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Fundamental Physical Constants and Primary Physical Parameters

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Abstract

Every four years the Committee on Data for Science and Technology (CODATA) supplies a self-consistent set of values of the basic constants and conversion factors of physics recommended for international use. In 2013, the World-Universe Model (WUM) proposed a principally different depiction of the World as an alternative to the picture of the Big Bang Model. This article: 1) Gives the short history of Classical Physics before Special Relativity; 2) Calculates Fundamental Physical Constants based on experimentally measured Rydberg constant, Electrodynamic constant, Electron Charge-to-Mass Ratio, and Planck constant; 3) Discusses Electrodynamic constant and Speed of Light; 4) Considers Dimensionless Fundamental Parameters (Dirac Large Number Q and Dimensionless Rydberg Constant α); 5) Calculates Newtonian Constant of Gravitation based on the Inter-connectivity of Primary Physical Parameters; 6) Makes a detailed analysis of the Self-consistency of Fundamental Physical Constants and Primary Physical Parameters through the prism of WUM. The performed analysis suggests: 1) Discontinuing using the notion "Vacuum" and its characteristics (Speed of Light in Vacuum, Characteristic Impedance of Vacuum, Vacuum Magnetic Permeability, Vacuum Electric Permittivity); 2) Accepting the exact numerical values of Electrodynamic constant, Planck constant, Elementary charge, and Dimensionless Rydberg Constant α. WUM recommends the predicted value of Newtonian Constant of Gravitation in 2018 to be considered in CODATA Recommend Values of the Fundamental Physical Constants 2022.

Keywords

Classical Physics, Fundamental Physical Constants, Electrodynamic Constant, Speed of Light, Dirac Large Number, Dimensionless Rydberg Constant, Newtonian Constant of Gravitation, Self-Consistency of Fundamental Physical Constants

> It does not make any difference how beautiful your guess is, it does not make any difference how smart you are, who made the guess, or what his name is. If it disagrees with experiment, it is wrong. That is all there is to it.
>
> Richard Feynman

1. Introduction

The very first manuscript "World-Universe Model" (WUM) was uploaded on viXra in March 2013 [1]. At that time great results in Cosmology were achieved:

- The cosmic Far-Infrared Background Radiation was announced in 1999 [2];
- Temperature of the Microwave Background Radiation was measured in 2009 [3];
- Wilkinson Microwave Anisotropy Probe Observations were published in 2012 [4].

At the same time, the most important for the Cosmology, Newtonian constant of gravitation, proved too difficult to measure [5]. Its measurement precision was the worst among all Fundamental physical constants.

In 2013, we proposed a principally different Model that is, in fact, a Paradigm Shift for Cosmology. WUM is developed around two Primary Physical Parameters in various rational exponents which define all macro and micro features of the World: Dimensionless Rydberg Constant α and dimensionless quantity Q. While α is constant, Q increases with time, and is, in fact, a measure of the size and the age of the World.

2. Classical Physics before Special Relativity

In this Section we describe principal milestones in Classical Physics. Based on the analysis of the measured physical constants we conclude that the most important Fundamental constants could be calculated before Special Relativity [6].

Physical Aether was suggested as early as 17th century, by Isaac Newton. Following the work of Thomas Young (1804) and Augustin-Jean Fresnel (1816), it was believed that light propagates as a transverse wave within an elastic medium called Luminiferous Aether. At that time, it was realized that Aether could not be an elastic matter of an ordinary type that can only transmit longitudinal waves.

Unique properties of Aether were discussed by James McCullagh in 1846 who proposed a theory of a rotationally elastic medium, *i.e.*, a medium in which every particle resists absolute rotation. This theory produces equations analogous to Maxwell's electromagnetic equations [7]. Aether with these properties can transmit transverse waves.

We emphasize that Aether was abandoned in 1905 by Special Relativity. The Friedmann equations were first derived in 1922 from Einstein's field equations for the Friedmann-Lemaitre-Robertson-Walker metric and a perfect fluid with a given mass density ρ and pressure p, which is a medium of the universe.

In later years there have been classical physicists who advocated the existence of Aether:

- Nikola Tesla declared in 1937 in "Prepared Statement on the 81st birthday observance": "*All attempts to explain the workings of the universe without recognizing the existence of the aether and the indispensable function it plays in the phenomena are futile and destined to oblivion*" [8];
- Paul Dirac said in 1951 in the article in Nature, titled "Is there an Aether?" that "*we are rather forced to have an aether*" [9].

There are no Luminiferous Aether and Vacuum in WUM. The Model introduces the Medium of the World, which is composed of stable elementary particles: protons, electrons, photons, neutrinos, and Dark Matter Particles (DMPs). The existence of the Medium is a principal point of WUM. It follows from the observations of Intergalactic Plasma; Cosmic Microwave Background Radiation; Far-Infrared Background Radiation. According to WUM, Inter-Galactic voids discussed by astronomers are, in fact, examples of the Medium in its purest. The Medium is the absolute frame of reference [6].

Maxwell's equations were published by J. C. Maxwell in 1861 [10]. He calculated the velocity of electromagnetic waves from the value of an electrodynamic constant c measured by Weber and Kohlrausch in 1857 [11] and noticed that the calculated velocity was very close to the velocity of light measured by Fizeau in 1849 [12]. This observation made him suggest that light is an electromagnetic phenomenon [13].

We emphasize that c in Maxwell's equations is the electrodynamic constant (see Section 5) but not the speed of light in vacuum (see Section 6). It is worth noting that the speed of light in vacuum, commonly denoted as c, is not related to the World in our Model, because there is no Vacuum in It. Instead, there is the Medium of the World consisting of stable elementary particles.

Rydberg constant R_∞ is a physical constant relating to atomic spectra. The constant first arose in 1888 as an empirical fitting parameter in the Rydberg formula for the hydrogen spectral series [14].

Electron Charge-to-Mass Ratio e/m_e is a Quantity in experimental physics. It bears significance because the electron mass m_e cannot be measured directly. The e/m_e ratio of an electron was successfully measured by J. J. Thomson in 1897 [15]. We name it after Thomson: $R_T \equiv e/m_e$.

Planck Constant h was suggested by M. Planck in 1901 as the result of investigating the problem of black-body radiation. He used Boltzmann's equation from Statistical Thermodynamics: $S = k_B \ln W$ that shows the relationship between entropy S and the number of ways the atoms or molecules of a thermodynamic system can be arranged (k_B is the Boltzmann constant) [16].

3. Fundamental Physical Constants

Based on the experimentally measured values of the constants R_∞, R_T, c, h, and the magnetic constant (permeability of free space): $\mu_0 = 4\pi \times 10^{-7}\ \text{H/m}$ we calculate the most important constants as follows:

- Basic size unit *a*:

$$a = 0.5\left[8\left(\mu_0 h/c\right)^3 R_\infty R_T^6\right]^{1/5} = 1.7705641\times10^{-14}\ \text{m}$$

- Dimensionless Rydberg constant *α*:

$$\alpha = \left(2aR_\infty\right)^{1/3}$$

- Electron rest energy E_e:

$$E_e = \alpha hc/a$$

- Elementary charge *e*:

$$e^2 = 2\alpha h/\mu_0 c$$

All these Fundamental constants, including classical electron radius $a_o = a/2\pi$, were measured and could be calculated before Quantum Physics. It is worth noting that the constant α was later named "Sommerfeld's constant" and later "Fine-structure constant".

4. Basic Units

In WUM we introduce the following Basic Units:

- Size *a*;
- Time $t_0 = a/c$;
- Energy $E_0 = hc/a$.

We often use well-known physical parameters, keeping in mind that all of them can be expressed through the Basic Units of time t_0, size *a*, and energy E_0. For example, $c = a/t_0$ and $h = E_0 \times t_0$.

5. Electrodynamic Constant

In 1857, W. Weber and R. Kohlrausch determined that there was a quantity related to electricity and magnetism, "*the ratio of the absolute electrostatic unit of charge to the absolute electromagnetic unit of charge*" (in modern language, the electrodynamic constant *c* with the value of $c = 1/\sqrt{\mu_0 \varepsilon_0}$, where μ_0 is the permeability of free space and ε_0 is the permittivity of free space) and determined that it should have units of velocity. They measured this ratio by an experiment which involved charging and discharging the Leyden jar and measuring the magnetic force from the discharge current and found the value of $c = 3.107\times10^8\ \text{m/s}$ [10] remarkably close to the speed of light, which had recently been measured at $v_{light} = 3.15\times10^8\ \text{m/s}$ by H. Fizeau in 1849 [11] and at $v_{light} = 2.98\times10^8\ \text{m/s}$ by L. Foucault in 1850 [17]. However, Weber and Kohlrausch did not make the connection to the speed of light. In 1861, J. Maxwell established the connection to the speed of light and concluded that light is a form of electromagnetic radiation [9].

6. Speed of Light

The first measurement of the speed of light v_{light} was made by H. Fizeau in

1849: $v_{light} = 315000\ \text{km/s}$ with +5.1% error [18]. The last measurement of v_{light} with rotating mirror was made by A. Michelson in 1926: $v_{light} = 299796 \pm 4\ \text{km/s}$ with +12 ppm error [18].

Another way to find v_{light} is to independently measure the frequency f and wavelength λ of an electromagnetic wave and calculate it using the relation $v_{light} = f\lambda$. One way is to measure the resonance frequency of a cavity resonator. If the dimensions of the resonance cavity are also known, these can be used to find a wavelength of the wave. In 1947, L. Essen obtained the following result: $v_{light} = 299792.5 \pm 1\ \text{km/s}$ with +0.14 ppm error [18].

Interferometry is another method to find a wavelength of the electromagnetic radiation for determining v_{light}. A coherent beam of light (e.g. from a laser), with a known frequency f, is split to follow two paths and then recombined. By adjusting the path length while observing the interference pattern and carefully measuring the change in path length, the wavelength of the light λ can be found. The v_{light} is then calculated using the equation $v_{light} = f\lambda$. In 1972, using the laser interferometer method a group at the US National Bureau of Standards determined the speed of light to be $v_{light} = 299792456.2 \pm 1.1\ \text{m/s}$. This was 100 times less uncertain than the previously accepted value [18].

In 1983, the 17th meeting of the General Conference on Weights and Measures redefined the metre as: "*The metre is the length of the path traveled by light* (*in vacuum?*) *during a time interval of* 1/299,792,458 *of a second*". As a result of this definition, the value of the speed of light (in vacuum?) is exactly 299,792,458 m/s and has become a defined constant in the SI system of units [18].

Let us clarify a notion "Vacuum". A Vacuum is a space devoid of matter. An approximation to such vacuum is a region with a gaseous pressure much less than atmospheric pressure. Physicists often discuss ideal test results that would occur in a perfect vacuum, which they sometimes simply call "vacuum" or free space.

By definition, an *Outer space is the expanse that exists beyond Earth and its atmosphere and between celestial bodies. Outer space is not completely empty—it is a near perfect vacuum containing a low density of particles, predominantly a plasma of hydrogen and helium, as well as electromagnetic radiation, magnetic fields, neutrinos, dust, and cosmic rays. The baseline temperature of outer space is* 2.7255 *kelvins. The plasma between galaxies is thought to account for about half of the baryonic* (*ordinary*) *matter in the universe, having a number density of less than one hydrogen atom per cubic metre* [19].

We absolutely agree with this definition. Moreover in frames of WUM, we calculate the density of the Intergalactic plasma: $n_p = n_e = 0.25480\ \text{m}^{-3}$ and the temperature of the Microwave Background Radiation: $T_{MBR} = 2.72518\ \text{K}$ [20], which are in good agreement with the results above.

The existence of the Intergalactic plasma was proved by the observations of Fast Radio Bursts, which are millisecond duration radio signals originating from distant galaxies. These signals are dispersed according to a precise physical law and this dispersion is a key observable quantity which, in tandem with a redshift measurement, can be used for fundamental physical investigations.

In WUM, the Outer space is the Medium of the World, which is composed of stable elementary particles: protons, electrons, photons, neutrinos, and DMPs. There is no Dark Energy in WUM. The experimental proves are: the Intergalactic plasma (protons, electrons), the Microwave Background Radiation (photons), the Cosmic Neutrino Background (neutrinos), and Mass-to-light ratios of Superclusters which are (300 - 500) times larger than that of Solar ratio (DMPs).

According to Maxwell's equations, electromagnetic waves in any bulk material move at the velocity v_{EM} that is a function of permeability μ_M and permittivity ε_M of the material:

$$v_{EM} = 1\big/\sqrt{\mu_M \varepsilon_M}$$

where $\mu_M = \mu_r \mu_0$ and $\varepsilon_M = \varepsilon_r \varepsilon_0$, and μ_r and ε_r are the relative permeability and permittivity of the material, respectively. Then, the velocity of electromagnetic waves is:

$$v_{EM} = c\big/\sqrt{\mu_r \varepsilon_r}$$

In case of vacuum: $\mu_r = \varepsilon_r = 1$ and $v_{EM} = c$. In case of Outer space $\mu_r > 1$ and $v_{EM} < c$ (see Section 9). It follows that there is no miracle in the maximum value of the velocity v_{EM} that equals to the value of the Electrodynamic constant c! In any bulk material including the Outer space $v_{EM} < c$.

In WUM, there are no speed of light in vacuum and massless photons because there is no vacuum in the World. In reality, there is the Medium of the World with the Intergalactic plasma and the minimum energy of photons passing through the Intergalactic plasma. We emphasize that c is the electrodynamic constant in Maxwell's equations but not a speed of light in vacuum as it is accepted now. Using the relation $v_{light} = f\lambda$ is, in fact, the way to measure the value of the electrodynamic constant [21].

In our opinion, in 1983 the 17th meeting of the General Conference on Weights and Measures redefined not only the metre, but as a result, the value of the electrodynamic constant that has become a defined constant in the SI system of units.

7. Dimensionless Fundamental Parameters

Arthur Eddington was the first physicist to recognize the significance of universal dimensionless constants, now considered among the most critical components of major physical theories.

7.1. Dirac Large Number *Q*

Inter-Connectivity of Primary Physical Parameters. The constancy of the universe fundamental constants, including Newtonian constant of gravitation, is now commonly accepted, although has never been firmly proven as a fact. All conclusions on the constancy of G are model-dependent. A commonly held opinion states that gravity has no established relation to other fundamental forces, so it does not appear possible to calculate it from other constants that can be measured more accurately, as it is done in some other areas of physics. WUM holds that there indeed exist relations between all physical parameters which depend on dimensionless time-varying quantity Q, which is a measure of the Size R and Age A_τ of the World and is, in fact, Dirac Large Number:

$$Q = \frac{R}{a} = \frac{A_\tau}{t_0}$$

In the present Epoch, $Q = 0.759972 \times 10^{40}$ [22].

According to WUM, the following parameters of the World depend on Q [22]:

- Newtonian parameter of gravitation G

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

- Hubble's parameter H

$$H = \frac{c}{a} \times Q^{-1}$$

- Age of the World A_τ

$$A_\tau = \frac{a}{c} \times Q$$

- The Worlds' radius of curvature in the fourth spatial dimension R

$$R = a \times Q$$

- Critical energy density ρ_{cr}

$$\rho_{cr} = 3\frac{hc}{a^4} \times Q^{-1}$$

- Concentration of intergalactic plasma (IGP) n_{IGP}

$$n_{IGP} = \frac{2\pi^2}{a^3} \frac{m_e}{m_p} \times Q^{-1}$$

- Minimum energy of photons E_{ph}

$$E_{ph} = \left(\frac{m_e}{m_p}\right)^{1/2} E_0 \times Q^{-1/2}$$

- Temperature of the Microwave Background Radiation (MBR) T_{MBR}

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

- Temperature of the Far-Infrared Background Radiation (FIRB) peak T_{FIRB}

$$T_{FIRB} = \frac{E_0}{k_B}\left(\frac{15}{4\pi^5}\right)^{1/4} \times Q^{-1/4}$$

- Fermi coupling parameter G_F

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

- Electronic neutrino mass m_{ν_e}

$$m_{\nu_e} = \frac{1}{24} m_0 \times Q^{-1/4}$$

- Muonic neutrino mass m_{ν_μ}

$$m_{\nu_\mu} = m_0 \times Q^{-1/4}$$

- Tauonic neutrino mass m_{ν_τ}

$$m_{\nu_\tau} = 6 m_0 \times Q^{-1/4}$$

where $\hbar$ is Dirac constant: $\hbar = h/2\pi$, $m_0 = h/ac$, m_p is a mass of a proton, m_e is a mass of an electron.

7.2. Dimensionless Rydberg Constant α

The mystery about α is actually a double mystery: The first mystery, the origin of its numerical value $\alpha \approx 1/137$, has been recognized and discussed for decades. The second mystery, the range of its domain, is generally unrecognized.

M. H. MacGregor

In Section 3, we calculate Dimensionless Rydberg Constant α:

$$\alpha = (2aR_\infty)^{1/3}$$

Rydberg constant R_∞ is a physical constant relating to atomic spectra. The constant first arose in 1888 as an empirical fitting parameter in the Rydberg formula for the hydrogen spectral series [14].

In WUM, the following parameters of the World depend on α:

- Rydberg constant R_∞

$$R_\infty = \alpha^3 \times \frac{1}{2a}$$

- Rydberg unit of energy Ry

$$Ry = \alpha^3 \times \frac{E_0}{2}$$

- Electron rest energy E_e

$$E_e = \alpha \times E_0$$

- Elementary charge e

$$e^2 = \alpha \times \frac{2h}{\mu_0 c}$$

WUM postulates that rest energies of Dark Matter Fermions (DMFs) and bosons are proportional to E_0 multiplied by different exponents of α and can be expressed with the following formulae [1]:

DMF1 (fermion)

$$E_{DMF1} = \alpha^{-2} \times E_0$$

DMF2 (fermion)

$$E_{DMF2} = \alpha^{-1} \times E_0$$

DIRAC (boson)

$$E_{DIRAC} = \alpha^{0} \times E_0$$

ELOP (boson)

$$E_{ELOP} = \alpha^{1} \times \frac{2E_0}{3}$$

DMF3 (fermion)

$$E_{DMF3} = \alpha^{2} \times E_0$$

DMF4 (fermion)

$$E_{DMF4} = \alpha^{4} \times E_0$$

According to WUM, a proton energy density in the Medium of the World ρ_p, equals to [22]:

$$\rho_p = \alpha \times \frac{2\pi^2 \rho_{cr}}{3}$$

the total DMF4 relative energy density ρ_{DMF4}, in terms of proton energy density ρ_p, equals to [22]:

$$\rho_{DMF4} = \frac{45}{\pi} \rho_p$$

Our Model holds that the energy density of all types of self-annihilating DMPs is proportional to ρ_p. In all, there are 5 different types of self-annihilating DMPs: DMF1, DMF2, DIRAC, ELOP, and DMF3. Then the total energy density of DM ρ_{DM} is:

$$\rho_{DM} = 5\rho_p$$

The total baryonic energy density ρ_B is:

$$\rho_B = 1.5\rho_p$$

The sum of electron and MBR energy densities ρ_{eMBR} equals to:

$$\rho_{eMBR} = \rho_e + \rho_{MBR} = 1.5\frac{m_e}{m_p}\rho_p + 2\frac{m_e}{m_p}\rho_p = 3.5\frac{m_e}{m_p}\rho_p$$

We take energy density of neutrinos ρ_ν to equal:

$$\rho_\nu = \rho_{MBR} = 2\frac{m_e}{m_p}\rho_p$$

For FIRB radiation energy density ρ_{FIRB} we take

$$\rho_{FIRB} = \frac{1}{5\pi}\frac{m_e}{m_p}\rho_p \approx 0.032\rho_{MBR}$$

which corresponds to the value of $0.034\rho_{MBR}$ calculated by E. L. Wright [23].

Then the energy density of the World ρ_W in Luminous Epoch equals to the theoretical critical energy density ρ_{cr}

$$\rho_W = \left[\frac{45}{\pi} + 6.5 + \left(5.5 + \frac{1}{5\pi}\right)\frac{m_e}{m_p}\right]\rho_p = \rho_{cr}$$

From this equation we can calculate the value of $1/\alpha$ using electron-to-proton mass ratio m_e/m_p:

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

which is in excellent agreement with the commonly adopted value of 137.035999. It follows that there is a direct correlation between constants α and m_e/m_p expressed by the obtained equation. As shown, m_e/m_p is not an independent constant but is instead derived from α [24]:

$$\frac{m_e}{m_p} = \frac{15/\pi\alpha - 450 - 65\pi}{55\pi + 2}$$

Summary:

- The World's energy density is inversely proportional to the dimensionless time-varying parameter Q in all cosmological times;
- The particles relative energy densities are proportional to constant α in Luminous Epoch;
- The α plays a central role in WUM;
- Constant α and quantity Q should be named "Universe Constant" and "World Parameter", respectively.

As a conclusion

There exist a number of competing cosmological models. In our opinion, the most probable model is the one that built on the minimum number of parameters. WUM is based on two parameters only: dimensionless Rydberg constant α and dimensionless quantity *Q*, which increases in time $Q \propto \tau$, and is, in fact, a measure of the Size and Age of the World. In WUM we often use well-known physical parameters, keeping in mind that all of them can be expressed through the Basic Units. Taking the relative values of physical parameters in terms of the Basic Units we can express all dimensionless parameters of the World through two Fundamental Parameters α and Q in various rational exponents, as well as small integer numbers and π.

8. Newtonian Constant of Gravitation

The accuracy of the measured value of Gravitational parameter G has increased only modestly since the original Cavendish experiment. Published values of G have varied rather broadly, and some recent measurements of high precision are, in fact, mutually exclusive. Table 1, borrowed from CODATA Recommended Values of the Fundamental Physical Constants, 2010, summarizes the results of measurements of the Newtonian parameter of gravitation relevant to the 2010 adjustment [5].

Observe that the values of G vary significantly depending on method. The disagreement in the values of G obtained by the various teams far exceeds the standard uncertainties provided with the values. Detailed analysis of the results of measurements of the Newtonian constant of gravitation in **Table 1** shows that there are three groups of measurements. Inside each such group, the measurements are not mutually exclusive; however, measurements outside of a group contradict the entire group. They are [25]:

Table 1. Measurements of Newtonian parameter of gravitation.

Source	Identification[a]	Method	10^{11} G $m^3 \cdot kg^{-1} \cdot s^{-2}$	Rel. stand. uncert u_r
Luther, Towler (1982)	NIST-82	Fiber torsion balance, dynamic mode	6.67248 (43)	6.4×10^{-5}
Karagioz, Izmailov (1996)	TR & D-96	Fiber torsion balance, dynamic mode	6.6729 (5)	7.5×10^{-5}
Bagley, Luther (1997)	LANL-97	Fiber torsion balance, dynamic mode	6.67398 (70)	1.0×10^{-4}
Gundlach, Merkowitz	UWash-00	Fiber torsion balance, dynamic compensation	6.674255 (92)	1.4×10^{-5}
Quinn, *et al.* (2001)	BIPM-01	Strip torsion balance, compensation mode, static deflection	6.67559 (27)	4.0×10^{-5}
Kleinevoß, *et al.* (2002)	UWup-02	Suspended body, displacement	6.67422 (98)	1.5×10^{-4}
Armstrong, Fitzgerald (2003)	MSL-03	Strip torsion balance, compensation mode	6.67387 (27)	4.0×10^{-5}
Hu, *et al.* (2005)	HUST-05	Fiber torsion balance, dynamic mode	6.67228 (87)	1.3×10^{-4}
Schlamminger, *et al.* (2006)	UZur-06	Stationary body, weight change	6.67425 (12)	1.9×10^{-5}
Luo *et al.* (2009); Tu, *et al.*	HUST-09	Fiber torsion balance, dynamic mode	6.67349 (18)	2.7×10^{-5}
Parks and Faller (2010)	JILA-10	Suspended body, displacement	6.67234 (14)	2.1×10^{-5}

[a]NIST: National Institute of Standards and Technology, Gaithersburg, MD, USA; TR&D: Tribotech Research and Development Company, Moscow, Russian Federation; LANL: Los Alamos National Laboratory, Los Alamos, New Mexico, USA; UWash: University of Washington, Seattle, Washington, USA; BIPM: International Bureau of Weights and Measures, S`evres, France; UWup: University of Wuppertal, Wuppertal, Germany; MSL: Measurement Standards Laboratory, Lower Hutt, New Zeland; HUST: Huazhong University of Science and Technology, Wuhan, PRC; UZur: University of Zurich, Zurich, Switzerland; JILA: JILA, University of Colorado and National Institute of Standards and Technology, Boulder, Colorado, USA.

- The first such group consists of six measurements with the average value of $G_1 = 6.67401(19)\times10^{-11}\ \mathrm{m}^3\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-2}\ (28.5\ \mathrm{ppm})$ and relative standard uncertainty 28.5 ppm;
- The second one consists of four measurements with the average value of $G_2 = 6.67250(16)\times10^{-11}\ \mathrm{m}^3\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-2}\ (24\ \mathrm{ppm})$;
- The third one consists of one measurement with the value of $G_3 = 6.67559(27)\times10^{-11}\ \mathrm{m}^3\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-2}\ (40\ \mathrm{ppm})$.

Clearly, the relative uncertainty of any such group is better than the uncertainty of the entire result set: G_1, G_2, and G_3 have relative standard uncertainties that are about 4, 5, and 3 times smaller than the average value of G (2010):

$$G(2010) = 6.67384(80)\times10^{-11}\ \mathrm{m}^3\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-2}\ (120\ \mathrm{ppm})$$

The measurements falling into the three groups are mutually exclusive; it is therefore likely that one group of measurements is correct, and the others are not. The problem is which one?

To resolve the problem T. Quinn, C. Speake, and J. Luo organized the Royal Society meeting titled "The Newtonian constant of gravitation, a constant too difficult to measure?" in London on Feb. 2014 [26].

According to J. Luo:

"*The Newtonian gravitational constant G holds an important place in physics. Though there have been about* 300 *measurements of G since the first laboratory measurement by Cavendish over* 200 *years ago, its measurement precision is the worst among all the fundamental physics constants*."

T. Quinn in the paper "*Outcome of the Royal Society meeting on G held at Chicheley Hall on* 27 *and* 28 *February* 2014 *to discuss 'The Newtonian constant of gravitation, a constant too difficult to measure?*" concluded [27]:

At the end of the meeting, a broad consensus was reached on the following main points

1) *The problem of arriving at a reliable value for G in the face of the wide dispersion of recent results* (*some* 450 *ppm, more than ten times the sigma of the individual results*) *is unlikely to be resolved by one or two additional results obtained, as in the past, by teams working independently.*

2) *There is nevertheless an urgent need to resolve this situation, unprecedented in the determination of one of the fundamental constants of physics. Although at present there is no pressing problem in theoretical physics that requires an accurate value of G, accurate values of the fundamental constants are an essential part of the foundations of physics. In almost all areas of the physical sciences, determinations of fundamental constants are at the frontiers of science. This is so in experimental gravitational physics where one of the characteristics of the work is the need to measure extremely small forces. The science and techniques used in the determination of G are those also used in tests of the equivalence principle, in tests of the inverse square law and in the search for other non-Newtonian forces. Quite apart from the results of such measurements, whether they are null experiments or ones leading to a value of a constant, the*

training of young scientists who participate has always been an important product of high metrology. The wide disagreement among recent measured values of G must cast some doubt on our abilities in this crucial area of small-force measurement and in other areas where similar techniques are used. This is an unsatisfactory situation.

3) *There are a number of key parameters some or all of which have to be measured with the highest accuracy in determinations of G. These include mass, density, length, time, electric current, voltage, capacitance, and angle. In some experiments, there may be others. Measurements of these must be traceable to verified national and international standards with evaluated uncertainties with respect to the SI. The experiments themselves must be conducted in laboratories having the highest quality of temperature and environmental control. All of this strongly points to a national metrology institute, or a laboratory closely associated with a national metrology institute, as being the most appropriate place for future experiments to take place.*

4) *Thus, instead of simply calling for new determinations of G, it is suggested that an international advisory board be created, made up largely of those who have already conducted a G experiment, to advise on the choice of method or methods, on the design of the experiment, on its construction and finally on the interpretation of the data and calculation of the results. This would be in contrast to the present situation in which outside criticism and comments can be brought to bear only when the experiment is finished and published when it is too late to affect the outcome. It is only by proceeding in this way that one might hope to obtain results that are demonstrably reliable.*

In 2014, G Rosi, *et al.* in the article "*Precision measurement of the Newtonian gravitational constant using cold atoms*" describe the following situation with G measurements [28]:

Most previous experiments performed were based on the torsion pendulum or torsion balance scheme as in the experiment by Cavendish in 1798, *and in all cases macroscopic masses were used. Here we report the precise determination of G using laser-cooled atoms and quantum interferometry. We obtain the value* $G = 6.67191(99)\times 10^{-11}\ \mathrm{m}^3\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-2}$ *with a relative uncertainty of* 150 *ppm. Our value differs by* 1.5 *combined standard deviations from the current recommended value of the CODATA. A conceptually different experiment such as ours helps to identify the systematic errors that have proved elusive in previous experiments, thus improving the confidence in the value of G. There is no definitive relationship between G and the other fundamental constants, and there is no theoretical prediction for its value, against which to test experimental results. Improving the precision with which we know G has not only a pure metrological interest but is also important because of the key role that G has in theories of gravitation, cosmology, particle physics and astrophysics and in geophysical models.*

A constancy of the universe fundamental constants, including Newtonian constant of gravitation, Planck Mass, Fermi coupling constant, is now commonly accepted, although has never been firmly established as a fact. All conclusions on the (almost) constancy of the Newtonian parameter of gravitation are model-dependent [1]. A commonly held opinion states that gravity has no established relation to other fundamental forces, so it does not appear possible to calculate it indirectly from other constants that can be measured more accurately, as is done in some other areas of physics. WUM holds that there indeed exist relations between all primary cosmological parameters that depend on dimensionless time-varying quantity Q.

In 2013, WUM proposed a principally different way to solve the problem of G measurement precision based on the inter-connectivity of the Gravitational parameter G and Fermi coupling parameter G_F that can be measured much more accurately than G.

In frames of WUM, a gravitodynamic parameter μ_g equals to:

$$\mu_g = \frac{4\pi G}{c^2} = \frac{1}{R} \times P$$

where P is a dimension-transposing parameter [24]:

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

Considering these equations it is easy to get an expression for the Gravitational parameter G:

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

For the Fermi coupling parameter G_F we have got the following expression [25]:

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

For the three groups of G measurements discussed above, parameter Q will take on the following values, respectively:

$$Q_1 = 0.759981(22) \times 10^{40}$$

$$Q_2 = 0.760153(18) \times 10^{40}$$

$$Q_3 = 0.759801(30) \times 10^{40}$$

The calculated value of the parameter Q_F based on the average value of the Fermi coupling parameter

$$G_F = 1.166364(5) \times 10^{-5}\ \text{GeV}^{-2}\ (4.3\ \text{ppm})$$

is:

$$Q_F = 0.75992106 \times 10^{40}$$

The value of Q_F is much more precise than the values of Q_1, Q_2, Q_3. With this value of Q_F we can make the choice of the first group of G measurements and significantly increase the precision of all Q-dependent parameters (see Section 7.1). The calculated value of G based on the average value of G_F is:

$$G = 6.6745358\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}$$

When these results were obtained, we sent the following letter to every member of the CODATA Task Group on Fundamental Physical Constants and every participant of the Royal Society Meeting [26]:

Recently I published on viXra [1] *a new paper which gives the self-consistent set of Q-dependent, time varying values of the basic parameters of the World: Fermi Coupling parameter, Newtonian parameter of Gravitation, Hubble's parameter, Age of the World, and Temperature of the Microwave Background Radiation. It describes in detail the adjustment of the values of the parameters based on the World-Universe Model. The obtained set of values is recommended for consideration in CODATA Recommended Values of the Fundamental Physical Constants* 2014.

At that time, CODATA stated the following value of G (2010):

$$G(2010) = 6.67384(80)\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}\ (120\ \text{ppm})$$

To the best of our knowledge, no breakthrough in G measurement methodology has been achieved since. Nevertheless, in 2015 CODATA recommended a more precise value of the Newtonian constant of gravitation

$$G(2014) = 6.67408\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}\ (47\ \text{ppm})$$

In 2018 the recommendation improved further:

$$G(2018) = 6.67430\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}\ (22\ \text{ppm})$$

Since 2013, the relative standard uncertainty of G measurements reduced from 120 ppm to 22 ppm! It seems that CODATA considered the WUM's recommendation of the predicted value of G and used it for G (2014) and G (2018) without any reference or explanation of their methodology. In any case, the predicted by WUM in 2013 value of G is in an excellent agreement with its accepted value in 2014 and in 2018.

Considering a more precise value of Fermi Coupling constant in 2014:

$$G_F(2014) = 1.1663787\times10^{-5}\ \text{GeV}^{-2}\ (0.51\ \text{ppm})$$

WUM calculated the predicted value of gravitational constant G^*_{2018} [29]:

$$G^*_{2018} = 6.674536\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}$$

which is x8 more accurate than G^*_{2014}. The predicted value of G^*_{2018} is in excellent agreement with the experimentally measured by Q. Li, *et al.* in 2018 values of G using two independent methods [30]:

$$G(1) = 6.674184\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}\ (11.64\ \text{ppm})$$

$$G(2) = 6.67484\times10^{-11}\ \text{m}^3\cdot\text{kg}^{-1}\cdot\text{s}^{-2}\ (11.61\ \text{ppm})$$

WUM recommend for consideration in CODATA Recommended Values of the Fundamental Physical Constants 2022 the predicted value of the Newtonian Constant of Gravitation G^{*}_{2018}.

9. Self-Consistency of Fundamental Physical Constants

Every four years CODATA supplies a self-consistent set of values of the basic constants and conversion factors of physics recommended for international use.

Table 2 borrowed from CODATA Recommended Values of the Fundamental Physical Constants, 2010, 2014, and 2018 summarizes the results of measurements of Universal, Electromagnetic, and Atomic and Nuclear constants. Observe that the most of Fundamental Physical Constants have more precise values with each adjustment. However, there are a few results that prompt some questions.

Table 2. Summary of the results of measurements of the fundamental physical constants relevant to the 2010, 2014, and 2018 adjustments.

Fundamental Physical Constant	Numerical Value. Relative Standard Uncertainty, 2010	Numerical Value. Relative Standard Uncertainty, 2014	Numerical Value. Relative Standard Uncertainty, 2018
Characteristic Impedance of Vacuum Z_0, Ω	376.730313461 exact	376.730313461 exact	376.730313668 1.5×10^{-10}
Newtonian Constant of Gravitation G, $\times 10^{-11}$ $m^3 \cdot kg^{-1} \cdot s^{-2}$	6.67384 1.2×10^{-4}	6.67408 4.7×10^{-5}	6.67430 2.2×10^{-5}
Planck constant h, $\times 10^{-34}$ $J \cdot Hz^{-1}$	6.62606957 4.4×10^{-8}	6.626070040 1.2×10^{-8}	6.62607015 exact
Speed of Light in Vacuum c, $m \cdot s^{-1}$	299792458 exact	299792458 exact	299792458 exact
Vacuum Electric Permittivity ε_0, $\times 10^{-12}$ $F \cdot m^{-1}$	8.8541878176 exact	8.8541878176 exact	8.8541878128 1.5×10^{-10}
Vacuum Magnetic Permeability μ_0, $\times 10^{-6}$ $N \cdot A^{-2}$	1.25663706144 exact	1.25663706144 exact	1.25663706212 1.5×10^{-10}
Elementary charge C, $\times 10^{-19}$	1.602176565 2.2×10^{-8}	1.6021766208 6.1×10^{-9}	1.602176634 exact
Electron Charge to Mass Quotient $-e/m_e$, $\times 10^{11}$ $C \cdot kg^{-1}$	−1.758820088 2.2×10^{-8}	−1.758820024 6.2×10^{-9}	−1.75882001076 3.0×10^{-10}
Fermi Coupling Constant $G_F/(\hbar c)^3$, $\times 10^{-5}$ $Ge \cdot V^{-2}$	1.166364 4.3×10^{-6}	1.1663787 5.1×10^{-7}	1.1663787 5.1×10^{-7}
Fine-Structure Constant α, $\times 10^{-3}$	7.2973525698 3.2×10^{-10}	7.2973525664 2.3×10^{-10}	7.2973525693 1.5×10^{-10}
Hartree Energy E_h, $\times 10^{-18}$ J	4.35974434 4.4×10^{-8}	4.359744650 1.2×10^{-8}	4.3597447222071 1.9×10^{-12}
Rydberg Constant R_∞, m^{-1}	10973731.568539 5.0×10^{-12}	10973731.568508 5.9×10^{-12}	10973731.568160 1.9×10^{-12}

9.1. Characteristic Impedance of Vacuum, Vacuum Electric Permittivity, Vacuum Magnetic Permeability, Speed of Light in Vacuum

In 2010 and 2014 these constants had exact values that equal to the theoretical values in free space. Whereas, in 2018 Characteristic Impedance of Vacuum Z_V, Vacuum Electric Permittivity ε_V, Vacuum Magnetic Permeability μ_V have different numerical values with $RSU = 1.5 \times 10^{-10}$. Z_V and ε_V were calculated based on the value of μ_V according to the following equations: $Z_V = \mu_V c$ and $\varepsilon_V = \left(\mu_V c_V^2\right)^{-1}$ with the exact value of speed of light in vacuum c_V (see **Table 2**).

Observe that the value of $\mu_V(2018)$ is larger than $\mu_V(2014)$. It means that there is a relative permeability of the Medium of the World μ_r and the magnetic permeability of the Medium μ_M equals to:

$$\mu_M = \mu_r \mu_0$$

The calculated value of μ_r is:

$$\mu_r = 1.00000000054$$

According to WUM, there is a relative electric permittivity of the Medium of the World ε_r and the electric permittivity of the Medium ε_M equals to:

$$\varepsilon_M = \varepsilon_r \varepsilon_0$$

Then, the speed of light in the Medium v_M can be calculated by the following equation:

$$v_M = \left(\mu_M \varepsilon_M\right)^{-1/2} = \left(\mu_r \mu_0 \varepsilon_r \varepsilon_0\right)^{-1/2} = c \big/ \left(\mu_r \varepsilon_r\right)^{1/2} < c$$

We emphasize that $\mu_0 = 4\pi \times 10^{-7}\ \text{H/m}$ is the magnetic constant (permeability of free space) in Maxwell's equations and c is the electrodynamic constant but not the speed of light in vacuum c_V.

In our opinion, the value of the electric permittivity of the Medium ε_M must be experimentally measured but not calculated as it is have done by CODATA for "Vacuum Electric Permittivity" ε_V.

The existence of the Medium of the World is a principal point of WUM. It consists of Intergalactic plasma, Microwave background radiation, Cosmic Far-Infrared background, Dark Matter particles including magnetic dipoles DIRACs and electric dipoles ELOPs. Cosmic Maxwell's equations should consider the macroscopically averaged electric dipole and magnetic dipole moment densities of the Medium in the presence of applied fields [31] as it has be done by H. Harmuth and K. Lukin [32] [33].

Detailed analysis of the measurements of the electrodynamic constant and speed of light, held in [21], shows that using the relation $v_{light} = f\lambda$ is, in fact, the way to measure the value of the electrodynamic constant c. In our view, the exact value of "speed of light in vacuum" (in CODATA) is nothing but the value of the electrodynamic constant.

9.2. Elementary Charge, Rydberg Constant, Hartree Energy, Electron Charge to Mass Quotient, Electron Mass

The relation used by CODATA to find elementary charge is:

$$e^2 = 2\alpha h / \mu_0 c$$

As of 2018, the elementary charge *e*, Planck constant *h*, and "speed of light in vacuum" (electrodynamic constant) *c* have the exact numerical values. The magnetic constant: $\mu_0 = const$. It means that the "Fine-Structure Constant" (Dimensionless Rydberg constant): $\alpha = const$. Following WUM:

$$\alpha^3 = 2aR_\infty = \left(R_\infty R_T\right)\left[8\left(\mu_0 h/c\right)^3\left(R_\infty R_T\right)\right]^{1/5}$$

Consequently, a product of R_∞ and R_T is:

$$\left(R_\infty R_T\right) = const$$

Hartree Energy E_h can be calculated by the following equation:

$$E_h = hcR_\infty$$

Electron mass m_e is:

$$m_e = e/R_T$$

The RSU of the numerical value of the Rydberg constant R_∞ is: $\text{RSU} = 1.9\times10^{-12}$. It means that the RSU of the numerical values of R_T, E_h, m_e must be the same as R_∞. In our view, it is worth accepting the exact values of all Fundamental Constants: Z_0, μ_0, ε_0, *α*, *h*, *c*, *e*, m_e, *a*, R_T, E_h, R_∞. We should concentrate our efforts on the measurements of time-varying Primary Physical Parameters.

10. Conclusion

The detailed analysis of the self-consistency of Fundamental physical constants based on the developed World-Universe Model shows that it is the right time to:

- Discontinue using the notion "Vacuum" and its characteristics;
- Correct the numerical values and relative standard uncertainty of Fundamental Physical Constants;
- Recommend for consideration in CODATA Recommended Values of the Fundamental Physical Constants 2022 the predicted value of the Newtonian Constant of Gravitation G^*_{2018}.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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