hand-side, the box height element dr is stretched by the term r/**λ** > 1 at the MOND limit.

We can rewrite equation 5 as

$$\frac{1}{p}\frac{dp}{dr} = -\frac{G\, m_\pi M}{k_B T\, r^2} \qquad (6)$$

The gravitational acceleration applied on a mass m inside the virtual box of figure 1 above due to the non-uniform pion tetrahedron condensate density is-

$$g_N = -\frac{k_B T}{m_\pi}\frac{1}{p}\frac{dp}{dr} = \frac{GM}{r^2} \qquad (7)$$

We propose below that particles are attracted to their antimatter particles and since the antimatter density at the bottom of the virtual box is higher than at its top (as part of the pion tetrahedron density), particles will have more frequent exchange reactions with pion tetrahedron condensate at the bottom and will move downwards.

However, far from the galaxy center at the extremely small MOND acceleration limit, a << a_0, the pion tetrahedron condensate is extremely diluted and we propose to scale up the virtual box height with the term $\frac{r}{\lambda}$ > 1 to allow more collisions to occur in the diluted virtual box. In the MOND limit, the antimatter density difference between the upper and lower virtual integration box surfaces is extremely low. Particles that will move downwards will increase the chiral entropy of the pion tetrahedron condensate since they will have more collisions that will increase the frequency of flipping the chirality of the pion tetrahedron condensate. The differential equation for the non-uniform condensate pressure (equation 5 above) with the scaling term $\frac{r}{\lambda}$ is -

$$\frac{1}{p}\frac{dp}{dr} = -\frac{Gm_\pi M}{k_B T\, r^2}\left(\frac{r}{\lambda}\right) \qquad (8)$$

The gravitational acceleration (equation 7 above) in the MOND limit is-

$$g_{MOND} = -\frac{k_B T}{m_\pi}\,\frac{1}{p}\,\frac{dp}{dr} = \frac{GM}{\lambda r} \qquad (9)$$

Hence, the acceleration far from the galaxy center, at r >> λ where $g \ll a_0$, is $\frac{GM}{\lambda r}$ and not the Newtonian acceleration $\frac{GM}{r^2}$ with $\lambda = \sqrt{\frac{MG}{a_0}}$ -

$$g_{MOND} = \frac{GM}{\lambda r} = \frac{\sqrt{GMa_0}}{r} \qquad (10)$$

The MOND gravitational acceleration at the galaxy edge is extremely small but will be larger than the Newtonian gravitation acceleration if r >> λ. For the milky-way mass, $\lambda = 51.5$ parsecs and the galaxy radius is about 16 parsecs so the MOND limit is not reached.

4. The Pion Tetrahedron Condensate and Matter Dynamics

In previous papers we proposed that hadron quarks perform quark exchange reactions with the pion tetrahedrons[9-10,17-20]. The pion tetrahedrons collide with each other like in the ideal gas model as shown in figure 2 below. The gluons exchanges may flip the quark flavor from d to u and vice versa. Other scattering events may occur with a smaller number of gluons exchanges.

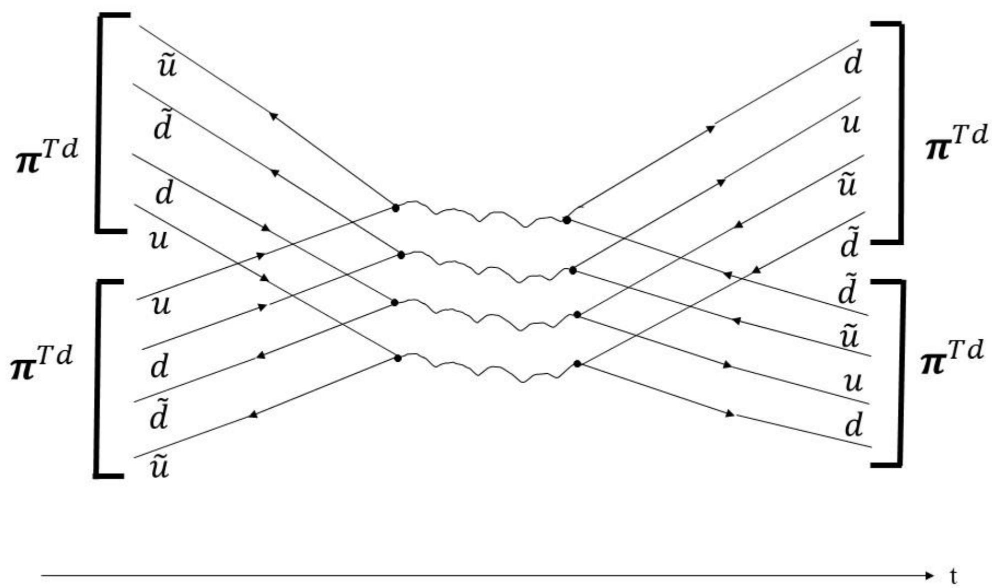

Figure 2 illustrates scattering of two pion tetrahedrons in the pion tetrahedron condensate.

Baryonic particles, a neutron or a proton for example, may interact with the pion tetrahedron condensate via tunneling. For example, a hot d and u quarks of an accelerated neutron (dud) or accelerated proton (uud) can be exchanged with a cold d and u quarks of a pion tetrahedron via gluons as shown in equation 11a and 11b and the Feynman diagram below. The two antiquarks of the pion tetrahedrons $\tilde{d}$ and $\widetilde{u}$ are the active reagents that trigger the exchange reactions as shown in the Feynman diagrams below -

$$dud + u\tilde{d}d\tilde{u} \rightarrow ddu + u\tilde{d}d\tilde{u} \qquad (11a)$$

$$uud + u\tilde{d}d\tilde{u} \rightarrow udu + u\tilde{d}d\tilde{u} \qquad (11b)$$

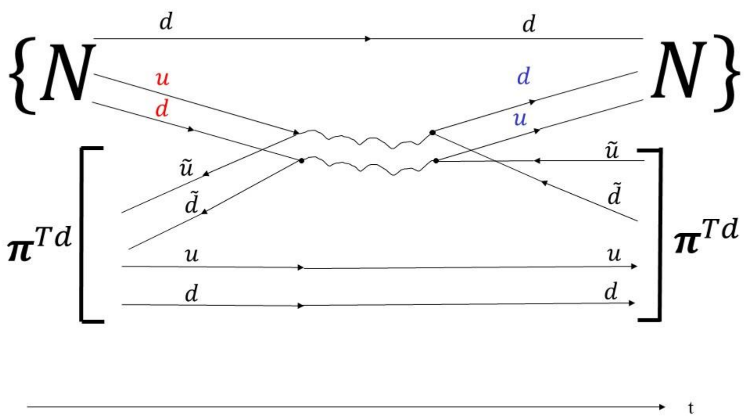

Figure 3 illustrates quarks exchange reaction of a neutron and a pion tetrahedron where the antiquarks $\tilde{d}$ *and* $\tilde{u}$ are the reagents that drive the exchange reactions via gluons.

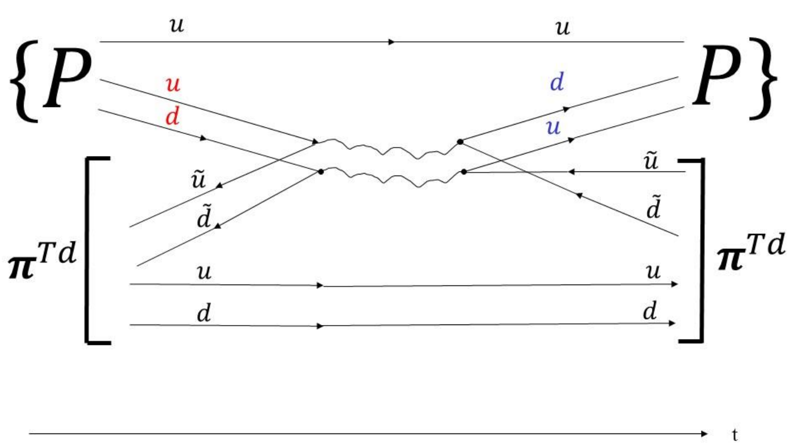

Figure 4 illustrates quarks exchange reaction of a proton and a pion tetrahedron where the antiquarks $\tilde{d}$ *and* $\tilde{u}$ are the reagents that drive the exchange reactions via gluons.

Feynman diagrams are used to describe high energy scattering events where momentum and energy is transferred in high energy particle colliders. However, we propose here that the quark exchange reactions described above with the pion tetrahedron condensate occur at low energies via tunneling and contribute to the binding energy of the protons and neutrons that are surrounded by a cloud of pion tetrahedrons. In a previous paper we used a double well potential model to describe the binding between a neutron and a proton in a deuterium nucleus[9] and here we propose that the double well potential model may be also used for protons and neutrons surrounded by pion tetrahedron cloud. Accordingly, equation 11a and 11b may be seen as dynamic equilibrium equations for tunneling reactions in a double well symmetric potentials and the barrier heights may be proportional to the condensation gap **Δ**.

$$dud + u\tilde{d}d\tilde{u} \rightleftarrows ddu + u\tilde{d}d\tilde{u} \qquad (12a)$$

$$uud + u\tilde{d}d\tilde{u} \rightleftarrows udu + u\tilde{d}d\tilde{u} \qquad (12b)$$

5. The Source of Gravity

We hypothesize that the source of gravity is the attraction of antimatter to matter, e.g. the underlying attraction of antiquarks and quarks. Protons' and neutrons' quarks attract the vacuum pion tetrahedrons antiquarks and create clouds of pion tetrahedrons around them with a density drop that depends on the mass of the nucleons similar to the atmospheric density. The protons and neutrons perform high frequency quark and antiquark exchange reactions with the pion tetrahedrons described by equation 12a and 12b via tunneling through the gap **Δ**. The protons and neutrons quarks are attracted to the antimatter densities of neighboring particles' clouds as shown in the figure 5 below. The source for gravity is than the attraction between quarks and antiquarks and the equation of the pion tetrahedron atmospheric like pressure drop around a massive body (equation 4) may be applicable for microscopic particles too.

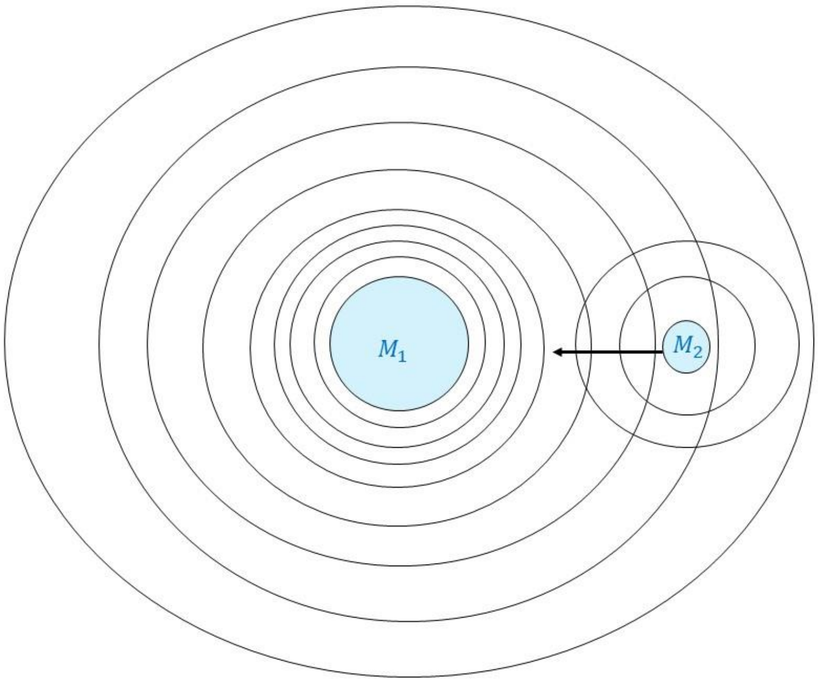

Figure 5 illustrates the pion tetrahedron densities around two masses, M1 >> M2. Since M1 attracts higher density of pion tetrahedrons, M2 will be attracted to it and will fall inwards in the direction of increasing pion tetrahedron density.

We propose to calculate the non-uniform pion tetrahedron condensate pressure based on an ideal gas approximation where the pion tetrahedrons gravitate in the field of a massive body (see equation 5). Then, based on the pion tetrahedron condensate pressure drop, a formula for the gravitational acceleration is proposed (see equations 7 and 9). The pion tetrahedron density far from galaxy clusters may form for example the KBC giant voids and the non-uniform pion tetrahedron condensate density may reach the extremely low MOND acceleration in the giant voids.

We assumed an ideal gas equation for the pion tetrahedrons in equation 4, however, the pion tetrahedron condensate is not an ideal gas. We assume that it can perform quark exchange reactions with matter particles and hence is reactive and it probably be better described for example by Sinha et al invisible superfluid fermion and antifermions Aether[21]. We proposed that the pion tetrahedrons are comprised of two light valence quarks and two light valence antiquarks, hence, antiquarks fill space in huge quantities and have a central role in physics.

Migdal studied π condensation in nuclear matter and suggested that neutral and charged pions condense to superfluid in neutron stars[22]. Sinha et al invisible superfluid Aether[21] pervades the entire universe and may account for the missing matter. Sinha et al assumed that the density of visible matter in the universe is about 2* $10^{-31}\ \frac{gram}{cm^3}$ where the density of the invisible superfluid Aether is much higher and is on the order of $10^{-29}\ \frac{gram}{cm^3}$. The pion tetrahedron condensate may be the invisible superfluid Aether that may account for the missing matter with no need to add new dark matter particles and its density may be related to Einstein's equation cosmological constant Λ. However, the Aether model did not specify explicitly if its density may be non-uniform, $\Lambda(\vec{x})$, and did not specify the attraction mechanism between pairs that allows the condensation and create the gap that may be the quark exchange reactions via gluons shown in figure 2 above.

The differences between classical and quantum mechanics may be due to the antimatter discovered by Dirac[23] and included in the invisible Aether superfluid model[22]. The central roles of antimatter and the non-uniform pion tetrahedron condensate were not anticipated by general relativity and quantum mechanics. Their central roles are not fully understood still and the KBC giant voids and the non-uniform pion tetrahedron condensate need further study.

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