Mathematical Overview

of Hypersphere World – Universe Model

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Abstract

The Hypersphere World – Universe Model (WUM) provides a mathematical framework that allows calculating the primary cosmological parameters of the World that are in good agreement with the most recent measurements and observations. WUM explains the experimental data accumulated in the field of Cosmology and Astroparticle Physics over the last decades: the age of the World and critical energy density; the gravitational parameter and Hubble's parameter; temperatures of the cosmic microwave background radiation and the peak of the far-infrared background radiation; the concentration of intergalactic plasma and time delay of Fast Radio Bursts. Additionally, the Model makes predictions pertaining to masses of dark matter particles, photons, and neutrinos; proposes new types of particle interactions (Super Weak and Extremely Weak); shows inter-connectivity of primary cosmological parameters of the World. WUM proposes to introduce a new fundamental parameter Q in the CODATA internationally recommended values.

Keywords: "Hypersphere World – Universe Model"; "Primary Cosmological Parameters"; "Medium of the World"; "Macroobjects Structure"; "Gravitoelectromagnetism"; "Dark Matter Particles"; "Intergalactic Plasma"; "Microwave Background Radiation"; "Far-Infrared Background Radiation"; "Fast Radio Bursts", "Emergent Phenomena"; "CODATA".

1. Introduction

Hypersphere World – Universe Model (WUM) views the World as a 3-dimensional Hypersphere that expands along the fourth spatial dimension in the Universe. A Hypersphere is an example of a 3-Manifold which locally behaves like regular Euclidean 3-dimensional space: just as a sphere looks like a plane to small enough observers. WUM is based on Maxwell's equations (ME) that form the foundation of Electromagnetism and Gravitoelectromagnetism. According to ME, there exist two measurable physical characteristics: energy density and energy flux density.

WUM makes reasonable assumptions in the main areas of Cosmology. The remarkable agreement of the calculated values of the primary cosmological parameters with the observational data gives us considerable confidence in the Model.

The principal idea of WUM is that the energy density of the World ρ_W equals to the critical energy density ρ_{cr} necessary for 3-Manifold at any cosmological time. ρ_{cr} can be found by considering a sphere of radius R_M and enclosed mass M, with a small test mass m on the periphery of the sphere. Mass M can be calculated by multiplication of ρ_{cr} by the volume of the sphere. The equation for ρ_{cr} can be found from the escape speed calculation for test mass m :

$$\rho_{cr} = \frac{3H^2c^2}{8\pi G} \tag{1.1}$$

where G is the gravitational constant, H is Hubble's parameter, and c is the gravitoelectrodynamic constant that is identical to the electrodynamic constant c in Maxwell's equations.

WUM introduces a fundamental dimensionless time-varying parameter Q that is the measure of the curvature of the Hypersphere. Q can be calculated from the average value of the gravitational constant and in present epoch equals to (see Section 2):

$$Q = 0.759972 \times 10^{40} \tag{1.2}$$

WUM develops a mathematical framework that allows for direct calculation of a number of cosmological parameters through Q . The precision of such parameters increases by orders of magnitude (see Section 2). Below we will use the following fundamental constants:

- basic unit of length $a = 2\pi a_0$, a_0 being the classical electron radius;
- h - Planck constant;
- basic unit of energy $E_0 = \frac{hc}{a}$ that is the basic gravitoelectrodynamic charge in WUM;
- basic unit of energy density $\rho_0 = \frac{hc}{a^4}$;
- basic unit or surface energy density $\sigma_0 = \frac{hc}{a^3} = \rho_0 a$;
- basic unit of mass $m_0 = \frac{h}{ac}$;
- basic unit of frequency $\nu_0 = \frac{c}{a}$;
- α - the fine-structure constant.

2. Primary Cosmological Parameters

Equation (1.1) can be rewritten as

$$\frac{4\pi G}{c^2} \times \frac{2}{3}\rho_{cr} = \mu_g \times \rho_M = H^2 \tag{2.1}$$

where μ_g is the gravitomagnetic parameter and ρ_M is the energy density of the Medium. Hubble's parameter H can be expressed: $H = \frac{c}{R}$, where R is the Hubble's radius and is the radius of the Hypersphere in WUM. Introducing the dimensionless parameter Q:

$$Q = \frac{R}{a} = \nu_0 H^{-1} \tag{2.2}$$

we can rewrite (2.1)

$$\frac{8\pi G a^2}{c^4} \times \frac{1}{3}\rho_{cr} = \frac{8\pi G a^2}{c^4} \times \rho_{MO} = \frac{8\pi G a^2 \rho_0}{c^4} \times \frac{\rho_{MO}}{\rho_0} = \; Q^{-2} \tag{2.3}$$

where ρ_{MO} is the energy density of Macroobjects of the World. Assuming that

$$\rho_{MO} = \rho_0 \times Q^{-1} \tag{2.4}$$

we can find the equation for the critical energy density:

$$\rho_{cr} = 3\rho_0 \times Q^{-1} \tag{2.5}$$

and for the gravitational constant:

$$G = \frac{a^3 c^3}{8\pi hc} H = \frac{a^2 c^4}{8\pi hc} \times Q^{-1} \tag{2.6}$$

We can calculate the value of G based on the value of H. Conversely, we can find the value of the Hubble's parameter based on the value of the gravitational parameter. H and G are interchangeable! Knowing value of one, it is possible to calculate the other.

According to (2.2) we can find the value of dimensionless parameter Q based on the value of H, but the accuracy of its measurements is very poor. We have obtained the value of Q in (1.2) based on the equation (2.6), and value of G that is measured with much better accuracy. Then we can calculate the value of H_0 in present epoch:

$$H_0 = \nu_0 Q^{-1} = 68.7457(83) \; \frac{km/s}{Mpc} \tag{2.7}$$

Thus calculated value of H_0 is in excellent agreement with experimentally measured value of $H_0 = 69.32 \pm 0.8 \; \frac{km/s}{Mpc}$ [1] and proves assumption (2.4).

3. Gravitation

In frames of WUM the parameter G can be calculated based on the value of the energy density of the Medium ρ_M [2]:

$$G = \frac{\rho_M}{4\pi} \times P^2 \tag{3.1}$$

where a dimension-transposing parameter P equals to:

$$P = \frac{a^3}{2h/c} \tag{3.2}$$

Then the Newton's law of universal gravitation can be rewritten in the following way:

$$F = G\frac{m \times M}{r^2} = \frac{\rho_M}{4\pi}\frac{\frac{a^3}{2L_{Cm}} \times \frac{a^3}{2L_{CM}}}{r^2} \tag{3.3}$$

where we introduced the measurable parameter of the Medium ρ_M instead of the phenomenological coefficient G ; and gravitoelectromagnetic charges $\frac{a^3}{2L_{Cm}}$ and $\frac{a^3}{2L_{CM}}$ instead of macroobjects masses m and M (L_{Cm} and L_{CM} are Compton length of mass m and M respectively). The gravitoelectromagnetic charges in (3.3) have a dimension of "Area", which is equivalent to "Energy", with the constant that equals to the basic unit of surface energy density σ_0 .

Following the approach developed in [2] we can find the gravitomagnetic parameter of the Medium μ_M :

$$\mu_M = R^{-1} \tag{3.4}$$

and the impedance of the Medium Z_M :

$$Z_M = \mu_M c = H = \tau^{-1} \tag{3.5}$$

where τ is a cosmological time. These parameters are analogous to the permeability μ_0 and impedance of electromagnetic field $Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \mu_0 c$, where ε_0 is the permittivity of electromagnetic field and $\mu_0 \varepsilon_0 = c^{-2}$.

It follows that measuring the value of Hubble's parameter anywhere in the World and taking its inverse value allows us to calculate the absolute Age of the World. The Hubble's parameter is then the most important characteristic of the World, as it defines the Worlds' Age. While in our Model Hubble's parameter H has a clear physical meaning, the gravitational parameter $G = \frac{c^3}{8\pi\sigma_0}H$ is a phenomenological coefficient in the Newton's law of universal gravitation.

The second important characteristic of the World is the gravitomagnetic parameter μ_M . Taking its inverse value, we can find the absolute radius of curvature of the World in the fourth spatial dimension. We emphasize that the above two parameters (Z_M and μ_M) are principally different physical characteristics of the Medium that are connected through the gravitoelectrodynamic constant c . It means that Time is not a physical dimension and is absolutely different entity than Space. Time is a factor of the World.

It follows that Gravity, Space and Time itself can be introduced only for a World filled with Matter consisting of elementary particles which take part in simple interactions at a microscopic level. The collective result of their interactions can be observed at a macroscopic level. Gravity, Space and Time are then emergent phenomena [3].

4. Intergalactic Plasma

In our Model, the World consists of stable massive elementary particles with lifetimes longer than the age of the World. Protons with mass m_p and energy $E_p = m_p c^2$ and electrons with mass m_e and energy $E_e = m_e c^2 = \alpha E_0$ have identical concentrations in the World: $n_p = n_e$.

Low density intergalactic plasma consisting of protons and electrons has plasma frequency ω_{pl} :

$$\omega_{pl}^2 = \frac{4\pi n_e e^2}{4\pi\varepsilon_0 m_e} = 4\pi n_e \alpha \frac{h}{2\pi m_e c} c^2 = 2n_e a c^2 \quad (4.1)$$

where e is the elementary charge. Since the formula calculating the potential energy of interaction of protons and electrons contains the same parameter k_{pe}:

$$k_{pe} = m_p \omega_{pl}^2 = m_e \omega_e^2 = m_e (2\pi\nu_0 \times Q^{-1/2})^2 \quad (4.2)$$

where we assume that ω_e is proportional to $Q^{-1/2}$, then ω_{pl}^2 is proportional to Q^{-1}. Energy densities of protons and electrons are then proportional to Q^{-1}, similar to the critical energy density $\rho_{cr} \propto Q^{-1}$.

We substitute $\omega_{pl}^2 = \frac{m_e}{m_p}(2\pi\nu_0 \times Q^{-1/2})^2$ into (4.1) and calculate concentration of protons and electrons:

$$n_p = n_e = \frac{2\pi^2}{a^3}\frac{m_e}{m_p} \times Q^{-1} = 0.25480 \ m^{-3} \quad (4.3)$$

A. Mirizzi, *et al.* found that the mean diffuse intergalactic plasma density is bounded by $n_e \lesssim 0.27\ m^{-3}$ [4] corresponding to the WMAP measurement of the baryon density [5]. The Mediums' plasma density (4.3) is in good agreement with the estimated value [4].

From equation (4.2) we obtain the value of the lowest radio-wave frequency ν_{pl} :

$$\nu_{pl} = \frac{\omega_{pl}}{2\pi} = (\frac{m_e}{m_p})^{1/2}\nu_0 \times Q^{-1/2} = 4.5322\ Hz \tag{4.4}$$

Photons with energy smaller than $E_{ph} = h\nu_{pl}$ cannot propagate in plasma, thus $h\nu_{pl}$ is the smallest amount of energy a photon may possess. This amount of energy can be viewed as the rest energy of photons that equals to

$$E_{ph} = \left(\frac{m_e}{m_p}\right)^{1/2} \times E_0 \times Q^{-1/2} = 1.8743 \times 10^{-14}\ eV \tag{4.5}$$

The above value is in good agreement with the value $E_{ph} \lesssim 2.2 \times 10^{-14}\ eV$ estimated in [6]. The results obtained in [4] and [6] prove assumption (4.2).

$\rho_p = n_p E_p$ is the energy density of protons in the Medium. The relative energy density of protons Ω_p is then the ratio of ρ_p/ρ_{cr} :

$$\Omega_p = \frac{\rho_p}{\rho_{cr}} = \frac{2\pi^2\alpha}{3} = 0.048014655 \tag{4.6}$$

This value is in good agreement with experimentally found value of 0.049 ± 0.013 [7] and proves assumption (4.2).

According to WUM, the black body spectrum of Microwave Background Radiation (MBR) is due to thermodynamic equilibrium of photons with low density intergalactic plasma consisting of protons and electrons. $\rho_e = n_e E_e$ is the energy density of electrons in the Medium. We assume that the energy density of MBR ρ_{MBR} equals to twice the value of ρ_e :

$$\rho_{MBR} = 2\rho_e = 4\pi^2\alpha\frac{m_e}{m_p}\rho_0 \times Q^{-1} = \frac{8\pi^5}{15}\frac{k_B^4}{(hc)^3}T_{MBR}^4 \tag{4.7}$$

where k_B is the Boltzmann constant and T_{MBR} is MBR temperature. We can now calculate the value of T_{MBR}:

$$T_{MBR} = \frac{E_0}{k_B}(\frac{15\alpha}{2\pi^3}\frac{m_e}{m_p})^{1/4} \times Q^{-1/4} = 2.72518\ K \tag{4.8}$$

Thus calculated value of T_{MBR} is in excellent agreement with experimentally measured value of $2.72548 \pm 0.00057\ K$ [8] and proves assumption (4.7).

5. Fast Radio Bursts

Fast Radio Burst *(FRB) is a high-energy astrophysical phenomenon manifested as a transient radio pulse lasting only a few milliseconds. These are bright, unresolved, broadband, millisecond flashes found in parts of the sky outside the Milky Way. The component frequencies of each burst are delayed by different amounts of time depending on the wavelength. This delay is described by a value referred to as a Dispersion Measure (DM) which is the total column density of free electrons between the observer and the source of FRB. Fast radio bursts have DMs which are: much larger than expected for a source inside the Milky Way [9]; and consistent with propagation through ionized plasma [10].* In this Section we calculate a time delay of FRB based on the characteristics of the Intergalactic Plasma discussed in [11] (see Section 4).

Consider a photon with initial frequency ν_{emit} and energy E_{emit} emitted at time τ_{emit} when the radius of the hypersphere World in the fourth spatial dimension was R_{emit} . The photon is continuously losing kinetic energy as it moves from galaxy to the Earth until time τ_{obsv} when the radius is $R_{obsv} = R_0$. The observer will measure ν_{obsv} and energy E_{obsv} and calculate a redshift:

$$1 + \mathrm{z} = \frac{\nu_{emit}}{\nu_{obsv}} = \frac{E_{emit}}{E_{obsv}} \tag{5.1}$$

Recall that τ_{emit} and τ_{obsv} are cosmological times (ages of the World at the moments of emitting and observing). A light-travel time distance to a galaxy d_{LLT} equals to

$$d_{LTT} = c(\tau_{obsv} - \tau_{emit}) = ct_{LTT} = R_0 - R_{emit} \tag{5.2}$$

Let's calculate photons' traveling time t_{ph} from a galaxy to the Earth taking into account that the rest energy of photons E_{ph} is much smaller than the energy of photons E_γ: $E_{ph} \ll E_\gamma$.

$$t_{ph} = \frac{1}{c}\int_{R_{emit}}^{R_0} \frac{dr}{\sqrt{1-\frac{E_{ph}^2}{E_\gamma^2}}} = t_{LTT} + \Delta t_{ph} \tag{5.3}$$

where Δt_{ph} is photons' time delay relative to the light-travel time t_{LLT} that equals to:

$$\Delta t_{ph} = \frac{1}{2c}\int_{R_{emit}}^{R_0} \frac{E_{ph}^2}{E_\gamma^2} dr \tag{5.4}$$

All observed FRBs have redshifts $z < 1$. It means that we can use the Hubble's law: $d_{LTT} = R_0 z$. Then

$$R_{emit} = (1 - z)R_0 \tag{5.5}$$

Photons' rest energy squared at radius r between R_{emit} and R_0 equals to (3.5):

$$E_{ph}^2 = \frac{m_e}{m_p}\frac{a}{r}E_0^2 \tag{5.6}$$

According to WUM, photons' energy E_γ on the way from galaxy to an observer can be expressed by the following equation:

$$E_\gamma = zE_{obsv} + (1 - z)\frac{R_0}{r}E_{obsv} = z\frac{R_0}{r}E_{obsv}(\frac{1-z}{z} + \frac{r}{R_0}) \tag{5.7}$$

which reduces to E_{emit} at (5.5) and to E_{obsv} at $r = R_0$. Placing the values of the parameters (5.5), (5.6), (5.7) into (5.4), we have for photons' time delay:

$$\Delta t_{ph} = \frac{1}{2z^2}\frac{c}{a}\frac{m_e}{m_p}\frac{1}{\nu^2}\int_{1-z}^{1}\frac{xdx}{\left(x+\frac{1-z}{z}\right)^2} = \frac{1}{2z^2}\frac{c}{a}\frac{m_e}{m_p}\frac{1}{\nu^2}\int_{\frac{1-z^2}{z}}^{\frac{1}{z}}\frac{\left(y-\frac{1-z}{z}\right)dy}{y^2} =$$

$$= \frac{1}{2z^2}\left[ln\left(\frac{1}{1-z^2}\right) - \frac{z^2}{1+z}\right]\frac{c}{a}\frac{m_e}{m_p} \times \frac{1}{\nu^2} =$$

$$= \frac{4.61}{z^2}\left[ln\left(\frac{1}{1-z^2}\right) - \frac{z^2}{1+z}\right] \times (\frac{\nu}{1GHz})^{-2} \tag{5.8}$$

where $x = r/R_0$ and $y = x + \frac{1-z}{z}$. Taking z=0.492 [7] we get the calculated value of photons' time delay

$$\Delta t_{ph}^{cal} = 2.189 \times (\frac{\nu}{1GHz})^{-2} \tag{5.9}$$

which is in good agreement with experimentally measured value [7]

$$\Delta t_{ph}^{exp} = 2.438 \times (\frac{\nu}{1GHz})^{-2} \tag{5.10}$$

It is worth to note that in our calculations there is no need in the dispersion measure.

6. Neutrinos

It is now established that there are three different types of neutrino: electronic ν_e, muonic ν_μ, and tauonic ν_τ, and their antiparticles. Neutrino oscillations imply that neutrinos have non-zero masses [12] [13].

Let's take neutrino masses m_{ν_e}, m_{ν_μ}, m_{ν_τ} that are near [14]

$$m_\nu = m_0 \times Q^{-1/4} \tag{6.1}$$

Their concentrations n_ν are then proportional to

$$n_\nu \propto \frac{1}{a^3} \times Q^{-3/4} \tag{6.2}$$

and energy densities of neutrinos are proportional to Q^{-1}, since critical energy density ρ_{cr} is proportional to Q^{-1} (see Section 2).

Experimental results obtained by M. Sanchez [15] show $\nu_e \to \nu_{\mu,\tau}$ neutrino oscillations with parameter Δm^2_{sol} given by

$$2.3 \times 10^{-5}\ eV^2/c^4 \leq \Delta m^2_{sol} \leq 9.3 \times 10^{-5}\ eV^2/c^4 \tag{6.3}$$

and $\nu_\mu \to \nu_\tau$ neutrino oscillations with parameter Δm^2_{atm} :

$$1.6 \times 10^{-3}\ eV^2/c^4 \leq \Delta m^2_{atm} \leq 3.9 \times 10^{-3}\ eV^2/c^4 \tag{6.4}$$

where Δm^2_{sol} and Δm^2_{atm} are mass splitting for solar and atmospheric neutrinos respectively. Significantly more accurate result was obtained by P. Kaus, *et al.* [16] for the ratio of the mass splitting:

$$\sqrt{\frac{\Delta m^2_{sol}}{\Delta m^2_{atm}}} \cong 0.16 \approx \frac{1}{6} \tag{6.5}$$

Let's assume that muonic neutrino's mass indeed equals to

$$m_{\nu_\mu} = m_\nu = m_0 \times Q^{-1/4} \cong 7.5 \times 10^{-3}\ eV/c^2 \tag{6.6}$$

From equation (6.5) it then follows that

$$m_{\nu_\tau} = 6m_\nu \cong 4.5 \times 10^{-2}\ eV/c^2 \qquad (6.7)$$

Then the squared values of the muonic and tauonic neutrino masses fall into ranges (6.3) and (6.4):

$$m_{\nu_\mu}^2 \cong 5.6 \times 10^{-5}\ eV^2/c^4$$

$$m_{\nu_\tau}^2 \cong 2 \times 10^{-3}\ eV^2/c^4 \qquad (6.8)$$

Let's assume that electronic neutrino mass equals to

$$m_{\nu_e} = \frac{1}{24} m_\nu \cong 3.1 \times 10^{-4}\ eV/c^2 \qquad (6.9)$$

The sum of the calculated neutrino masses

$$\Sigma m_\nu \cong 0.053\ eV/c^2 \qquad (6.10)$$

is also in a good agreement with the value of 0.06 eV/c^2 discussed in literature [17].

Considering that all elementary particles, including neutrinos, are fully characterized by their four-momentum $(\frac{E_{\nu i}}{c}, \boldsymbol{p}_{\nu i})$:

$$(\frac{E_{\nu i}}{c})^2 - \boldsymbol{p}_{\nu i}^2 = (m_{\nu i} c)^2$$

$$i = e, \mu, \tau \qquad (6.11)$$

we obtain the following neutrino energy densities $\rho_{\nu i}$ in accordance with theoretical calculations made by L. D. Landau and E. M. Lifshitz [18]:

$$\rho_{\nu i} = \frac{8\pi c}{h^3} \int_0^{p_F} p^2 \sqrt{p^2 + m_{\nu i}^2 c^2}\, dp =$$

$$= \frac{2\pi (p_F c)^4}{(hc)^3} \times F(x_{\nu i}) \qquad (6.12)$$

where p_F is Fermi momentum,

$$F(x_{\nu i}) = \frac{x_{\nu i}^{1/2}(2x_{\nu i}+1)(x_{\nu i}+1/2)^{1/2} - ln\left[x_{\nu i}^{1/2} + (x_{\nu i}+1)^{1/2}\right]}{2x_{\nu i}^2} \qquad (6.13)$$

$$x_{\nu i} = (\frac{p_F}{m_{\nu i}c})^2 \tag{6.14}$$

$$m_{\nu i} = A_i m_0 \times Q^{-1/4} \tag{6.15}$$

$$A_i = \frac{1}{24};\ 1;\ 6 \tag{6.16}$$

Let's take the following value for Fermi momentum p_F:

$$p_F^2 = \frac{h^2}{2\pi^2 a^2} \times Q^{-1/2} = p_{F0}^2 \times Q^{-1/2} \tag{6.17}$$

where $p_{F0}^2 = \frac{h^2}{2\pi^2 a^2}$ is the extrapolated value of p_F at the Beginning when $Q = 1$. Using (6.13), we obtain neutrinos relative energy densities $\Omega_{\nu i}$ in the Medium in terms of the critical energy density ρ_{cr}:

$$\Omega_{\nu i} = \frac{\rho_{\nu i}}{\rho_{cr}} = \frac{1}{6\pi^3} F(y_{\nu i}) \tag{6.18}$$

where

$$y_{\nu i} = (2\pi^2 A_i^2)^{-1} \tag{6.19}$$

It's commonly accepted that concentrations of all types of neutrinos are equal. This assumption allows us to calculate the total neutrinos relative energy density in the Medium:

$$\Omega_\nu = \frac{\rho_\nu}{\rho_{cr}} = \frac{\rho_{\nu e} + \rho_{\nu\mu} + \rho_{\nu\tau}}{\rho_{cr}} = 0.45801647 \tag{6.20}$$

One of the principal ideas of WUM holds that energy densities of Medium particles are proportional to proton energy density in the World's Medium [2]:

$$\Omega_p = \frac{2\pi^2\alpha}{3} = 0.048014655 \tag{6.21}$$

which depends on the fundamental parameter α. We take the value of Ω_ν to equal

$$\Omega_\nu = \frac{30}{\pi}\Omega_p = 20\pi\alpha = 0.45850618 \tag{6.22}$$

which is remarkably close to its value calculated in (6.20).

The assumptions made in (6.6), (6.9), (6.17) and (6.22) are further supported by the excellent numerical agreement of calculated and measured value of fine-structure constant α discussed in Section 11.

7. Cosmic Far-Infrared Background

The cosmic Far-Infrared Background (FIRB), which was announced in January 1998, is part of the Cosmic Infrared Background, with wavelengths near 100 microns that is the peak power wavelength of the black body radiation at temperature 29 K. In this Section we introduce Bose-Einstein Condensate (BEC) drops of dineutrinos whose mass is about Planck mass, and their temperature is around 29 K. These drops are responsible for the FIRB [14].

According to [19]-[21], the size of large cosmic grains D_G is roughly equal to the length L_F:

$$D_G \sim L_F = a \times Q^{1/4} = 1.6532 \times 10^{-4}\, m \tag{7.1}$$

and their mass m_G is close to the Planck mass $M_P = 2.17647 \times 10^{-8}\, kg$:

$$m_G \sim (10^{-9} \Leftrightarrow 10^{-7})\, kg \tag{7.2}$$

The density of grains ρ_G is about:

$$\rho_G \sim \frac{6}{\pi}\frac{M_P}{L_F^3} \approx 9.2 \times 10^3\, kg/m^3 \tag{7.3}$$

According to WUM, Planck mass M_P equals to [3]

$$M_P = 2m_0 \times Q^{1/2} \tag{7.4}$$

Note that the value of M_P is increasing with cosmological time, and is proportional to $\tau^{1/2}$. Then,

$$\frac{d}{d\tau}M_P = \frac{M_P}{2\tau} \tag{7.5}$$

A grain of mass $B_1 M_P$ and radius $B_2 L_F$ is receiving energy from the Medium of the World as the result of dineutrinos Bose-Einstein Condensation (see Section 8) at the following rate:

$$\frac{d}{d\tau}(B_1 M_P c^2) = \frac{B_1 M_P c^2}{2\tau} \tag{7.6}$$

where B_1 and B_2 are parameters.

The received energy will increase the grain's temperature T_G, until equilibrium is achieved: power received equals to the power irradiated by the surface of a grain in accordance with the Stefan-Boltzmann law

$$\frac{B_1 M_P c^2}{2\tau} = \sigma_{SB} T_G^4 \times 4\pi B_2^2 L_F^2 \tag{7.7}$$

where σ_{SB} is Stefan-Boltzmann constant:

$$\sigma_{SB} = \frac{2\pi^5 k_B^4}{15 h^3 c^3} \tag{7.8}$$

With Nikola Tesla's principle at heart – *There is no energy in matter other than that received from the environment* – we apply the World equation [22] to a grain:

$$B_1 M_P c^2 = 4\pi B_2^2 L_F^2 \sigma_0 \tag{7.9}$$

where σ_0 is a basic unit of surface energy density:

$$\sigma_0 = \rho_0 a \tag{7.10}$$

We then calculate the grain's stationary temperature T_G to be

$$T_G = \left(\frac{15}{4\pi^5}\right)^{1/4} \frac{hc}{k_B L_F} = 28.955\ K \tag{7.11}$$

This result is in an excellent agreement with experimentally measured value of $29\ K$ [23]-[34] and proves the assumptions (7.1), (7.2) and (7.9).

Cosmic FIRB radiation is not a black body radiation. Otherwise, its energy density ρ_{FIRB} at temperature T_G would be too high and equal to the energy density of the Medium of the World:

$$\rho_{FIRB} = \frac{8\pi^5}{15} \frac{k_B^4}{(hc)^3} T_G^4 = \frac{2}{3}\rho_{cr} = \rho_M \tag{7.12}$$

The total flux of the FIRB radiation is the sum of the contributions of all individual grains. Comparing equations (7.11) and (4.8), we can find the relation between the grains' temperature and the temperature of the MBR:

$$T_G = (3\Omega_e)^{-1/4} \times T_{MBR} \tag{7.13}$$

where electron relative energy density Ω_e in terms of the critical energy density equals to

$$\Omega_e = \frac{m_e}{m_p}\Omega_p \tag{7.14}$$

8. Bose-Einstein Condensate

New cosmological models employing the Bose-Einstein Condensates (BEC) have been actively discussed in literature in recent years [35]-[49]. The transition to BEC occurs below a critical temperature T_c , which for a uniform three-dimensional gas consisting of non-interacting particles with no apparent internal degrees of freedom is given by

$$T_c = [\zeta(3/2)]^{-2/3}\frac{h^2 n_X^{2/3}}{2\pi m_X k_B} \approx \frac{h^2 n_X^{2/3}}{11.918 m_X k_B} \tag{8.1}$$

where n_X is the particle density, m_X is the mass per boson, ζ is the Riemann zeta function:

$$\zeta(3/2) \approx 2.6124 \tag{8.2}$$

According to our Model, we can take the value of the critical temperature T_c to equal the stationary temperature T_G of Large Grains (see equation (7.11)). Let's assume that the energy density of boson particles ρ_X equals to the MBR energy density (see (4.7)):

$$\rho_X = n_X m_X = 2\frac{m_e}{m_p}\rho_p = 4\pi^2\alpha\frac{m_e}{m_p}\frac{hc}{L_F^4} = 1.5690 \times 10^{-4} \times \frac{hc}{L_F^4} \tag{8.3}$$

Taking into account equations (7.11), (8.1) and (8.3), we can calculate the value of n_X :

$$n_X = [47.672\pi^2\alpha\frac{m_e}{m_p}\left(\frac{15}{4\pi^5}\right)^{1/4}]^{3/5} \times L_F^{-3} =$$

$$= 0.011922 \times L_F^{-3} = 2.6386 \times 10^9\ m^{-3} \tag{8.4}$$

and the value of the mass m_X :

$$m_X = \frac{\rho_X}{n_X c^2} = 0.013161 \times m_0 \times Q^{-1/4} = 0.987 \times 10^{-4}\ eV/c^2 \tag{8.5}$$

m_X is about 10 orders of magnitude larger than the rest mass of photon's (see (4.5)) and is in the range of neutrinos masses (see Section 6).

The calculated values of mass and concentration of dineutrinos satisfy the conditions for their Bose-Einstein condensation. Consequently, BEC drops whose masses are about Planck mass can be created. The stability of such drops is provided by the detailed equilibrium between the energy absorption from the Medium of the World (provided by dineutrinos as a result of their Bose-Einstein condensation) and re-emission of this energy in FIRB at the stationary temperature $T_G \approx 29\ K$ (see Section 7).

In WUM the FIRB energy density ρ_{FIRB} equals to [14]

$$\rho_{FIRB} = \frac{1}{5\pi}\frac{m_e}{m_p}\rho_p = \frac{2\pi\alpha}{15}\frac{m_e}{m_p} \qquad (8.6)$$

which is 10π times smaller than the energy density of MBR and dineutrinos:

$$\rho_{FIRB} = \frac{1}{10\pi}\rho_{MBR} \approx 0.032\rho_{MBR} \qquad (8.7)$$

The ratio between FIRB and MBR corresponds to the value of 3.4% calculated by E. L. Wright [50].

The assumptions made in (8.3) and (8.6) are further supported by the excellent numerical agreement of calculated and measured value of fine-structure constant α discussed in Section 11.

9. Multicomponent Dark Matter

Dark Matter (DM) is among the most important open problems in both cosmology and particle physics. There are three prominent hypotheses on nonbaryonic DM, namely Hot Dark Matter (HDM), Warm Dark Matter (WDM), and Cold Dark Matter (CDM).

A neutralino with mass m_N in $100 \Leftrightarrow 10{,}000\ GeV/c^2$ range is the leading CDM candidate. Light DMP that are heavier than WDM and HDM but lighter than neutralinos are DM candidates too. Subsequently, we will refer to the light DMP as WIMPs. Their mass m_{WIMP} falls into $1 \Leftrightarrow 10\ GeV/c^2$ range. It is known that a sterile neutrino with mass m_{ν_s} in $1 \Leftrightarrow 10\ keV/c^2$ range is a good WDM candidate. In our opinion, a tauonic neutrino is a good HDM candidate.

In addition to fermions discussed above, we offer another type of DMP – spin-0 bosons, consisting of two fermions each. There exist two types of DM bosons which we called DIRACs and ELOPs [51]. DIRACs are magnetic dipoles with mass m_0, consisting of two

Dirac monopoles with mass about $\frac{m_0}{2}$ and charge $\mu = \frac{e}{2\alpha}$. Dissociated DIRACs can only exist at nuclear densities or at high temperatures. In our opinion, Dirac monopoles are the smallest building blocks of constituent quarks and hadrons (mesons and baryons).

The second spin-0 boson is the ELOP (named by analogy to an **EL**ectron- nortis**OP** dipole). ELOP weighs $\frac{2}{3}m_e$ and consists of two preons with mass $m_{pr} = \frac{1}{3}m_e$ and charge $e_{pr} = \frac{1}{3}e$ which we took to match the Quark Model. ELOPs break into two preons at nuclear densities or at high temperatures. In particle physics, preons are postulated to be "point-like" particles, conceived to be subcomponents of quarks and leptons [52].

WUM postulates that masses of DMP are proportional to m_0 multiplied by different exponents of α and can be expressed with the following formulae:

CDM particles (neutralinos and WIMPs):

$$m_N = \alpha^{-2}m_0 = 1.3149950\ \ TeV/c^2 \tag{9.1}$$

$$m_{WIMP} = \alpha^{-1}m_0 = 9.5959823\ \ GeV/c^2 \tag{9.2}$$

DIRACs:

$$m_{DIRAC} = 2\alpha^0\frac{m_0}{2} = 70.025267\ \ MeV/c^2 \tag{9.3}$$

ELOPs:

$$m_{ELOP} = 2\alpha^1\frac{m_0}{3} = 340.66606\ \ keV/c^2 \tag{9.4}$$

WDM particles (sterile neutrinos):

$$m_{\nu_s} = \alpha^2 m_0 = 3.7289402\ \ keV/c^2 \tag{9.5}$$

These values fall into the ranges estimated in literature. The role of those particles in macroobject cores built up from fermionic dark matter will be discussed in Section 10.

Our Model holds that the energy densities of all types of DMP are proportional to the proton energy density ρ_p in the World's Medium (see (4.6)) In all, there are 5 different types of DMP. Then the total energy density of DMP is

$$\rho_{DM} = 5\rho_p = 0.24007327\rho_{cr} \tag{9.6}$$

which is close to the measured DM energy density: $\rho_{DM} \cong 0.268\,\rho_{cr}$ [53]. Note that one of outstanding puzzles in particle physics and cosmology relates to so-called cosmic coincidence: the ratio of dark matter density in the World to baryonic matter density in the Medium of the World $\cong 5$ [54], [55].

Neutralinos, WIMPs, and sterile neutrinos are Majorana fermions, which partake in the annihilation interaction with strength equals to α^{-2}, α^{-1}, and α^{2} respectively (see Section 10). The signatures of DMP annihilation with expected masses of 1.3 TeV, 9.6 GeV, 70 MeV, 340 keV, and 3.7 keV are found in spectra of the diffuse gamma-ray background and the emission of various macroobjects in the World [51].

10. Macroobject Cores Built Up From Fermionic Dark Matter

In this section, we discuss the possibility of all macroobject cores consisting of DMP introduced in Section 9. The first phase of stellar evolution in the history of the World may be dark stars, powered by Dark Matter heating rather than fusion. Neutralinos and WIMPs, which are their own antiparticles, can annihilate and provide an important heat source for the stars and planets in the World.

In our view, all macroobjects of the World (including galaxy clusters, galaxies, star clusters, extrasolar systems, and planets) possess the following properties:

- Macroobject cores are made up of DMP;
- Macroobjects consist of all particles under consideration, in the same proportion as they exist in the World's Medium;
- Macroobjects contain other particles, including DM and baryonic matter, in shells surrounding the cores.

Taking into account the main principle of the World – Universe Model (all physical parameters can be expressed in terms of α, Q , small integer numbers, and π) we modify the published theory of Fermionic Compact Stars (FCS) developed by G. Narain, *et al*. [56] as follows. We take a scaling solution for a free Fermi gas consisting of fermions with mass m_f in accordance with following equations:

Maximum mass: $M_{max} = A_1 M_F$; (10.1)

Minimum radius: $R_{min} = A_2 R_F$; (10.2)

Maximum density: $\rho_{max} = A_3 \rho_0$ (10.3)

where

$$M_F = \frac{M_P^3}{m_f^2}; \quad R_F = \frac{M_P}{m_f}\frac{L_{Cf}}{2\pi}; \quad \rho_0 = \frac{hc}{a^4} \tag{10.4}$$

and M_P is Planck mass, L_{Cf} is a Compton length of the fermion. A_1, A_2, and A_3 are parameters. Let us choose π as the value of A_2 (instead of $A_2 = 3.367$ taken by G.

Narain, *et al.* [56]). Then diameter of FCS is proportional to the fermion Compton length L_{Cf}. We use $\pi/6$ as the value of A_1 (instead of $A_1 = 0.384$ taken by G. Narain, *et al.* [56]). Then A_3 will equal to

$$A_3 = (\frac{m_f}{m_0})^4 \qquad (10.5)$$

Table 1 summarizes the parameter values for FCS made up of various fermions:

Table 1

Fermion	**Fermion relative mass** m_f/m_0	**Macroobject relative mass** M_{max}/M_0	**Macroobject relative radius** R_{min}/L_g	**Macroobject relative density** ρ_{max}/ρ_0
Sterile neutrino	α^2	α^{-4}	α^{-4}	α^8
Preon	$3^{-1}\alpha^1$	$3^2\alpha^{-2}$	$3^2\alpha^{-2}$	$3^{-4}\alpha^4$
Electron-proton (white dwarf)	α^1, β	β^{-2}	$(\alpha\beta)^{-1}$	$\alpha^3\beta$
Monopole	2^{-1}	2^2	2^2	2^{-4}
WIMP	α^{-1}	α^2	α^2	α^{-4}
Neutralino	α^{-2}	α^4	α^4	α^{-8}
Interacting WIMPs	α^{-1}	β^{-2}	β^{-2}	β^4
Interacting neutralinos	α^{-2}	β^{-2}	β^{-2}	β^4
Neutron (star)	$\approx \beta$	β^{-2}	β^{-2}	β^4

where

$$M_0 = \frac{4\pi m_0}{3} \times Q^{3/2} \tag{10.6}$$

$$L_g = a \times Q^{1/2} \tag{10.7}$$

$$\beta = \frac{m_p}{m_0} \tag{10.8}$$

A maximum density of neutron stars equals to the nuclear density:

$$\rho_{max} = \beta^4 \rho_0 \tag{10.9}$$

which is the maximum possible density of any macroobject in the World.

A Compact Star made up of heavier particles – WIMPs and neutralinos – could in principle have a much higher density. In order for such a star to remain stable and not exceed the nuclear density, WIMPs and neutralinos must partake in an annihilation interaction whose strength equals to α^{-1} and α^{-2} respectively.

Scaling solution for interacting WIMPs can also be described with equations (10.1), (10.2), (10.3) and the following values of A_1, A_2 and A_3:

$$A_{1max} = \frac{\pi}{6}(\alpha\beta)^{-2} \tag{10.10}$$

$$A_{2min} = \pi(\alpha\beta)^{-2} \tag{10.11}$$

$$A_{3max} = \beta^4 \tag{10.12}$$

The maximum mass and minimum radius increase about two orders of magnitude each and the maximum density equals to the nuclear density. Note that parameters of a FCS made up of strongly interacting WIMPs are identical to those of neutron stars.

In accordance with the paper by G. Narain, *et al*. [56], the most attractive feature of the strongly interacting Fermi gas of WIMPs is practically constant value of FCS minimum radius in the large range of masses M_{WIMP} from

$$M_{WIMPmax} = \frac{\pi}{6}(\alpha\beta)^{-2} M_F = \frac{1}{\beta^2} M_0 \tag{10.13}$$

down to

$$M_{WIMPmin} = \alpha^4 M_{WIMPmax} \tag{10.14}$$

$M_{WIMPmin}$ is more than eight orders of magnitude smaller than $M_{WIMPmax}$. It makes strongly interacting WIMPs good candidates for stellar and planetary cores of extrasolar systems with Red stars [51].

When the mass of a FCS made up of WIMPs is much smaller than the maximum mass, the scaling solution yields the following equation for parameters A_1 and A_2:

$$A_1 A_2^3 = \pi^4 \tag{10.15}$$

Compare $\pi^4 \cong 97.4$ with the value of 91 used by G. Narain, *et al.* [56].

Minimum mass and maximum radius take on the following values:

$$A_{1min} = \frac{\pi}{6}\sqrt{6}(\alpha\beta)^2 \tag{10.16}$$

$$A_{2max} = \pi\sqrt[6]{6}(\alpha\beta)^{-2/3} \tag{10.17}$$

It follows that the range of FCS masses ($A_{1min} \Leftrightarrow A_{1max}$) spans about three orders of magnitude, and the range of FCS core radii ($A_{2min} \Leftrightarrow A_{2max}$) – one order of magnitude. It makes WIMPs good candidates for brown dwarf cores too [51].

Scaling solution for interacting neutralinos can be described with the same equations (10.1), (10.2), (10.3) and the following values of A_1^*, A_2^* and A_3^*:

$$A_{1max}^* = \frac{\pi}{6}(\alpha^2\beta)^{-2} \tag{10.18}$$

$$A_{2min}^* = \pi(\alpha^2\beta)^{-2} \tag{10.19}$$

$$A_{3max}^* = \beta^4 \tag{10.20}$$

In this case, the maximum mass and minimum radius increase about four orders of magnitude each and the maximum density equals to the nuclear density. Note that parameters of a FCS made up of strongly interacting neutralinos are identical to those of neutron stars.

Practically constant value of FCS minimum radius takes place in the huge range of masses M_N from

$$M_{Nmax} = \frac{\pi}{6}(\alpha\beta)^{-2}\alpha^2 M_F = \frac{1}{\beta^2}M_0 \tag{10.21}$$

down to

$$M_{Nmin} = \alpha^8 M_{Nmax} \tag{10.22}$$

M_{Nmin} is more than seventeen orders of magnitude smaller than M_{Nmax}. It makes strongly interacting neutralinos good candidates for stellar and planetary cores of extrasolar systems with Main-sequence stars [51].

When the mass of a FCS made up of neutralinos is much smaller than the maximum mass, the scaling solution yields the following equation for parameters A_1^* and A_2^*:

$$A_1^* {A_2^*}^3 = \pi^4 \qquad (10.23)$$

Minimum mass and maximum radius take on the following values:

$$A_{1min}^* = \frac{\pi}{6}\sqrt{6}(\alpha^2\beta)^2 \qquad (10.24)$$

$$A_{2max}^* = \pi\sqrt[6]{6}(\alpha^2\beta)^{-2/3} \qquad (10.25)$$

It means that the range of FCS masses ($A_{1min}^* \Leftrightarrow A_{1max}^*$) is about twelve orders of magnitude, and the range of FCS core radiuses ($A_{2min}^* \Leftrightarrow A_{2max}^*$) is about four orders of magnitude.

Fermionic Compact Stars have the following properties:

- The maximum potential of interaction U_{max} between any particle or macroobject and FCS made up of any fermions

$$U_{max} = \frac{GM_{max}}{R_{min}} = \frac{c^2}{6} \qquad (10.26)$$

does not depend on the nature of fermions;

- The minimum radius of FCS made of any fermion

$$R_{min} = 3R_{SH} \qquad (10.27)$$

equals to three Schwarzschild radii and does not depend on the nature of the fermion;

- FCS density does not depend on M_{max} and R_{min} and does not change in time while $M_{max} \propto \tau^{3/2}$ and $R_{min} \propto \tau^{1/2}$.

11. Energy Density of Dineutrinos, FIRB and the World

Our Model holds that the energy densities of all types of Dark Matter particles (DMP) are proportional to the proton energy density in the World's Medium. In all, there are 5 different types of DMP (see Section 9). Then the total energy density of Dark Matter (DM) Ω_{DM} is

$$\Omega_{DM} = 5\Omega_p \tag{11.1}$$

The total electron energy density Ω_{etot} is:

$$\Omega_{etot} = 1.5\frac{m_e}{m_p}\Omega_p \tag{11.2}$$

The MBR energy density Ω_{MBR} equals to [1]:

$$\Omega_{MBR} = 2\frac{m_e}{m_p}\Omega_p \tag{11.3}$$

We took energy density of dineutrinos $\Omega_{\nu\bar{\nu}}$ and FIRB Ω_{FIRB} (see Section 8):

$$\Omega_{\nu\bar{\nu}} = \Omega_{MBR} = 2\frac{m_e}{m_p}\Omega_p \tag{11.4}$$

$$\Omega_{FIRB} = \frac{1}{5\pi}\frac{m_e}{m_p}\Omega_p = \frac{1}{10\pi}\Omega_{MBR} \approx 0.032\Omega_{MBR} \tag{11.5}$$

Then the energy density of the World Ω_W

$$\Omega_W = \left[\frac{13}{2} + \left(\frac{11}{2} + \frac{1}{5\pi}\right)\frac{m_e}{m_p} + \frac{45}{\pi}\right]\Omega_p = 1 \tag{11.6}$$

Equation (11.6) contains such exact terms as the result of the Models' predictions and demonstrates consistency of WUM. From (11.6) we can calculate the value of α, using electron-to-proton mass ratio $\frac{m_e}{m_p}$

$$\frac{1}{\alpha} = \frac{\pi}{15}\left[450 + 65\pi + (55\pi + 2)\frac{m_e}{m_p}\right] = 137.03600 \tag{11.7}$$

which is in an excellent agreement with the commonly adopted value of 137.035999074(44). It follows that there exists a direct correlation between constants α and $\frac{m_e}{m_p}$ expressed by equation (11.6). As shown above, $\frac{m_e}{m_p}$ is not an independent constant, but is instead derived from α.

12. Grand Unified Theory

At the very Beginning (*Q=1*) all extrapolated fundamental interactions of the World – strong, electromagnetic, weak, Super Weak and Extremely Weak (proposed in WUM), and

gravitational – had the same cross-section of $(\frac{\pi a}{2})^2$, and could be characterized by the Unified coupling constant: $\alpha_U = 1$. The extrapolated energy density of the World was four orders of magnitude smaller than the nuclear energy density [57]. The average energy density of the World has since been decreasing in time $\rho_W \propto Q^{-1} \propto \tau^{-1}$.
The gravitational coupling parameter α_G is similarly decreasing:

$$\alpha_G = Q^{-1} \propto \tau^{-1} \tag{12.1}$$

The weak coupling parameter α_W is decreasing as follows:

$$\alpha_W = Q^{-1/4} \propto \tau^{-1/4} \tag{12.2}$$

The strong α_S and electromagnetic α_{EM} coupling parameters remain constant in time:

$$\alpha_S = \alpha_{EM} = 1 \tag{12.3}$$

The difference in the strong and the electromagnetic interactions is not in the coupling parameters but in the strength of these interactions depending on the particles involved: electrons with charge e and monopoles with charge $\mu = \frac{e}{2\alpha}$ in electromagnetic and strong interactions respectively.

The super weak coupling parameter α_{SW} and the extremely weak coupling parameter α_{EW} proposed in WUM are decreasing as follows:

$$\alpha_{SW} = Q^{-1/2} \propto \tau^{-1/2} \tag{12.4}$$

$$\alpha_{EW} = Q^{-3/4} \propto \tau^{-3/4} \tag{12.5}$$

According to WUM, the coupling strength of super-weak interaction is $\sim 10^{-10}$ times weaker than that of weak interaction. The possibility of such ratio of interactions was discussed in the developed theoretical models explaining CP and Strangeness violation [58]-[61]. Super-weak and Extremely-weak interactions provide an important clue to Physics beyond the Standard Model.

13. Conclusion

WUM holds that there exist relations between all Q-dependent parameters: Newtonian parameter of gravitation and Hubble's parameter; Critical energy density and Fermi coupling parameter; Temperatures of the Microwave Background Radiation and Far-Infrared Background Radiation peak. The calculated values of these parameters are in good agreement with the latest results of their measurements.

Today, Fermi coupling parameter G_F is known with the highest precision [57]:

$$\frac{G_F}{(\hbar c)^3} = \sqrt{30}(2\alpha\frac{m_e}{m_p})^{1/4} \times \frac{m_p}{m_e}\frac{1}{E_0^2} \times Q^{-1/4} \qquad 13.1$$

Based on its average value we can calculate and significantly increase the precision of all Q-dependent parameters. We propose to introduce Q as a new Fundamental Parameter tracked by CODATA, and use its value in calculation of all Q-dependent parameters.

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