**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), \( \rho_{cr} \) (Critical energy density of the World), \( T_{MBR} \) (Temperature of the microwave background radiation), \( m_a \) (Axion mass), \( m_\nu \) (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 \( G_F \)

\[
\frac{G_F}{(hc)^3} = \mathcal{K} \times \frac{m_p}{m_e E_0^2} \times Q^{-\frac{1}{4}} \tag{1}
\]

where \( h \) 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 \( G \)

\[
G = \frac{a^2 c^4}{8\pi \hbar c} \times Q^{-1} \tag{3}
\]

- 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 \( T_{MBR} \)

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

where \( k_B \) is Boltzmann constant and \( \alpha \) 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**

<table>
<thead>
<tr>
<th>Source</th>
<th>Identification</th>
<th>Method</th>
<th>$10^{11} G$</th>
<th>Rel. stand. uncert.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luther and Towler (1982)</td>
<td>NIST-82</td>
<td>Fiber torsion balance, dynamic mode</td>
<td>6.672 48(43)</td>
<td>$6.4 \times 10^{-5}$</td>
</tr>
<tr>
<td>Karagioz and Izmailov (1996)</td>
<td>TR&amp;D-96</td>
<td>Fiber torsion balance, dynamic mode</td>
<td>6.672 9(5)</td>
<td>$7.5 \times 10^{-5}$</td>
</tr>
<tr>
<td>Bagley and Luther (1997)</td>
<td>LANL-97</td>
<td>Fiber torsion balance, dynamic mode</td>
<td>6.673 98(70)</td>
<td>$1.0 \times 10^{-4}$</td>
</tr>
<tr>
<td>Gundlach and Merkowitz (2000, 2002)</td>
<td>UWash-00</td>
<td>Fiber torsion balance, dynamic compensation</td>
<td>6.674 255(92)</td>
<td>$1.4 \times 10^{-5}$</td>
</tr>
<tr>
<td>Quinn et al. (2001)</td>
<td>BIPM-01</td>
<td>Strip torsion balance, compensation mode, static deflection</td>
<td>6.675 59(27)</td>
<td>$4.0 \times 10^{-5}$</td>
</tr>
<tr>
<td>Kleinevoß (2002); Kleinevoß et al. (2002)</td>
<td>UWup-02</td>
<td>Suspended body, displacement</td>
<td>6.674 22(98)</td>
<td>$1.5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Armstrong and Fitzgerald (2003)</td>
<td>MSL-03</td>
<td>Strip torsion balance, compensation mode</td>
<td>6.673 87(27)</td>
<td>$4.0 \times 10^{-5}$</td>
</tr>
<tr>
<td>Hu et al. (2005)</td>
<td>HUST-05</td>
<td>Fiber torsion balance, dynamic mode</td>
<td>6.672 28(87)</td>
<td>$1.3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Schlamminger et al. (2006)</td>
<td>UZur-06</td>
<td>Stationary body, weight change</td>
<td>6.674 25(12)</td>
<td>$1.9 \times 10^{-5}$</td>
</tr>
<tr>
<td>Luo et al. (2009); Tu et al. (2010)</td>
<td>HUST-09</td>
<td>Fiber torsion balance, dynamic mode</td>
<td>6.673 49(18)</td>
<td>$2.7 \times 10^{-5}$</td>
</tr>
<tr>
<td>Parks and Faller (2010)</td>
<td>JILA-10</td>
<td>Suspended body, displacement</td>
<td>6.672 34(14)</td>
<td>$2.1 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

*aNIST: 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, Sèvres, France; UWup: University of Wuppertal, Wuppertal, Germany; MSL: Measurement Standards Laboratory, Lower Hutt, New Zealand; 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>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Numerical value</th>
<th>Unit</th>
<th>Relative std. uncert., ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermi coupling parameter</td>
<td>$\frac{G_F}{(hc)^3}$</td>
<td>1.166364(5) $\times 10^5$</td>
<td>GeV$^{-2}$</td>
<td>4.3</td>
</tr>
<tr>
<td>Newtonian parameter of gravitation 2010</td>
<td>$G$</td>
<td>6.67384(80) $\times 10^{11}$</td>
<td>m$^3$ kg$^{-1}$ s$^{-2}$</td>
<td>120</td>
</tr>
<tr>
<td>Temperature of microwave background radiation</td>
<td>$T_{MBR}$</td>
<td>2.72548(57)</td>
<td>K</td>
<td>210</td>
</tr>
<tr>
<td>Hubble’s parameter WMAP (9-years)</td>
<td>$H_0$</td>
<td>69.32(80)</td>
<td>km s$^{-1}$ Mpc$^{-1}$</td>
<td>11540</td>
</tr>
<tr>
<td>Age of the World</td>
<td>$A_t$</td>
<td>13.798(37)</td>
<td>Byr</td>
<td>2680</td>
</tr>
</tbody>
</table>

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

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

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:

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

Based on the value of $Q$ calculated in (8), we obtain the value of the temperature of the microwave background radiation:
\[ T_{\text{MBR}} = 2.725181(82) \text{ K} \]  \hspace{1cm} (10)

the value of the Hubble's parameter is

\[ H_0 = 2.22790(27) \times 10^{-18} \text{ s}^{-1} = 68.7457(83) \frac{\text{km/s}}{\text{Mpc}} \]  \hspace{1cm} (11)

the age of the World is

\[ A_t = 4.48854(54) \times 10^{17} \text{ s} = 14.2233(17) \text{ Byr} \]  \hspace{1cm} (12)

and the size of the World is

\[ R = 1.34563(16) \times 10^{26} \text{ m} \]  \hspace{1cm} (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**

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

\[
G_1 = 6.67401 (19) \times 10^{-11} \, m^3 k g^{-1} s^{-2}
\]  

and relative standard uncertainty 28.5 ppm;

- The second one consists of four measurements with the average value of

\[
G_2 = 6.67250 (16) \times 10^{-11} \, m^3 k g^{-1} s^{-2}
\]  

and relative standard uncertainty 24 ppm;

- The third one consists of one measurement with the value of

\[
G_3 = 6.67559 (27) \times 10^{-11} \, m^3 k g^{-1} s^{-2}
\]  

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

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

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

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

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

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:

$$T_1 = 2.725199 \text{ K}$$

$$T_2 = 2.725045 \text{ K}$$

$$T_3 = 2.725360 \text{ K}$$

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 $\mathcal{K}$:

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

and rewrite equation (1) as

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

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

$$Q_F = 0.759960 (13) \times 10^{40}$$
The difference between $Q_1$ and $Q_F$ equals to $21 \times 10^{-6}$ 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

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

(29)

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

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

(30)

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

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

(31)

the value of the Hubble's parameter is:

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

(32)

the age of the World is:

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

(33)

and the size of the World is:

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

(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.

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References