KBC Void and the 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. Based on Modified Newtonian Dynamics (MOND) theory, we propose to calculate the non-uniform pion tetrahedron condensate density in space and propose a formula for the gravitation acceleration based on the non-uniform pion tetrahedron condensate. A microscopic mechanism for the MOND acceleration crossover at the galaxies' edges is proposed in terms of the non-uniform pion tetrahedron condensate. The major difference between classical and quantum physics may be the antimatter and the non-empty vacuum discovered by Dirac. The central roles of antimatter and the non-empty QCD vacuum in physics were not anticipated by both general relativity (GR) and quantum mechanics (QM). Their central roles are not fully understood still and the KBC voids and the non-uniform pion tetrahedron condensate are two examples that need further study.

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

1. KBC Voids

Banik[1,2] assumes 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. According to Banik, 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) gives a snapshot of structure in the infant universe, suggesting that matter today should be rather uniformly spread out. However, directly counting the number of galaxies in different regions does indeed suggest 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.

Banik cites Kennan, Barger and Cowie (KBC) that 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[3]. The presence of a largescale under-density in the local universe, such as the KBC void, could introduce significant biases into the interpretation of cosmological observables, and, in particular, into the inferred effects of dark energy on the expansion rate.

2. QCD Vacuum Quark Condensate

Brodsky and Shrock[4] presented a new perspective on the nature of quark and gluon condensates in quantum chromodynamics where the QCD condensates is 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[5] argues in favor of the non-vanishing QCD vacuum quark condensate and refutes the notion of Brodsky et al in-hadron only quark and gluon condensates.

We propose that the QCD vacuum pion tetrahedron condensate[6] density is non-uniform and anisotropic and for example should drop in KBC voids in analogy to earth's atmospheric density drop[7]. Based on the MOND theory, we propose to calculate the non-uniform and anisotropic pion tetrahedron condensate density, to calculate the gravitation acceleration from the non-uniform pion tetrahedron condensate density also in the extreme MOND limit at the galaxies edges, and to calculate the momentum transfer from matter to the pion tetrahedron condensate using Feynman diagrams. We propose a microscopic mechanism for the MOND acceleration crossover far from galaxies centers in terms of the pion tetrahedron condensate.

3. Non-Uniform Pion Tetrahedron Condensate and the MOND Theory

In 1983 Milgrom proposed the Modified Newtonian Dynamics theory, MOND[8,9,10,11], that explained the observed rotational curves of galaxies avoiding the need to add the controversial dark matter[12]. MOND is a phenomenological theory and does not provide a microscopic mechanism that explains the crossover to the extremely low accelerations limit far from the galaxy centers. Milgrom proposed a new acceleration constant $a_0 = 10^{-10}$ cm/sec^2 that fits well the observed galaxy rotation curves. The MOND gravitational force and acceleration in the limit of a << a_0 is -

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

In a previous paper[6] we assumed that the QCD vacuum pion tetrahedron condensate drops like the atmospheric density due to the gravity exponential law as shown in the figure below on the left side. We proposed that the pressure difference on the virtual box top and bottom surfaces are due to the non-uniform pion tetrahedron condensate induced by the massive stars and galaxies like ideal gas atmospheric density calculation -

$$p_{up}A - p_{bottom}A = -\frac{\rho A dh GM}{r^2} \tag{3}$$

Assuming an ideal gas state equation for the pion tetrahedron condensate particles m_π–

$$\rho = \frac{m_\pi n}{V} = \frac{m_\pi p}{k_B T} \tag{4}$$

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

$$\frac{dp}{p} = -\frac{G\, m_\pi M}{k_B T\, r^2} dr \tag{5}$$

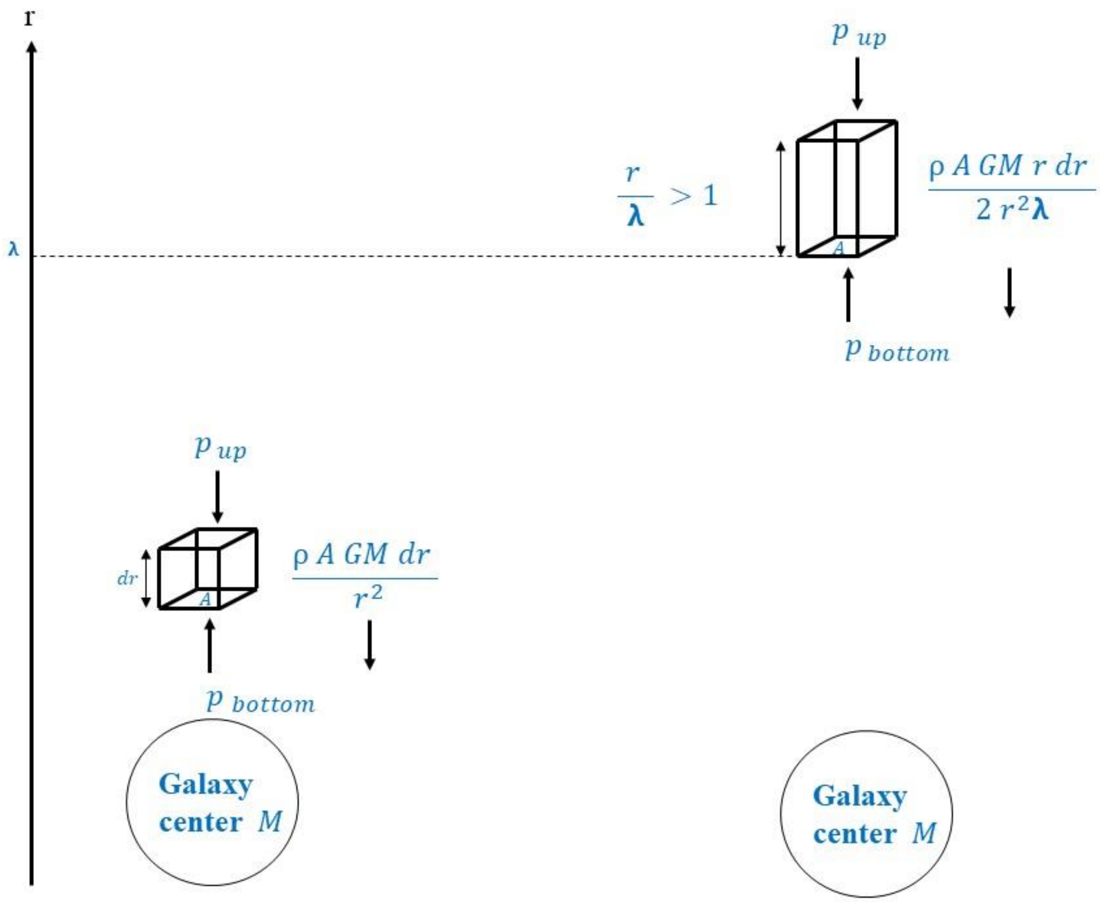

Figure 1 illustrates on the left-hand-side the pion tetrahedron condensate density in a virtual box of area A and height dh close to the galaxy center and on the right-hand-side, the box height is stretched by the scale parameter r/**λ** > 1 at the galaxy edge.

We can rewrite equation 5 as

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

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

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

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 effectively more collisions to take place on the upper and bottom surface of the virtual box having extremely diluted condensate density. The force balance differential equation 5 with the scaling term is -

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

The gravitational acceleration formula of equation 7 applied in this MOND limit is

$$g_{MOND} = -\frac{k_B T}{m_\pi}\,\frac{1}{p}\,\frac{dp}{dr} = \frac{GM}{\lambda r} \qquad (11)$$

Hence, the acceleration far from the galaxy center, at r > λ and $g \ll a_0$, is stronger than the Newtonian acceleration $\frac{GM}{r^2}$ and is given by $\frac{GM}{\lambda r}$ and with $\lambda = \sqrt{\frac{MG}{a_0}}$ -

$$g_{MOND} = \frac{GM}{\lambda r} = \frac{\sqrt{GMa_0}}{r} \qquad (12)$$

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 galaxy, λ = 51.5 parsec where its radius is about 16 parsec only and it does not reach the MOND limit.

4. The Pion Tetrahedron Condensate Dynamics

We propose to calculate the non-uniform pion tetrahedron condensate pressure based on an ideal gas model in the gravitational field of a static massive body that may be a star, a galaxy or a galaxy cluster. Then, based on the non-uniform pion tetrahedron condensate pressure we proposed a formula for the gravitational acceleration (equation 7). The static distribution of galaxy clusters in the cosmic web filaments may form for example KBC voids and the non-uniform pion tetrahedron condensate pressure calculated as a solution of the differential equation 5 will be diluted in the KBC void. To complete the proposed pion tetrahedron condensate approach we need to add how moving bodies change the state of the pion tetrahedron condensate, e.g. adding a pion tetrahedron condensate dynamics.

In previous papers [6,7,13,14,15,16] we proposed that quark and anti-quark exchange reactions with the pion tetrahedron condensate should transfer momentum in various reactions. For example, a hot d quark of a neutron (dud) can exchange a cold d quark of a pion tetrahedron $u\tilde{d}d\widetilde{u}$ as shown in the equation 13 and the Feynman diagram below.

$$dud + u\tilde{d}d\widetilde{u} \rightarrow dud + u\tilde{d}d\widetilde{u} \qquad (13)$$

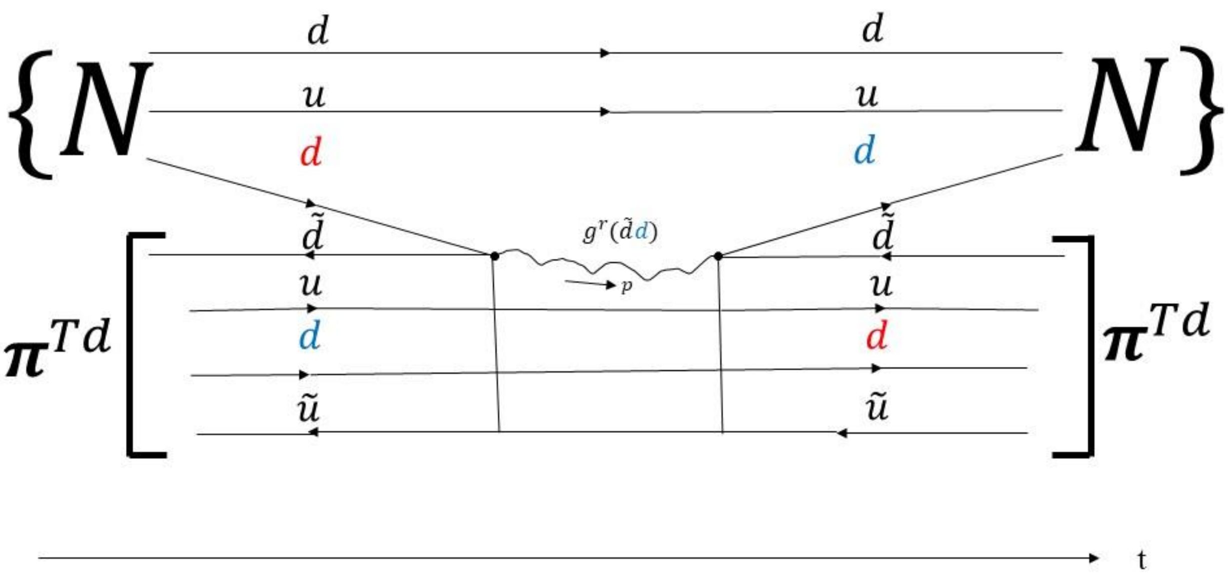

Figure 2 illustrates scattering of a quark d of a neutron by a pion tetrahedron performing a quark exchange reaction.

The quark exchange reaction can transfer momentum to the pion tetrahedron condensate cooling down the hot neutron. The Feynman diagram describes the quark exchange reaction and allows computing the energy and momentum transfer from the scattered neutron to the pion tetrahedron condensate. If the neutron will be a part of a massive body like a star that moves in space, it will affect the pion tetrahedron condensate distribution in space. Hence, the pion tetrahedron condensate dynamics should be calculated by quantum mechanics via Feynman diagrams for example.

We assumed above an ideal gas equation of state for the pion tetrahedron condensate in equation 4, however, the pion tetrahedron condensate is clearly not an ideal gas. We assume that it performs quark exchange reactions with matter particles, and hence it should be described by a more realistic equation of state to get more realistic model. We also assumed that the pion tetrahedrons are massive and are comprised of two light valence quarks and two light valence antiquarks with equal quantities in space. Hence, antiquarks exist everywhere in space in huge quantities, and they have a central and dynamic role in physics. The unique differences between classical and quantum physics may be due to the antimatter and the non-empty vacuum discovered by Dirac[16]. The central roles of antimatter and the non-empty QCD vacuum in physics were not anticipated by both general relativity (GR) and quantum mechanics (QM). Their central roles are not fully understood still and the KBC voids and the non-uniform pion tetrahedron condensate are two examples that need further study.

References

[1] Banik, I., (Nov 20, 2023), "Do we live in a giant void? It could solve the puzzle of the universe's expansion", https://theconversation.com/do-we-live-in-a-giant-void-it-could-solve-the-puzzle-of-the-universes-expansion-216687

[2] Mazurenko, S., Banik, I., Kroupa, P., Haslbauer, M., (Nov 20, 2023), "A simultaneous solution to the Hubble tension and observed bulk flow within 250 h −1 Mpc", https://arxiv.org/abs/2311.17988

[3] Keenan, R.C., Barger, A.J, Cowie, L.L., (2013) "EVIDENCE FOR A ~300 MEGAPARSEC SCALE UNDER-DENSITY IN THE LOCAL GALAXY DISTRIBUTION", The Astrophysical Journal, 775:62 (16pp), 2013, September 20.

[4] Brodsky, S. B., Shrock, R., (2008), "On Condensates in Strongly Coupled Gauge Theories", https://arxiv.org/abs/0803.2541

[5] Lee, T., (2012), "Vacuum quark condensate, chiral Lagrangian, and Bose-Einstein statistics", https://arxiv.org/abs/1206.1637

[6] Rom, R., (Apr 2023), "The Quantum Chromodynamics Gas Density Drop and the General Theory of Relativity Ether", Journal of High Energy Physics, Gravitation and Cosmology, 9, No. 2. https://www.scirp.org/journal/paperinformation.aspx?paperid=124153

[7] Rom, R., (Jan 2024), "The Pionic Deuterium and the Pion Tetrahedron Vacuum Polarization", Journal of High Energy Physics, Gravitation and Cosmology, 10, No. 1.

[8] Milgrom, M. (1983), "A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis", ApJ, 270, 365.

[9] Milgrom, M. (1983), "A modification of the Newtonian dynamics - Implications for galaxies", ApJ, 270, 371.

[10] Milgrom, M. (1983), "A MODIFICATION OF THE NEWTONIAN DYNAMICS - IMPLICATIONS FOR GALAXY SYSTEMS", ApJ, 270, 384.

[11] Milgrom, M., (2014), "The MOND paradigm of modified dynamics",

http://www.scholarpedia.org/article/The_MOND_paradigm_of_modified_dynamics

[12] Kroupa, P. et al, (2023), "The many tensions with dark-matter based models and implications on the nature of the Universe", https://arxiv.org/abs/2309.11552

[13] Rom, R., (Apr 2023), "Matter Reactors", Journal of High Energy Physics, Gravitation and Cosmology, 9, No. 2. https://www.scirp.org/journal/paperinformation.aspx?paperid=124154

[14] Rom, R., (Apr 2023), "The Principal Role of Antimatter", Journal of High Energy Physics, Gravitation and Cosmology, 9, No. 2.
https://www.scirp.org/journal/paperinformation.aspx?paperid=124156

[15] Rom, R., (Apr 2023), "The Black Hole Spray and the Cosmic Web", Journal of High Energy Physics, Gravitation and Cosmology, 9, No. 2.
https://www.scirp.org/journal/paperinformation.aspx?paperid=124288

[16] Rom, R., (Oct 2023), "The QCD Ground State Chiral Tetrahedron Symmetry", Journal of High Energy Physics, Gravitation and Cosmology, 9, No. 4.
https://www.scirp.org/journal/paperinformation.aspx?paperid=128344

[17] Dirac, P.A.M. (1928), "The Quantum Theory of the Electron",
https://www.rpi.edu/dept/phys/Courses/PHYS6520/DiracElectron.pdf