World-Universe Model. Self-Consistency of Fundamental Physical Constants

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Abstract

Every four years the Committee on Data for Science and Technology (CODATA) provides 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 makes a detailed analysis of the self-consistency of Fundamental Physical Constants through the prism of WUM. The performed analysis suggests: discontinuing using the notion "Vacuum" and its characteristics (Speed of Light in Vacuum, Characteristic Impedance of Vacuum, Vacuum Magnetic Permeability, Vacuum Electric Permittivity); correcting the numerical value and relative standard uncertainty of Hartree energy; accepting the exact numerical values of Planck constant and Elementary charge. WUM recommends the predicted value of Newtonian Constant of Gravitation (x8 more accurate than the 2018 value) to be considered in CODATA Recommend Values of the Fundamental Physical Constants 2022.

Keywords

"World-Universe Model"; "Fundamental Physical Constants"; "Self-Consistency"; "Medium of World"; "Maxwell's Equations"; "Newtonian Constant of Gravitation"; "Rydberg Constant"; "Hartree Energy"; "Planck Constant"; "Elementary Charge"; "Characteristic Impedance"; "Fermi Coupling Constant"

1. Introduction

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

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

- The cosmic Far-Infrared Background was announced in 1999 [1];
- Microwave Background Radiation temperature was measured in 2009 [2];
- Nine-Year Wilkinson Microwave Anisotropy Probe Observations were published in 2012 [3].

At the same time, the most important for the Cosmology, Newtonian constant of gravitation G, proved too difficult to measure [4]. Its measurement precision was the worst among all Fundamental physical constants.

2. Newtonian Constant of Gravitation

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 [5]. According to Jun 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*".

At that time, CODATA stated the following value of the gravitational constant G:

$$G(2010) = 6.67384 \times 10^{-11} m^3 kg^{-1} s^{-2} \ (120\, ppm)$$

with Relative Standard Uncertainty (RSU): $RSU = 1.2 \times 10^{-4} = 120\, ppm$

Terry 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 [6]:

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 carried out 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 carried out 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.

Subsequently, the National Institute of Standards and Technology (NIST) announced that it would organize "**Newtonian constant of gravitation international consortium**" with a following proposal [7]:

BACKGROUND. *Recent measurements of the Newtonian constant of gravitation G are in disagreement, with discrepancies that are roughly ten times the quoted uncertainties in some cases. This is clearly an unsatisfactory situation for one of the most basic fundamental constants in classical physics. The disagreement calls into question our ability to measure small forces on a laboratory scale. It also raises the question of whether the Newtonian force law is a complete description of gravity at these distances. This issue was recently discussed at a Royal Society scientific meeting entitled The Newtonian constant of gravitation, a constant too difficult to measure? [6]. The conclusions of that meeting are included as the appendix to this proposal. Given the history of discrepancies, it is unlikely that one or two more experiments will resolve the situation even if they are done with the oversight of an advisory committee. Instead possible sources of bias, not previously tested for, should be checked. In addition, there needs to be redundancy and tests for reproducibility order to determine a reliable value for G. This proposal describes an approach to arrive at such a value.*

METHOD. *As an effort to resolve this situation, a consortium will be formed consisting of capable individuals and institutions willing to collaborate on a large-scale project to determine a reliable* *value for G. Participants would either produce the necessary apparatus and make measurements of G, or they would use an apparatus made at another institution and repeat the measurements. In some cases, participants that produce an apparatus might also make measurements with a different apparatus produced at another institution. It is expected that different institutions will produce different types of apparatus to implement independent experimental approaches. In contrast to previous projects, it is proposed that two identical copies of each type of apparatus be produced and used to make the measurements. Work will continue until consistency is achieved between the two devices by the institution that produced them. Then, each of the two devices will be taken apart and loaned to two other members of the consortium who will repeat the measurements using their own procedures and data analysis. Basic instructions for putting the device back together will be provided, but to avoid bias, operating procedures and data analysis will be done independently. Details of how the apparatus will be distributed will depend on the number of members in the consortium and their availability to make the measurements. When the experiments are completed, the results will be compared. If they agree, then a valid value for G will have been obtained. If not, then there will be multiple results that could uncover a pattern for the disagreements to guide the search for possibly overlooked systematic effects. 1 This approach will test for possible systematic bias associated with the location of the measurement, the design of the apparatus, and the personnel carrying out the measurement, which have not previously been fully tested.*

PARTICIPANTS NIST *will consider being one of the institutions where two copies of an apparatus will be produced, and new measurements of G will be carried out. Simultaneously with NIST, other institutions might each make two copies of an apparatus based on a different design and carry out the proposed measurement and redistribution procedure. Participants could also collaborate by repeating measurements with either of the two copies already made at one of the primary institutions. Another role for participants who are experienced in doing such experiments would be as members of an international advisory board to act as consultants for the groups making the measurements.*

JOINING THE CONSORTIUM. *People considering participating in this project are invited to apply for a collaborative partnership. A statement of possible interest and intended level of participation may be sent to bigg@nist.gov.*

WORKSHOP. *To refine the plan for the project and exchange ideas for experiments, a workshop will be held at NIST on 9-10 October 2014.*

The NIST workshop was focused on determining a path forward and whether a consortium could provide a useful means to resolve the discrepancy in measurements of the value of the Newtonian constant of gravitation G . The workshop had 13 invited talks including the following:

Harold V. Parks and James E. Faller presented an account of their experiment to measure G with a suspended laser interferometer and obtained the value of [8]:

$$G = (6.67234 \pm 0.00014) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

Riley Newman, Michael Bantel, Eric Berg, and William Cross measured G with a cryogenic torsion pendulum operating below 4 K in a dynamic mode in which G is determined from the change in torsional period when a field source mass is moved between two orientations. The measurement was made using an as-drawn CuBe torsion fibre, a heat-treated CuBe fibre, and an as-drawn Al5056 fibre. The unweighted average of three G-values, with the unweighted average of their uncertainties, is [9]:

$$G = 6.67433(13) \times 10^{-11} m^3 kg^{-1} s^{-2} (19\, ppm)$$

S. Schlamminger, R. E. Pixley, F. Nolting, J. Schurr, and U. Straumann reported a final result of a measurement of G obtained after an experimental effort that lasted over one decade [10]:

$$G = 6.674252(122) \times 10^{-11} m^3 kg^{-1} s^{-2}$$

Terry Quinn, Clive Speake, Harold Parks, and Richard Davis reported the BIPM measurements of G performed in 2001 and 2013. While their review contains no new results, it includes more detailed descriptions of certain key parameters that enter into the determination of G [11]:

$$G = 6.67554(16) \times 10^{-11} m^3 kg^{-1} s^{-2}\ (25\, ppm)$$

The result of NIST workshop is as follows [12]:

NIST held a workshop on the Newtonian Constant of gravitation, G, on October 9-10, 2014 as a follow up to February 2014 Royal Society meeting in London. The NIST workshop was focused on determining a path forward and whether a consortium could provide a useful means to resolve the discrepancy. This document provide a brief summary of the conclusions of the workshop. The workshop had 53 registered participants with 25 from outside of NIST. It included 13 invited talks, a panel discussion, and a summary discussion. Several of the talks were focused on new methods of measuring G, whereas the discussions and panel session were about how to address the situation of conflicting measurements of G. The participants unanimously recommended that the community needed to respond to this situation. In was strongly felt that the primary value of the effort focused on G was more about resolving a discrepancy in science than the value itself. Given the news coverage and press around G it is clear that the public is interested, and since some of the future realizations of mass – i.e. the Watt Balance – depend on large mechanical instruments, there is value in understanding what has gone wrong with previous measurements of G. Due to both the difficulty of getting funding and to provide a scientific venue for discussions and advice during a measurement campaign, it was recommended that one or more organizations1 act as a convening body for annual or biannual meetings focused on this specific topic and campaign. There was also strong consensus that in moving forward new measurements of G by new teams with existing apparatus that have led to some of the outliers would be very valuable in helping to resolve the discrepancy. Two such apparatus were offered pending discussions between the owners and the potential new teams. There was also strong consensus that additional new approaches would be very important in helping to resolve the discrepancy and several such approaches, including atom interferometers, were discussed at the meeting. 1 Both the International Committee on Weights and Measures (CIPM) and a working group of the International Union of Pure and Applied Physics (IUPAP) were discussed as possible convening bodies and both provide clear benefits to the broader community. The former for the National Measurement Institutes in particular and the latter to the broader physics community. The issue of a consortium had moderate support and was viewed as a means of providing some approaches with access to both expertise and independent measurements, traceability, or reduced uncertainty for key measurements. An additional benefit is that a consortium could provide National Measurement Institutes (NMIs) with a means of contributing support services such as precision length metrology to a local or regional participant. Finally, in the case of an apparatus that can be easily relocated or moved, the consortium could provide an independent measurement by additional *teams. This would lower overall cost of participation and provide additional means of looking for systematics. This concept, in part, was the basis for suggesting that new measurements be made with each existing apparatus that produced values of G that appear to be outliers. The most controversial discussion was around the value of blind measurements. While some people were for completely blind measurements, others supported limited blindness to help in more efficiently searching for systematics. No final decision or recommendation was made on this topic, and it will probably be left to the individual teams or consortia to determine how best to proceed. In summary the community believes that a convening body can contribute to creating a close community that can support those wishing to help resolve this discrepancy, and that in some situations teaming or a consortium can further enhance the likelihood of success in what is seen as a very difficult measurement, but one that is important scientifically to resolve. G remains one of the oldest of the fundamental constants that has such low precision. Follow up actions Since the workshop, the proposal for a Working Group of the IUPAP, to function as an advisory body for work on the Newtonian constant G, was approved at the IUPAP General Assembly in Singapore on Friday November 7, 2014. A proposal has been submitted to the CIPM to approve of an advisory committee and endorse further work on experiments to determine Big G.*

In 2014, **G. Rosi, F. Sorrentino, L. Cacciapuoti, M. Prevedelli, and G. M. Tino** reported the precise determination of G using laser-cooled atoms and quantum interferometry and obtained the value [13]:

$$G = 6.67191(99) \times 10^{-11} m^3 kg^{-1} s^{-2}\ (150\ ppm)$$

Clearly, the described measurements falling into three groups that are mutually exclusive as it was in 2010 [14]. It is therefore likely that one group of measurements is correct, and the others are not. No breakthrough in G measurement methodology has been achieved in 2014. Nevertheless, in 2015 CODATA recommended more precise value of the Newtonian Constant of Gravitation [15]:

$$G(2014) = 6.67401 \times 10^{-11} m^3 kg^{-1} s^{-2}\ (47\ ppm)$$

These value is based on a least-squares adjustment that takes into account all data available up to 31 December 2014. In 2018 the recommendation improved further:

$$G(2018) = 6.67430 \times 10^{-11} m^3 kg^{-1} s^{-2}\ (22\ ppm)$$

Since 2013, the relative standard uncertainty of G measurements reduced x6. It seems that CODATA considered the WUM recommendation of the predicted value of G and used it for G(2014) without any reference or explanation of their methodology (see Section 3).

3. Predicted by WUM Value of Newtonian Constant of Gravitation

In 2013, WUM proposed a principally different way to solve the problem of G measurement precision and made some predictions of values of Primary Cosmological Parameters (PCPs). WUM revealed a self-consistent set of time-varying values of PCPs: Gravitation parameter, Hubble's parameter, Age of the World, Temperature of the Microwave Background Radiation, the concentration of Intergalactic plasma, and the minimum energy of photons that can pass through the Intergalactic plasma [14], [16].

Based on the inter-connectivity of these parameters, WUM solved the Missing Baryon problem and predicted the values of PCPs, which were experimentally confirmed in 2015 – 2018. The set of values obtained by WUM was recommended for consideration in CODATA Recommended Values of the Fundamental Physical Constants 2014 [17].

According to WUM, the predicted value of the gravitational constant G^*_{2014} equals to :

$$G^*_{2014} = 6.67420 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

This value is in good agreement with the experimentally measured values by Riley Newman, *et al.* [9] and by S. Schlamminger, *et al.* [10].

Considering a more precise value of Fermi Coupling constant in 2014 (see **Table 1**) we calculate the predicted value of gravitational constant G^*_{2018} [17]:

$$G^*_{2018} = 6.674536 \times 10^{-11} m^3 kg^{-1} s^{-2}$$

which is x8 more accurate than G^*_{2014}. The predicted value G^*_{2018} is in excellent agreement with the experimentally measured by Qing Li, *et al.* in 2018 values of G using two independent methods [18]:

$$G(1) = 6.674184 \times 10^{-11} m^3 kg^{-1} s^{-2}\ (11.64\, ppm)$$

$$G(2) = 6.67484 \times 10^{-11} m^3 kg^{-1} s^{-2}\ (11.61\, ppm)$$

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}.

4. Self-Consistency of Fundamental Physical Constants

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

Table 1, 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.

4.1. 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 vacuum with the value of the electrodynamic constant c equals to the exact value of speed of light in vacuum. Whereas, in 2018 these constants have different numerical values with $RSU = 1.5 \times 10^{-10}$. By definition, constants Z_0 and ε_0 were calculated based on the value of μ_0 according to the following equations: $Z_0 = \mu_0 c$ and $\varepsilon_0 = (\mu_0 c^2)^{-1}$ with the exact value of speed of light in vacuum c.

Table 1. 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	376.730 313 461 exact	376.730 313 461 exact	376.730 313 668 1.5×10^{-10}
Newtonian Constant of Gravitation G, $\times 10^{-11}\ m^3 kg^{-1} s^{-2}$	6.673 84 1.2×10^{-4}	6.674 08 4.7×10^{-5}	6.674 30 2.2×10^{-5}
Planck constant h , $\times 10^{-34}\ J\ Hz^{-1}$	6.626 069 57 4.4×10^{-8}	6.626 070 040 1.2×10^{-8}	6.626 070 15 exact
Speed of Light in Vacuum $c, m\ s^{-1}$	299 792 458 exact	299 792 458 exact	299 792 458 exact
Vacuum Electric Permittivity ε_0 , $\times 10^{-12}\ F\ m^{-1}$	8.854 187 8176 exact	8.854 187 8176 exact	8.854 187 8128 1.5×10^{-10}
Vacuum Magnetic Permeability μ_0 , $\times 10^{-6}\ N\ A^{-2}$	1.256 637 061 44 exact	1.256 637 061 44 exact	1.256 637 062 12 1.5×10^{-10}
Elementary charge C, $\times 10^{-19}$	1.602 176 565 2.2×10^{-8}	1.602 176 6208 6.1×10^{-9}	1.602 176 634 exact
Electron Charge to Mass Quotient $-e/m_e$, $\times 10^{11}\ C\ kg^{-1}$	−1.758 820 088 2.2×10^{-8}	−1.758 820 024 6.2×10^{-9}	−1.758 820 01076 3.0×10^{-10}
Fermi Coupling Constant $G_F/(\hbar c)^3$, $\times 10^{-5}\ GeV^{-2}$	1.166 364 4.3×10^{-6}	1.166 3787 5.1×10^{-7}	1.166 3787 5.1×10^{-7}
Fine-Structure Constant α , $\times 10^{-3}$	7.297 352 5698 3.2×10^{-10}	7.297 352 5664 2.3×10^{-10}	7.297 352 5693 1.5×10^{-10}
Hartree Energy E_h , $\times 10^{-18}\ J$	4.359 744 34 4.4×10^{-8}	4.359 744 650 1.2×10^{-8}	4.359 744 722 2071 1.9×10^{-12}
Rydberg Constant R_∞ , m^{-1}	10 973 731.568 539 5.0×10^{-12}	10 973 731.568 508 5.9×10^{-12}	10 973 731.568 160 1.9×10^{-12}

Observe that the value of $\mu_0(2018)$ is larger than $\mu_0(2014)$. 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 electrodynamic constant of the Medium c_M can be calculated by the following equation:

$$c_M = (\mu_M \varepsilon_M)^{-1/2} = (\mu_r \mu_0 \varepsilon_r \varepsilon_0)^{-1/2}$$

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 dipole DIRAC and electric dipole ELOP. 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 [19].

4.2. Rydberg Constant, Hartree Energy, Planck Constant

As of 2018, Rydberg Constant R_∞ is the most accurately measured Fundamental physical constant. Hartree Energy E_h can be calculated by the following equation:

$$E_h = hcR_\infty$$

The RSU of its numerical value depends on the RSU of the numerical value of Planck constant h and RSU of the electrodynamic constant c . CODATA supposed that c is the speed of light in vacuum with the exact numerical value. Considering the exact numerical value of Planck constant, CODATA gave the RSU of E_h : $RSU = 1.9 \times 10^{-12}$ that equals to the RSU of R_∞ .

In our view, it is not correct because the electrodynamic constant c discussed in Section 4.1. has an RSU $\sim 10^{-10}$ and consequently, E_h should have the RSU $\sim 10^{-10}$.

4.3. Elementary Charge, Characteristic Impedance of Vacuum

The relation used by CODATA to determine elementary charge is:

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

As of 2018, the Elementary charge e, Planck constant h, and speed of light in vacuum c have the exact numerical values. It means that the ratio α/μ_0 must be a constant. No explanation for this calculation is provided.

In our view, we should use the following relation:

$$Z_0 = \frac{2h}{e^2}\alpha$$

The RSU of the numerical value of α is: $RSU = 1.5 \times 10^{-10}$. It means that the RSU of the numerical value of Z_0 must be the same. Z_0 cannot have the exact value as it was supposed in 2010 and 2014.

5. 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:

    - Speed of Light in Vacuum;
    - Characteristic Impedance of Vacuum;
    - Vacuum Magnetic Permeability;
    - Vacuum Electric Permittivity;

- correct the numerical value and relative standard uncertainty of Hartree energy;
- accept the exact numerical values of Planck constant and Elementary charge;
- 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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