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Fine Structure Constants Across Cosmic Realms: Exploring

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Stanislav Konstantinov

Abstract- The article identifies the factors influencing the value of the fine structure of the baryonic and dark matter of the universe in the process of its evolution. These include the temperature, pressure, and polarization of dark matter under the influence of the fifth interaction in the direction (l, b) ~ (303º, - 27º). A strong anisotropy of cosmological parameters was found at a level of ~5σ in the direction (l, b) ~ (303º, - 27º), which is in good agreement with the data of other cosmological probes. Thus, as observations and calculations show, the value of fine structure during the evolution of the Universe and its anisotropy has undergone changes depending on temperature, density and pressure.

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I. Introduction

The concept of fine structure was introduced into physics in the 1916 by Arnold Sommerfeld to describe the energy sublevels discovered experimentally in the emission spectra of atoms. Since then, many other manifestations of the same constant relationship have been revealed in various phenomena associated with the interactions of elementary particles. In quantum electrodynamics, the fine structure constant measures electromagnetism - one of the four fundamental forces in nature (others are gravity, weak nuclear force, and potent nuclear force). The electromagnetic force keeps the electrons moving around the nucleus in the atom of the universe, otherwise all matter would be shattered into pieces. Until recently, it was believed this is an invariable force in time and space. Currently, in quantum electrodynamics, the following value of the fine structure of elementary particles has been experimentally obtained:

$$\alpha = 7.2973525376\ (50) \times 10^{-3} = 1 / 137.035999679$$

$$\alpha = \frac{e^2}{\hbar c\ 4\pi\varepsilon_0} = \frac{e^2}{2\varepsilon_0 hc} \qquad (1)$$

Where e is the elementary electric charge,
$\hbar = h / 2\pi$ is the Dirac constant (or the reduced Planck constant),
c is the speed of light in a vacuum,
ε_0 is the dielectric constant.

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In other words, the theory of fine structure had not just a technical significance for clarifying the details of the experiment, but also an important theoretical significance. But Sommerfeld's 1916 study had not yet completed it, unexplained details remained, and selection rules had not been formulated. The next step in the development of the theory was already taken by Dirac. Until recently, it was believed that the value of fine structure is a constant value in time and space.

However, in articles published on April 27, 2020, in the journal Science Advances, scientists at the University of South Wales in Sydney, working under the guidance of a professor John Webb, reported that four new measurements of light emitted by a quasar 13 billion light-years from Earth confirm past research by Professor John Webb that found variations in the values of the fine structure (Figure: 1) [1, 2].

Figure 1: The light emitted by the quasar J1120 + 0641 13 billion light years from Earth

Not only do universal constants appear to scientists to be variables at the outer edges of the cosmic Universe, but anomalies also only occur in one direction, which looks odd. Astrophysicists today continue to find hints that one of the cosmological constants, the fine structure, is not all that constant after all. Professor Webb stated: "We found a hint that this constant fine structure number was different in certain universe regions. Not only as a function of time, but also in the direction of the Universe, which is strange if true. In the current study, a group of scientists studied the quasar, which allowed them to return to a time when the Universe was only a billion years old, which has never happened before. Thus, the Universe cannot be isotropic from the point of view of the laws of physics that is, it is statistically different in all directions. It may contain some directions or preferred directions in which

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the laws of physics change, but not in the perpendicular direction. The Universe in a sense has a dipole structure. "[1, 2]. A strong anisotropy of cosmological parameters was found at a level of ~5σ in the direction (l, b) ~ (303°, - 27°), which is in good agreement with the data of other cosmological probes [3]. In favor of the local expansion of the Universe, the results of a new study carried out using data from the NASA X-ray apparatus "Chandra" speak X-ray Observatory and ESA's XMM-Newton. Migkas and his colleagues have examined some 842 galaxy clusters during the course of their study, and established that the expansion rate of our universe appeared to differ from region to region. "We managed to pinpoint a region that seems to expand slower than the rest of the universe, and one that seems to expand faster!", Migkas noted [3]. In article "Probing cosmic isotropy with a new X-ray galaxy cluster sample through the LX−T scaling relation" authors write: "In this work, we investigate the directional behavior of the X-ray luminosity-temperature (LX−T) relation of galaxy clusters. A tight correlation exists between the luminosity and temperature of the X-ray-emitting intracluster medium. While the measured luminosity depends on the underlying cosmology, the temperature can be determined without any cosmological assumptions. By exploiting this property one can effectively test the isotropy of cosmological parameters over the full extragalactic sky. Here, we used 313 homogeneously selected X-ray galaxy clusters from the MCXC catalog and obtained core-excised temperatures for all of them. We find that the behavior of the LX−T relation heavily depends on the direction of the sky. Performing a joint analysis of the three samples, the final anisotropy is further intensified (~5σ), toward (l,b)~(303°,−27°), which is in good agreement with other cosmological probes [3].In an earlier article "Fundamental experiments on the detection of the anisotropy of physical space and their possible interpretation" 2015 Dr. Yu.A. Baurov, Yu.G. Sobolev, F. Meneguzzo presented a new interpretation of the global anisotropy of the physical space of the Universe [4]. It is radically different from that in the standard cosmological model ΛCDM (Λ- Cold Dark Matter), the inflationary theory of anisotropy. In space anisotropy, Dr. Yu. Baurov, exposed the cosmological vector potential - a new force of nature (fifth force) generated by the interaction of elementary particles of matter with dark matter and acting in the direction of right ascension $\alpha=293^0\pm10^0$ and declination $\delta=36^0\pm10^0$ [4]. In 2015, Dr. Attila Krasnahorkai and his colleagues at the Institute for Nuclear Research of the Hungarian Academy of Sciences (Debrecen) published an article in which they concluding that they had discovered the fifth interaction [5]. In 2019, Attila Krasnagorsky confirmed the discovery of the fifth interaction in new experiments with helium [6]. This experiment of thy Hungarian researcher Dr. Attila Kraznahorsky interested Professor John Webb as a possible reason for the anisotropy of the value of the fine structure in a strictly defined direction of motion in the Universe (l, b) ~ (303°, −27°). A group of theoretical physicists led by Jonathan Fan from the University of California (Irvine, USA) decided to check the results of their Hungarian colleagues. Professor Yonotan Feng carefully studied the work of Dr. Attila Kraznahorsky and stated that the fifth interaction does not violate any laws of nature. The new scalar field may belong to a hypothetical dark matter particle - the photophobic X-boson, which, like the Higgs boson, creates a scalar field responsible for the fifth interaction between dark matter and ordinary (baryonic) matter. Dr. Jonathan Fehn of the University of California, Irvine, in a 2017 press release, said: "For decades, we have known about four fundamental forces: gravity, electromagnetism, and strong and weak nuclear forces. The discovery of a possible fifth force will completely change our understanding of the Universe, which will entail the unification of the fifth force and dark matter."[7]. In light of the above, we can conclude that the value of the fine structure constant can depend on many factors. Next we will look at what exactly can influence the size of the fine structure.

II. Dependence of the Magnitude of the Fine Structure on Temperature During the Evolution of the Universe

When the vacuum is polarized and transformed into a substance, the change in the vacuum energy w can be represented as a sum [8]:

$$w = w^p + w^e \qquad (2)$$

where w^p is the vacuum polarization,

$$w^p << E^2 / 8\pi; \qquad (3)$$

w^e is the change in the energy of the substance at the production of particles

$$w^e = eET\varkappa, \quad \varkappa = \frac{e^2E^2T}{4\pi^3}\exp(-\pi\frac{m^2}{\hbar E}) \qquad (4)$$

The creation of particles is the main reason for the change in the energy of the vacuum. The small value of the reverse reaction w^p implies the limitation on the electric field E strength for the given time T ($E_s \approx 10^{16}$ [V × cm^{-1}] is the critical Schwinger's field) [9]. For an electromagnetic field, the polarization energy density of a quantum vacuum can also be represented as the sum of two terms (2). Where is the first term w^p (w_0) quadratic in the electric and magnetic fields:

$$w_0 = \frac{\left(\mathbf{E}^2 + \mathbf{H}^2\right)}{8\pi} \qquad (5)$$

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determines the energy of a non-interacting electromagnetic field before critical values electric strengths Schwinger's field Es = 1.32 × 10^{16}[V × cm^{-1}] and magnetic field strength H = 10^{16} [Gs]. The second term, w^e (w_1), describes the interaction of photons due to the production of electron-positron pairs [10]:

$$w_I = 2D\left[3\mathbf{E}^2\mathbf{E}^2 - \mathbf{H}^2\mathbf{H}^2 - \left(\mathbf{E}^2\mathbf{H}^2 + \mathbf{H}^2\mathbf{E}^2\right)\right] + 7D\left[(\mathbf{EH})^2 + (\mathbf{HE})^2\right] \quad (6)$$

The constant D can be calculated by the methods of quantum electrodynamics [10] and in Gaussian units

$$D \equiv \eta \frac{\hbar^3}{m^4c^5} \quad (7)$$

Where η is the dimensionless coefficient

$$\eta \equiv \frac{\alpha^2}{45\times(4\pi)^2} \approx 7.5\times10^{-9} \quad (8)$$

α is the fine structure constant (1),
m is the mass of the electron,
c is the speed of light.

It is convenient D to write the coefficient through the Compton wavelength of the electron $\lambda\!\!\!^{-} = \hbar/mc$ in the form [10]:

$$D = \eta \frac{\lambda\!\!\!^{-3}}{mc^2} \quad (9)$$

It is of interest to estimate the value of the energy w_I/w_0 ratio. This quantity is equal to the ratio of the energy of the field contained in the volume $\lambda\!\!\!^{-3}$ to the rest energy of the electron. In addition, this ratio must also be multiplied by a small dimensionless coefficient η. For a magnetic field strength of the order of $H \sim 10^6\, Gs$, we obtain $w_I/w_0 \sim 10^{-20}$, so the contribution of the interaction to the total field energy is indeed minimal.

Let us move on to the description of the electromagnetic field in terms of the Fourier components of fields, using the expansion of fields in plane waves,

$$\mathbf{E}(\mathbf{r},t) = \sum_k \mathbf{E}_k(t)e^{i\mathbf{kr}}, \qquad \mathbf{H}(\mathbf{r},t) = \sum_k \mathbf{H}_k(t)e^{i\mathbf{kr}} \quad (10)$$

Then the total Hamiltonian of the field in the volume, following (2), is the sum of the free Hamiltonian and the interaction Hamiltonian

$$H = H_0 + H_I, \quad (11)$$

$$H_0 = \frac{V}{8\pi}\sum_k \left(\mathbf{E}_k^+\mathbf{E}_k + \mathbf{H}_k^+\mathbf{H}_k\right), \quad (12)$$

$$H_I = 2VD\sum_{\{k_i\}}\left\{3\left(\mathbf{E}_{k_1}^+\mathbf{E}_{k_2}\right)\left(\mathbf{E}_{k_3}^+\mathbf{E}_{k_4}\right) - \left(\mathbf{H}_{k_1}^+\mathbf{H}_{k_2}\right)\left(\mathbf{H}_{k_3}^+\mathbf{H}_{k_4}\right) - \right.$$
$$\left. - \left(\mathbf{E}_{k_1}^+\mathbf{E}_{k_2}\right)\left(\mathbf{H}_{k_3}^+\mathbf{H}_{k_4}\right) - \left(\mathbf{H}_{k_4}^+\mathbf{H}_{k_3}\right)\left(\mathbf{E}_{k_2}^+\mathbf{E}_{k_1}\right)\right\}\Delta(\mathbf{k}_1 - \mathbf{k}_2 + \mathbf{k}_3 - \mathbf{k}_4) +$$
$$+ 7VD\sum_{\{k_i\}}\left\{\left(\mathbf{E}_{k_1}^+\mathbf{H}_{k_2}\right)\left(\mathbf{E}_{k_3}^+\mathbf{H}_{k_4}\right) + \left(\mathbf{H}_{k_4}^+\mathbf{E}_{k_3}\right)\left(\mathbf{H}_{k_2}^+\mathbf{E}_{k_1}\right)\right\}\Delta(\mathbf{k}_1 - \mathbf{k}_2 + \mathbf{k}_3 - \mathbf{k}_4). \quad (13)$$

Here $\Delta(\mathbf{k}) = 1$, if $\mathbf{k} = 0$ and $\Delta(\mathbf{k}) = 0$ if $\mathbf{k} \neq 0$. In (12) and (13), we can move on to the operators of the creation a_{kj}^+ and destruction a_{kj} of photons, using the representations of the operators of the Fourier components of fields:

$$\mathbf{E}_k = -i\sqrt{\frac{2\pi\hbar\omega_k}{V}}\sum_j \left(a_{kj}^+ - a_{-kj}\right)\mathbf{e}_j(\mathbf{k}),$$

$$\mathbf{H}_k = ic\sqrt{\frac{2\pi\hbar}{V\omega_k}}\sum_j \left(a_{kj}^+ + a_{-kj}\right)\left[\mathbf{k}\times\mathbf{e}_j(\mathbf{k})\right], \quad (14)$$

Where, $\omega_k = ck$, and for the polarization vectors $\mathbf{e}_j(\mathbf{k})$, the orthonormality and completeness conditions are valid:

$$\mathbf{e}_{j_1}^*(\mathbf{k})\mathbf{e}_{j_2}(\mathbf{k}) = \delta_{j_1 j_2}, \qquad \sum_j e_j^{\alpha *}(\mathbf{k})e_j^{\alpha'}(\mathbf{k}) = \delta_{\alpha\alpha'} - \frac{k_\alpha k_{\alpha'}}{k^2}, \quad (15)$$

as well as conditions

$$\mathbf{k}\mathbf{e}_j(\mathbf{k}) = 0, \qquad \mathbf{e}_j^*(-\mathbf{k}) = \mathbf{e}(\mathbf{k}) \quad (16)$$

The free Hamiltonian of the field (12) is reduced to the sum of the Hamiltonians of harmonic oscillators,

$$H_0 = \sum_{kj}\hbar\omega_k\left(a_{kj}^+ a_{kj} + \frac{1}{2}\right) \quad (17)$$

The electromagnetic field, taking into account nonlinear effects, is characterized by the complete Hamiltonian (11). To take into account the interaction in a many-particle system, as a rule, the Hamiltonian of non-interacting particles is chosen as the leading approximation, in our case it is (17), and the interaction Hamiltonian (13) is considered as a perturbation. This choice, as noted above, is not the best, since in the leading approximation the effects caused by the interaction are entirely ignored, which in the case under consideration, although small, can, as we will see, lead to qualitatively new effects. From the self-consistent approach to the description of many-particle systems it is known that taking into account interaction effects in the central approximation leads to a change in the dispersion law of the original particles and, thus, we move from the representation of free particles to the language of collective excitations - quasiparticles. It is natural to assume that in the case considered here, interaction effects will lead to a renormalization of the

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"primary" speed of light, included in the free Hamiltonian. Taking into account this consideration, we split the complete Hamiltonian (17) into the central part and the perturbation differently, namely

$$H = H_S + H_C\,, \tag{18}$$

Where we choose the self-consistent (or approximating) Hamiltonian in the form similar to the free Hamiltonian (17), but with the speed of light $\tilde{c}$ renormalized due to the photon-photon interaction:

$$H_S = \sum_{k,j} \hbar\tilde{\omega}_k a_{kj}^{+} a_{kj} + E_0\,, \tag{19}$$

Where $\tilde{\omega}_k = \tilde{c}k$

The correlation Hamiltonian describing the interaction of renormalized or "dressed" photons is chosen so that the total Hamiltonian remains unchanged:

$$H_C = \sum_{k,j} \hbar\left(\omega_k - \tilde{\omega}_k\right) a_{kj}^{+} a_{kj} + \sum_k \hbar\omega_k - E_0 + H_I\,. \tag{20}$$

This Hamiltonian describes the interaction of photons propagating at a renormalized speed of light, which we will not consider. Formulas (19), (20) include a term that does not contain operators, taking into account which is necessary for the correct formulation of the self-consistent field model. We chose it because the approximating Hamiltonian (19) is as close as possible to the exact Hamiltonian. It means that it is necessary to require that the value $I \equiv \left|\left\langle H - H_S \right\rangle\right| = \left|\left\langle H_C \right\rangle\right|$ be minimal, i.e., equal to zero. From here, we obtain the conditions natural for the theory of a self-consistent field:

$$\left\langle H \right\rangle = \left\langle H_S \right\rangle, \qquad \left\langle H_C \right\rangle = 0 \tag{21}$$

Averaging is performed using the statistical operator

$$\rho = \exp\beta\left(F - H_S\right), \tag{22}$$

Where F is the free energy and is the reciprocal temperature value $\beta = 1/T$. Condition (21) allows us to determine the non-operator part of Hamiltonian (19):

$$E_0 = 2\left(c - \tilde{c}\right)\sum_k \hbar k f_k + \sum_k \hbar ck + \left\langle H_I \right\rangle \tag{23}$$

where the distribution function of renormalized photons has the Planck form

$$f_k = \left\langle a_{kj}^{+} a_{kj} \right\rangle = \frac{1}{\exp\left(\beta\hbar\tilde{\omega}_k\right) - 1} \tag{24}$$

and does not depend on the polarization index. From the normalization condition of the statistical operator (22) $\mathrm{Sp}\rho = 1$ follows the expression for the free energy of radiation

$$F = 2\left(c - \tilde{c}\right)\sum_k \hbar k f_k + \sum_k \hbar ck + \left\langle H_I \right\rangle + 2T\sum_k \ln\left(1 - e^{-\beta\hbar\tilde{\omega}_k}\right). \tag{25}$$

If we neglect the photon-photon interaction and zero-point fluctuations, formula (25), follows the usual formulas of the thermodynamics of black radiation [22]. It is natural to require that in the approximation used with Hamiltonian (19) and free energy (25), as in the case of a gas of non-interacting photons, thermodynamic relations must be satisfied. Since the introduced renormalized speed itself, in principle, can depend on thermodynamic variables to satisfy the thermodynamic relations, the following condition must be met:

$$\frac{\partial F}{\partial \tilde{c}} = 0\,. \tag{26}$$

From this condition and formula (25) follows the relationship that determines the renormalized speed:

$$\tilde{c} - c = \frac{\dfrac{\partial\left\langle H_I \right\rangle}{\partial \tilde{c}}}{2\dfrac{\partial}{\partial \tilde{c}}\sum_k \hbar k f_k} \tag{27}$$

Since (27) includes the temperature-dependent distribution function (24), then, naturally, the speed of light is a function of temperature. Thus, the average of the interaction Hamiltonian should be calculated. In this case, as in the theory of phonons in solids [19, 20], divergent integrals appear. When describing phonons within the continuum model, it is natural to cut off such integrals at a wave number equal to the inverse of the average distance between particles or, when integrating over frequency, at the Debye frequency. In the case of photons, the divergent integrals will be cut off at the wave number, the choice of which will be discussed a little later.

Taking this into account, calculating the average of the interaction Hamiltonian (13) gives

$$\left\langle H_I \right\rangle = \frac{1312V}{15\pi^2} D \cdot \hbar^2 c^2 \cdot J\left(\frac{k_m^4}{4} + J\right) \tag{28}$$

where, $J = 6\zeta(4)\left(\dfrac{T}{\hbar\tilde{c}}\right)^4$, $\zeta(4) = \pi^4/90 \approx 1{,}0823$ is the zeta function. Let be the ratio of the temperature-dependent speed of light to the "base" speed of light. Considering that $\sum_k \hbar k f_k = \dfrac{V\hbar}{2\pi^2}J$, from (27), we find the equation for:

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$$\sigma = 1 + \frac{328}{15} D \cdot \hbar c \cdot k_m^4 + \frac{328 \cdot 16}{5} \zeta(4) D \cdot \hbar c \left(\frac{T}{\hbar c} \right)^4 \cdot \frac{1}{\sigma^4} \quad (29)$$

It follows that the ratio of the speed of light at zero temperature $\tilde{c}_0$ to the "primary" speed of light $\sigma_0 \equiv \tilde{c}_0 / c$ is determined by the formula:

$$\sigma_0 = 1 + \frac{328}{15} D \cdot \hbar c \cdot k_m^4 \quad (30)$$

The directly measurable speed is the speed of light at zero temperature. As follows from (30), this speed does not coincide with the "primary" speed of light due to taking into account the interaction of photons. Due to the weakness of this interaction, should differ very little, and in the leading approximation they could be considered equal, which would not affect subsequent conclusions.

Experiments show that if an external field acts on the vacuum, then due to its energy, the production of fundamental particles is possible [10]. Precisely because the vacuum is not virtual, but a natural physical object (dark matter) and has a structure, the polarization of the vacuum leads not to virtual, but natural radiation corrections to the laws of quantum electrodynamics [11]. The interaction of the electromagnetic field with the vacuum (dark matter) leads to a dependence of the speed of light propagation on the radiation temperature. Estimates show that in the modern era, even at very high temperatures, such as those that exist in the bowels of stars, the temperature-dependent correction to the speed of light is minimal[10]:

$$\Delta \tilde{c} = \tilde{c} - c_0 \approx 10^{-5}\, cm/s \quad (31)$$

Where Δc is the temperature-dependent correction to the speed of light,
c is the speed of light in the interior of a star,
c_0 is the speed of light in the space vacuum.

However, in the cosmological model of the hot Universe, in the first moments after the Big Bang, the temperature was so high that the speed of light was many orders of magnitude higher than the modern one. The effect of the dependence of the speed of light on temperature should be essential for understanding the early evolution of the Universe. As a result, Dr. Yuri Poluektov obtained a dependence for the fine structure constant, recorded through the observed speed of light [10]:

$$\alpha_0 \equiv \frac{e^2}{\hbar \tilde{c}_0} \quad (32)$$

With the expansion of the Universe and its cooling, the speed of light decreased and has now reached its value, almost equal to the speed of light at zero temperature. At Planck's temperature, Tp $\approx 1.42 \times 10^{32}$[K] ≈ 10^{19}[GeV], the speed of light $\tilde{c}_p$ would be much higher than the modern one:

$$\tilde{c}_p / \tilde{c}_0 \approx 0.8 \cdot 10^{17} \quad (33)$$

Dr. Yu. Poluektov presented in Table 1 how the speed of light changed as the Universe cooled in the first moments after the Big Bang [10].

Table 1

t, s	$T,\ GeV$	T, K	$\tau = T / T_0$	n, cm^{-3}	$\tilde{c}/\tilde{c}_0$
$5.4 \cdot 10^{-44}$	$1.2 \cdot 10^{19}$	$1.42 \cdot 10^{32}$	$4.9 \cdot 10^{22}$	$1.3 \cdot 10^{47}$	$0.8 \cdot 10^{17}$
10^{-39}	10^{16}	10^{29}	$3.5 \cdot 10^{19}$	$1.6 \cdot 10^{45}$	$2.3 \cdot 10^{14}$
10^{-11}	100	10^{15}	$3.5 \cdot 10^{5}$	$6.5 \cdot 10^{36}$	$1.5 \cdot 10^{3}$
10^{-5}	0.2	$2 \cdot 10^{12}$	$6.9 \cdot 10^{2}$	$1.4 \cdot 10^{35}$	10
10^{-2}	10^{-2}	$2 \cdot 10^{11}$	69	$2.5 \cdot 10^{34}$	1.9
1.5	$0.7 \cdot 10^{-3}$	$0.8 \cdot 10^{10}$	2.8	$4.9 \cdot 10^{30}$	1.00003

The reason for the significant effect immediately after the universe's birth during weak photon-photon interaction, as can be seen from the penultimate column of the table, is the extremely high density of photons at such temperatures [10].

III. Dependence of the Acceptable Structure Value on Pressure during Polarization of Quantum Vacuum (Dark Matter) in the Nucleus of a Hydrogen Atom and Neutron Stars

The CMS collaboration in experiments at the Large Hadron Collider in 2019 studied the distribution of

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reaction products in pp collisions with energies from 1 TeV to 13 TeV. It was found that a decrease in the mass of elementary particles obtained from data up to an energy of 13 TeV, a decrease in the value of the interaction constants at a confidence level of 95% depend on the energy at which the measurements were made. This effect, explained by vacuum polarization, was observed in experiments; in particular, a decrease in the mass of b- and c-quarks was measured, as well as a change in the strong interaction constant [12]. The vacuum polarization effect leads to charge screening at low energies. With increasing energy, acceptable structure magnitude (α) changes logarithmically:

$$\alpha(E) = \frac{\alpha_0}{1-\Delta\alpha(E)} \quad (34)$$

Where E is the electric field strength,

Δ α is the incremental value calculated as part of QCD

In 2018 Professor Volker Burkert carried out a series of experiments at the CEBAF accelerator. After the collision of fast electrons with the mass of liquid hydrogen (the source of protons), the researchers registered the particles arising from their interaction - an electron, a proton, and two photons. It allowed for the first time to measure the pressure at the center of the proton, bombarding the proton with electrons, the energy of which reached 100 MeV or more, which allowed the electron to penetrate the proton's structure [13]. Volker Burkert and his colleagues from Jefferson's laboratory found that the pressure in a proton can exceed 10^{35} Pascal [13]. It is known that at such a pressure polarization of the quantum vacuum is observed, and by formula (34), changing the value of the fine structure constant.

Professor A.V. Rykov RAS, Institute of Physics of the Earth, relying on his theory of vacuum, as well as the energy of polarization of the vacuum and its electromagnetic parameters (ε_0, μ_0), calculated the value of the fine structure of the near-Earth quantum vacuum (dark matter) and intranuclear quantum vacuum. According to him, the fine structure of the near-Earth quantum vacuum α_e = 0.0072975 or (1/137) and the fine structure inside the hydrogen nucleus α_x = 0.00318157 (1/314) determine electromagnetism in the first case, and nuclear forces in the second case [14]. Professor A.V. Rykov determined the elastic deformation force in near-Earth quantum vacuum $F=1.155 \times 10^{19}$ [kg / s^2] and inside the proton nucleus $F=5.211\times10^{26}$ [kg / s^2]. Thus, the elasticity of quantum vacuum inside the nucleus is seven orders of magnitude higher than that of near-Earth quantum vacuum (dark matter) [14].

IV. Conclusion

Thus, the meaning of the fine structure is determined by five fundamental interactions: electromagnetic, gravitational, strong and weak nuclear interactions and the fifth interaction between baryonic matter and quantum vacuum (dark matter) and their derivatives: temperature and pressure. In quantum electrodynamics (QED), the fine structure constant is a measure of electromagnetism, and shows with what force in baryonic matter electrons are held in atoms or in positronium of dark matter during its polarization, and in quantum chromodynamics (QCD) a measure of nuclear forces counteracting the force pressure of 10^{35} Pascal inside the nucleus of an atom directed outward [15]. Vacuum is involved in all fundamental interactions, but if the polarization of the vacuum in electromagnetic interactions is accompanied by the formation of electron-positron pairs with the participation of exchanged virtual photons, then in nuclear interaction the polarization of the quantum vacuum is accompanied by the formation of three unstable π-mesons (π^0, $\pi+$, $\pi-$) with the participation of virtual exchange pions and the subsequent creation of short-lived protons and antiprotons. At the same time, the energy spectrum of the birth of new particles and antiparticles changes, which indicates a difference in the structure of the quantum vacuum when it is included in the nuclei of atoms [15]. Professor Anatoly Rykov called the medium of virtual pi-mesons, participating as exchange particles in atomic interactions, the meson ether. If we assume that the meson structure of the ether is formed by a triple of pions π^0,π^+,π^- should be held by a force corresponding to the value of the nuclear fine structure, then it will exceed the value of the fine structure of the physical vacuum, which has an electron + positron pair. This corresponds to reality [14].

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