FUNDAMENTAL PARAMETER Q

RECOMMENDED VALUES OF THE NEWTONIAN PARAMETER OF GRAVITATION, HUBBLE'S PARAMETER, AGE OF THE WORLD, AND TEMPERATURE OF THE MICROWAVE BACKGROUND RADIATION

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This paper 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.

Keywords: World – Universe Model, Fundamental Parameter Q , Fermi Coupling Parameter, Gravitational Parameter, Hubble's Parameter, Temperature of Microwave Background Radiation, Size of the World, Age of the World, CODATA.

The constancy of the universe fundamental constants, including Fermi coupling constant G_F , Newtonian constant of gravitation G , Planck mass M_P , Planck length L_P , is now commonly accepted, although has never been firmly established as a fact. All conclusions on the constancy of G are model-dependent [1].

In our opinion, it is impossible to either prove or disprove the constancy of G . Consequently, variability of G with time can legitimately be explored. Alternative cosmological models describing the Universe with time varying G are widely discussed in literature (see e.g. [1] and references therein).

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* [Wikipedia, Gravitational constant].

The World – Universe Model holds that there indeed exist relations between all Q-dependent, time varying parameters: G_F , G , M_P , L_P , H_0 (Hubble's parameter), R (Size of the World), A_t (Age of the World), ρ_{cr} (Critical energy density of the World), T_{MBR} (Temperature of the microwave background radiation), m_a (Axion mass), m_ν (Neutrino mass), etc. [1].

In accordance with the World – Universe Model, the basic parameters of the World can be expressed as follows:

- Fermi coupling parameter G_F

$$\frac{G_F}{(\hbar c)^3} = \mathcal{K} \times \frac{m_p}{m_e}\frac{1}{E_0^2} \times Q^{-\frac{1}{4}} \tag{1}$$

where $\hbar$ is Dirac constant, c is the electrodynamic constant, m_p is the mass of a proton, m_e is the mass of an electron, $\mathcal{K}\sim 1$ is a coefficient (its exact value is discussed below), and basic energy unit E_0 equals to

$$E_0 = \frac{hc}{a} = 1.1219288 \times 10^{-11}\, J = 0.070025267\ GeV \tag{2}$$

where $h = 2\pi\hbar$ is Planck constant, a_0 is the classical radius of an electron , and $a = 2\pi a_0$;

- Newtonian parameter of gravitation G

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

- Hubble's parameter H_0

$$H_0 = \frac{c}{a} \times Q^{-1} \tag{4}$$

- Age of the World A_t

$$A_t = \frac{a}{c} \times Q \tag{5}$$

- Size of the World R

$$R = a \times Q \tag{6}$$

- Temperature of the microwave background radiation T_{MBR}

$$T_{MBR} = \frac{E_0}{k_B}\left(\frac{15\alpha}{2\pi^3}\frac{m_e}{m_p}\right)^{\frac{1}{4}} \times Q^{-\frac{1}{4}} \tag{7}$$

where k_B is Boltzmann constant and α is the fine-structure constant.

In this work, we are going to:

- Find the value of the fundamental parameter Q based on CODATA's value of Newtonian parameter of gravitation G ;

- Based on Q, predict the values of the temperature of the microwave background radiation T_{MBR}, Hubble's parameter H_0, and Age of the World A_t with much higher precision than currently recommended values.

Wikipedia has this to say about G [Gravitational constant]:

The accuracy of the measured value of G has increased only modestly since the original Cavendish experiment. G is quite difficult to measure, as gravity is much weaker than other fundamental forces, and an experimental apparatus cannot be separated from the gravitational influence of other bodies. 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 constant of gravitation relevant to the 2010 adjustment [2]:

Table 1

Source	Identification[a]	Method	10^{11} G $\mathrm{m^3\,kg^{-1}\,s^{-2}}$	Rel. stand. uncert u_r
Luther and Towler (1982)	NIST-82	Fiber torsion balance, dynamic mode	6.672 48(43)	6.4×10^{-5}
Karagioz and Izmailov (1996)	TR&D-96	Fiber torsion balance, dynamic mode	6.672 9(5)	7.5×10^{-5}
Bagley and Luther (1997)	LANL-97	Fiber torsion balance, dynamic mode	6.673 98(70)	1.0×10^{-4}
Gundlach and Merkowitz (2000, 2002)	UWash-00	Fiber torsion balance, dynamic compensation	6.674 255(92)	1.4×10^{-5}
Quinn et al. (2001)	BIPM-01	Strip torsion balance, compensation mode, static deflection	6.675 59(27)	4.0×10^{-5}
Kleinevoß (2002); Kleinvoß et al. (2002)	UWup-02	Suspended body, displacement	6.674 22(98)	1.5×10^{-4}
Armstrong and Fitzgerald (2003)	MSL-03	Strip torsion balance, compensation mode	6.673 87(27)	4.0×10^{-5}
Hu et al. (2005)	HUST-05	Fiber torsion balance, dynamic mode	6.672 28(87)	1.3×10^{-4}
Schlamminger et al. (2006)	UZur-06	Stationary body, weight change	6.674 25(12)	1.9×10^{-5}
Luo et al. (2009); Tu et al. (2010)	HUST-09	Fiber torsion balance, dynamic mode	6.673 49(18)	2.7×10^{-5}
Parks and Faller (2010)	JILA-10	Suspended body, displacement	6.672 34(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.

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.

Table 2 summarizes the recommended values of the Q-dependent parameters under consideration:

Table 2

Quantity	**Symbol**	**Numerical value**	**Unit**	**Relative std. uncert., ppm**
Fermi coupling parameter	$\frac{G_F}{(\hbar c)^3}$	1.166364(5) x 10^{-5}	GeV^{-2}	4.3
Newtonian parameter of gravitation 2010	G	6.67384(80) x 10^{-11}	$m^3\ kg^{-1}\ s^{-2}$	120
Temperature of microwave background radiation	T_{MBR}	2.72548(57)	K	210
Hubble's parameter WMAP (9-years)	H_0	69.32(80)	km s^{-1} Mpc^{-1}	11540
Age of the World	A_t	13.798(37)	Byr	2680

where ppm is one part per million.

In accordance with equation (3), the calculated value of the parameter Q based on the average value of the gravitational parameter G from Table 2 is

$$Q = 0.760000(91) \times 10^{40} \tag{8}$$

From equation (1), we calculate the value of $\mathcal{K}$ based on the average value of the Fermi coupling parameter G_F from Table 2:

$$\mathcal{K} = 0.2908293(87) \tag{9}$$

Based on the value of Q calculated in (8), we obtain the value of the temperature of the microwave background radiation:

$$T_{MBR} = 2.725181(82)\ K \quad (10)$$

the value of the Hubble's parameter is

$$H_0 = 2.22790(27) \times 10^{-18}\ s^{-1} = 68.7457(83)\ \frac{km/s}{Mpc} \quad (11)$$

the age of the World is

$$A_t = 4.48854(54) \times 10^{17}\ s = 14.2233(17)\ Byr \quad (12)$$

and the size of the World is

$$R = 1.34563(16) \times 10^{26}\ m \quad (13)$$

The values of the discussed parameters recommended for consideration in CODATA Recommended Values of the Fundamental Physical Constants, 2014 are presented in Table 3:

Table 3

Quantity	**Symbol**	**Numerical value**	**Unit**	**Relative std. uncert., ppm**
Fundamental parameter Q	Q	0.760000(91) x 10^{40}		120
Fermi coupling parameter	$\frac{G_F}{(\hbar c)^3}$	1.166364(5) x 10^{-5}	GeV^{-2}	4.3
Newtonian parameter of gravitation 2010	G	6.67384(80) x 10^{-11}	$m^3\ kg^{-1}\ s^{-2}$	120
Temperature of microwave background radiation	T_{MBR}	2.725181(82)	K	30
Hubble's parameter	H_0	68.7457(83)	km s^{-1} Mpc^{-1}	120
Age of the World	A_t	14.2233(17)	Byr	120

As the result of the adjustment of the values of the parameters based on the World – Universe Model, we obtained a set of values with significantly higher accuracy for Hubble's parameter H_0, Age of the World A_t, and Temperature of the Microwave Background Radiation T_{MBR}. The relationships between the fundamental parameters discussed in [1] allow us to calculate all of them based on the value of any two parameters known with the highest precision. At the moment, these are G and G_F with substantiated value of parameter $\mathcal{K}$ (see below).

Further improvements in precision of G will allow us to further increase the precision of H_0, A_t, and T_{MBR}.

One could, however, increase the precision of G itself based on other parameters. Recently, the precision of T_{MBR} seems to be improving the fastest. Once T_{MBR} is measured with relative standard uncertainty that is lower than 30 ppm, precision of G, H_0 and A_t will all improve.

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.

- The first such group consists of six measurements with the average value of

$$G_1 = 6.67401(19) \times 10^{-11}\, m^3 kg^{-1} s^{-2} \tag{14}$$

  and relative standard uncertainty 28.5 ppm;
- The second one consists of four measurements with the average value of

$$G_2 = 6.67250(16) \times 10^{-11}\, m^3 kg^{-1} s^{-2} \tag{15}$$

  and relative standard uncertainty 24 ppm;
- The third one consists of one measurement with the value of

$$G_3 = 6.67559(27) \times 10^{-11}\, m^3 kg^{-1} s^{-2} \tag{16}$$

  and relative standard uncertainty 40 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 (see Table 2) respectively.

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. With the help of World – Universe Model, more precise measurement of T_{MBR} can help us narrow down the correct group of G measurements.

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

$$Q_1 = 0.759981(22) \times 10^{40} \tag{17}$$

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

$$Q_3 = 0.759801(30) \times 10^{40} \tag{19}$$

Let's find the values of all discussed parameters based on the value of the T_{MBR} :

$$Q = \frac{15\alpha}{2\pi^3}\frac{m_e}{m_p}\left(\frac{E_0}{k_B T_{MBR}}\right)^4 = 0.760203 \times \left(\frac{2.725}{T_{MBR}}\right)^4 \times 10^{40} \tag{20}$$

$$G = \frac{a^2 c^4}{8\pi hc}\left(\frac{15\alpha}{2\pi^3}\frac{m_e}{m_p}\right)^{-1} \times \left(\frac{k_B T_{MBR}}{E_0}\right)^4 =$$

$$= 6.67206 \times \left(\frac{T_{MBR}}{2.725}\right)^4 \times 10^{-11}\ m^3 kg^{-1} s^{-2} \tag{21}$$

$$\mathcal{K} = \frac{G_F E_0^2}{(\hbar c)^3}\frac{m_e}{m_p}\frac{E_0}{k_B T_{MBR}}\left(\frac{15\alpha}{2\pi^3}\frac{m_e}{m_p}\right)^{\frac{1}{4}} = 0.290849 \times \left(\frac{2.725}{T_{MBR}}\right) \tag{22}$$

where 2.725 is the reference temperature of the microwave background radiation in K°.

The values of T_{MBR} corresponding to the values of G_1, G_2, and G_3 (14) (15) (16) are:

$$T_1 = 2.725199\ K \tag{23}$$

$$T_2 = 2.725045\ K \tag{24}$$

$$T_3 = 2.725360\ K \tag{25}$$

The right group of the measurements of G can be selected once the relative standard uncertainty of the measurement of T_{MBR} becomes significantly better than 30 ppm.

In accordance with the World – Universe Model [1] we can choose the following value for the parameter $\mathcal{K}$:

$$\mathcal{K} = \left(1800\alpha\frac{m_e}{m_p}\right)^{\frac{1}{4}} = \sqrt{30}\left(2\alpha\frac{m_e}{m_p}\right)^{\frac{1}{4}} = 0.29082535 \tag{26}$$

and rewrite equation (1) as

$$\frac{G_F}{(\hbar c)^3} = \sqrt{30}\left(2\alpha\frac{m_e}{m_p}\right)^{\frac{1}{4}}\frac{m_p}{m_e}\frac{1}{E_0^2} \times Q^{-\frac{1}{4}} \tag{27}$$

We now calculate the value of Q_F based on the average value of the Fermi coupling parameter G_F from Table 2:

$$Q_F = 0.759960(13) \times 10^{40} \tag{28}$$

The difference between Q_1 and Q_F equals to 21×10^{-6} which is smaller than the standard uncertainty of Q_1, and the relative standard uncertainty of Q_F equals to 17 ppm that is about 1.7 times smaller than the relative standard uncertainty of Q_1.

With this value of $\mathcal{K}$ we can make the choice of the first group of G measurements and significantly increase the precision of all Q-dependent parameters.

The value of G in this case equals to

$$G = 6.67420(11) \times 10^{-11}\ m^3 kg^{-1} s^{-2} \tag{29}$$

Compare to the CODATA recommended value of G published in 2010:

$$G = 6.67384(80) \times 10^{-11}\ m^3 kg^{-1} s^{-2} \tag{30}$$

The value of the temperature of the microwave background radiation is:

$$T_{MBR} = 2.725218(12)\ K \tag{31}$$

the value of the Hubble's parameter is:

$$H_0 = 2.228017(38) \times 10^{-18}\ s^{-1} = 68.7494(12)\ \frac{km/s}{Mpc} \tag{32}$$

the age of the World is:

$$A_t = 4.488296(77) \times 10^{17}\ s = 14.22255(24)\ Byr \tag{33}$$

and the size of the World is:

$$R = 1.345557(23) \times 10^{26}\ m \tag{34}$$

To summarize: parameters G_F, G, H_0, A_t and T_{MBR} are all inter-connected. Today, we can substantially increase the precision of H_0, A_t and T_{MBR} based on G. Looking forward, better precision in measurement of any parameter may potentially increase the precision of all others.

Acknowledgements:

I'm grateful to my son Ilya who has reviewed and edited this work.

References

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