2. The Non-Equivalence of Inertial and Gravitational Mass within a Theory of Gravitational Charges

Abstract: To clarify the controversy over Newton's constant, G^{CODATA} = $6.673(10)\text{x}10^{-11}\ m^3 kg^{-1} s^{-2}$ - offered e.g. through enlarging its uncertainty from 128 ppm to 1500 ppm in 1998 - the formula $G_{AB} = \boldsymbol{G}(1-\Delta m_A/A\boldsymbol{m})^{-1}(1-\Delta m_B/B\boldsymbol{m})^{-1}$ is presented for the gravitational force between two isotopes with the mass numbers A and B, containing a constant $\boldsymbol{m}$ = 1.006727885(8) amu and a new defined mass defect $\Delta m_A = A\boldsymbol{m}-m_{Isotope,A}$. The formulae with the constant of nature $\boldsymbol{G}$ and for Δm_A emerge from the Unified Field consisting of the electromagnetic and of the covariant gravitational field with gravitational charges. The gravitational charge of the electron + proton system and of neutron g_n is the same $g_n = g\boldsymbol{m}$ with $\boldsymbol{G} = g^2/4\pi$. From available experiments with copper $\boldsymbol{G}$ = $6.576(6)\text{x}10^{-11}\ m^3 kg^{-1} s^{-2}$ is determined. With $\boldsymbol{G}$ and with the empirical known mass number dependent $\Delta_A^{MD} = \Delta m_A/A\boldsymbol{m}$, the new theory predicts aside of hydrogen: a composition dependent G_{AB} in a range of ~ 0.7 % (observed is 0.74 %). The relative difference of inertial and gravitational mass of a body is $\le$ 0.78 % and the Universality of Free Fall is violated in this order. A fall experiment with Li and Fe must directly show a measurable $\Delta a/a \approx 0.33\%$. The basic hypothesis of UFF was stated by Philoponus and Galileo Galilei and was taken over by Albert Einstein for the General Relativity Theory and for the gravity.

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Introduction

The oldest constant of physics, the gravitational constant G, introduced by Newton is also the least exactly known fundamental constant, Refs. **[11], [13], [16]**. In the 1998 recommendation for the CODATA value of the gravitational constant

$G^{CODATA} = 6.673(10)x10^{-11}\ m^3 kg^{-1} s^{-2}$,

Ref. **[1],** the uncertainty was surprisingly set higher by a factor of twelve because discrepancies had occurred in recent experiments. Hidden unknown systematic errors are presumed, such as the Kuroda effect which explains only deviations of measured values of G in the order of 200 ppm. But nowhere in physical literature there are investigations of systematic errors published explaining the measurements of G in the wide range of 7400 ppm observed between 1995 and 2002. Beside of this range, a time variation of G is also observed by Karagioz et al. Ref. **[13]**.

The situation is unique in physics and it is unsatisfactory. An explanation of the controversy over Newton's constant is required. Because of the observed discrepancies between experiment and theories, the main question arises: Is the accepted theory of gravity valid? Against the accepted theories, the experimental results of different groups allow the assumption that G is composition dependent and therefore the UFF is violated. Which experimental observations can be assembled with an assumed UFF-violation?

First, the motions of planets described with Kepler's third law seem to be composition dependent. The sidereal period T and the major axis R of planet orbit are known better than 10^{-8}. The inner planets, Mercury, Venus, earth, (Mars) have similar Fe/Ni kernel and fulfil the equality of R^3/T^2 with a relative uncertainty of about $6x10^{-5}$. But the orbits of inner planets and of outer (ice, rock and gaseous) planets offer a difference up to

$$\Delta(R^3/T^2)/(R_E^3/T_E^2) \sim 1.5x10^{-3}.$$

Hereby, R_E and T_E are the values of the earth. The difference is serious and can only be explained with a fulfilled relation

$$\Delta(R^3/T^2)/(R_E^3/T_E^2) < 10^{-7}$$

for all planets, would a composition independent gravity arise with equality of inertial and gravitational mass with UFF. Only in this case a basis would be given for a geometrized theory of gravity.

In this paper, a relation is developed between the observed composition dependent G and the "true" Newtonian constant ***G***. G is related to equality of the inertial and gravitational mass and ***G*** to a particle property. The latter is derived from the gravitational charges of the four stable particles e^-,e^+,p^+, and p^-. The introduction of gravitational charge for elementary particles is an essentially new idea in physics. It fills the lack of absence of gravitational interaction in the particle physics, namely, the gravity is essentially left out in this field of physics until now.

Conceptually, there are two different kinds of masses of a body: an inertial mass and a gravitational mass. The inertial mass is the proportionality factor between forces (any kind of force) applied to the body and the acceleration it receives in response to it in an inertial laboratory. The gravitational mass is a measure of the property of the body to attract by gravitation any other body. Using Newton's law of static gravitational force, to write the equation of motion of a body of inertial mass m^i and gravitational mass m^g in the gravitational field of another body with the gravitational mass M^g (for instance the earth) we have

$$m^i \, d^2 \boldsymbol{r}/dt^2 = -\frac{GM^g m^g}{r^3} \boldsymbol{r},$$

where $\boldsymbol{r}$ is the relative position vector between the centres of mass of the two bodies and G the proportionality factor of gravity. If $m^i \equiv m^g$ (equivalence of inertial and gravitational mass), then the acceleration $\boldsymbol{a} = d^2 \boldsymbol{r}/dt^2$ is the same for all bodies if G is constant. With the presumed constant value of G and with the equivalence $m^i \equiv m^g$, regardless of their mass and composition, the local acceleration of gravity on the surface of the earth amounts to about 981 $cm\ s^{-2}$, an identical value for all bodies. This is the so called Universality of Free Fall (UFF). A doubt about the equivalence $m^i \equiv m^g$ is an objective of this paper. But if $G x m^g/m^i$ is not a constant, the violation of UFF must be measured as acceleration difference of two bodies with different composition. The complete scientific assumption investigated in this article is:

The inertial mass m^i and gravitational mass m^g are not equivalent and their ratio m^g/m^i is composition dependent. Therefore, in the basic equation

(A) $\quad m\, a = -G\, M\, m/r^2$

the G *depends also on the composition of different bodies with the mass* m. *Responsible for this is the mass number dependence of the relative mass defect* Δ^{MD} *in a range of about 0.78% on one hand and the gravitational charges of the elementary particles, on the other hand. Furthermore, in the equation*

(B) $m^{i}\ a = -\ \boldsymbol{G}\ M^{g}\ m^{g}\ / r^{2}$,

G *is a constant of nature and the acceleration* a *is composition dependent. The UFF is violated in order of* $(m^{g} - m^{i})/m^{g}$ *which is between* $1.4x10^{-8}$ *and 0.78%. The two definition (A) for* G *with the assumption* $m^{i} = m^{g}$ *and (B) for* ***G*** *with the non-equivalence of inertial mass and gravitational mass has to investigated*

A systematic theoretical and experimental investigation of the above formulated assumption has not been performed until now; see for instance the review article of A. M. Nobili, Ref. **[15]** and the literature referenced in Ref. **[17]**. The measurements of isotope masses by J.H.E. Mattauch and A.H. Wastra are 40-50 years old and nowadays, all isotope masses are known very precisely, Ref. **[8].** The systematic investigation of UFF would lead automatically to the comparison of $\Delta a/a$ for bodies with special compositions granting the largest effects. The mass number dependent Δ^{MD} offers a remarkably small effect (< 0.05%) between the mass numbers 27 (Al) and 139 (La), where the most used composition of test bodies originates. But a systematic investigation of UFF and Δ^{MD} has not yet been performed.

At the end of this paper, an experiment will be proposed, comparing $\Delta a/a$ of test bodies composed of lithium/beryllium and of iron. The theoretically predicted fall time differences are larger than 5 ms from heights of fall above 110 m. They are directly measurable and offer immediately the violation of UFF.

The Newtonian Constant of Gravity

To explain the observed range of G, shown by the experimental results of different groups using different materials for the test masses, the gravitational force related to the isotopes in the test bodies is taken on one hand. This force can also be expressed with two composition independent constants $\boldsymbol{G}$ and $\boldsymbol{m}$. Since the gravitational force fulfils the superposition principle, the gravitational force between two macroscopic bodies, with the masses M_1 and M_2, can be certainly determined by them. On the other hand, a new expression for the mass defect of an isotope with the mass number A, Δm_A, will be used. The proof of the formulae for the gravitational force expressed with $\boldsymbol{G}$ and $\boldsymbol{m}$ and for the mass defect will not be dealt with here, but will be explained later as an attribute of the gravitational charge within a new Unified Field Theory.

With the superposition principle, the gravitational force between two bodies with the masses M_1 and M_2 consisting of mass particles m_i and m_j can be written

$$F = - \sum_{i=1}^{N_1} \sum_{j=1}^{N2} G_{ij} m_i m_j / r_{ij}^2 \qquad (1)$$

The summation runs over the mass particles, e.g. isotopes, in both bodies. A constant G_{ij} could never be measured with all particles because of the weakness of the gravitational forces. Below Newton's law of gravity

$F_{ij} \sim m_i m_j / r_{ij}^2$

with different proportionality constant G_{ij} will be allowed for different isotopes and measurable effects are derived.

For two isotopes with the mass numbers A and B the following denotation is used:

m_A is the inertial mass of the isotope with mass number A and

$m_A = A\boldsymbol{m} - \Delta m_A$,

with $\Delta m_A > 0$. The constant G_{AA} in

$F_{AA} = -G_{AA} M_1 M_2 / r^2$,

appears in the measurement of the gravitational force between the two masses

$M_1 = N_1 m_A$ and $M_2 = N_2 m_A$,

if both masses consist only of one isotope with the mass number A. The same denotation, only with the lower index B, is used for the isotope with the mass number B. The gravitational force F_{AB}, with the gravitational constant G_{AB}, specifies the force between two test masses, the one consisting to 100% of the isotope with the mass number A and the other to 100% of the isotope with the mass number B with

$M_2 = N_2 m_B$.

With these denotations, as well as with $\boldsymbol{G}$ and $\boldsymbol{m}$, two formulae for the gravitational force F_{AB} can be specified:

$$F_{AB} = -G_{AB}\, m_A m_B / r^2 = -G_{AB}\,(A\boldsymbol{m} - \Delta m_A)(B\boldsymbol{m} - \Delta m_B)/r^2 \qquad (2a)$$

$$F_{AB} = -\boldsymbol{G}\, A\, B\, \boldsymbol{m}^2 / r^2 \qquad (2b)$$

The relation (2a) is the well known relation between G_{AB} and the inertial masses m_A and m_B but according to the assumption, G_{AB} is not considered the same constant for all isotopes. The second relation (2b) is a new one. It is derived from the assumed gravitational charges of the Elementary Particles. The relation (2a) can be calculated for each isotope and is permissible on the basis of particle physics. The force F_{AB} is based on weighing of bodies and (2b) is calculable with the numbers of isotopes represented with the mass numbers A and B. Later in this paper, the gravitational charge of the (e^-, p^+) system and of the neutron will be identified with

$g\boldsymbol{m} = g(m_p - m_e),$

whereby m_p, m_e are the masses of proton and electron and the "true" Newtonian constant is simply

$\boldsymbol{G} = g^2/4\pi$.

The following important formula arises from the equations (2a) and (2b)

$$G_{AB} = \boldsymbol{G}(1 - \Delta m_A/A\boldsymbol{m})^{-1}(1 - \Delta m_B/B\boldsymbol{m})^{-1} \quad (3)$$

As mentioned, this relation connects two possibilities together defining the Newtonian proportionality factor with inertial masses on the one hand and with the gravitational charges of Elementary Particles on the other. The relation (3) connects G_{AB} and $\boldsymbol{G}$ together and can be calculated for each isotope combination. The units of G_{AB} and $\boldsymbol{G}$ are of course the same.

The gravitational force F_{AB} between two bodies with the inertial masses M^i_A and M^i_B, the one consisting of isotopes with the mass number A and the other of isotopes with the mass number B, and with the composition dependent G_{AB}, is:

$$M^i_A = \sum_{i=1}^{N_1} m_i = N_1 m_A \qquad \text{and} \quad M^i_B = \sum_{j=1}^{N_2} m_j = N_2 m_B$$

$$F_{AB} = -G_{AB} M^i_A M^i_B / r^2 = -\sum_{i=1}^{N_1} \sum_{j=1}^{N2} G_{AB} m_i m_j / r^2_{ij} \tag{4}$$

With the denotations

$$M^g_A = \sum_{i=1}^{N_1} A\boldsymbol{m} = N_1 A\boldsymbol{m},$$

and

$$M^g_B = \sum_{j=1}^{N_2} B\boldsymbol{m} = N_2 B\boldsymbol{m},$$

for the gravitational masses, with $\boldsymbol{G}$ and from (2b) a similar equation can be set

$$F_{AB} = -\boldsymbol{G} M^g_A M^g_B / r^2 = -\sum_{i=1}^{N_1} \sum_{j=1}^{N2} \boldsymbol{G} A\boldsymbol{m} B\boldsymbol{m} / r^2_{ij} \tag{5}$$

The equality of

$$G_{AB} M^i_A M^i_B = \boldsymbol{G} M^g_A M^g_B$$

means therefore,

$$G_{AB} m_A m_B = \boldsymbol{G} AB\boldsymbol{m}^2 .$$

With

$$m_A = A\boldsymbol{m} - \Delta m_A ,$$

and

$$m_B = B\boldsymbol{m} - \Delta m_B ,$$

follows the equation (3) for isotopes as well as for macroscopic bodies. Obviously the macroscopic measurable constant G_{AB} depends on the mass defects of the isotopes in the bodies. The composition dependent G_{AB} is connected to the empirically known mass number dependency of the mass defect. In the following (3) will be used as a reference equation between G_{AB} and the Newtonian $\boldsymbol{G}$.

The isotope masses are known in atomic mass units (amu) and their uncertainties are better than 0.1 ppm, Ref. **[8]**. The value of $\boldsymbol{m}$ = 1.006727885(8) amu is also well known. With these values the characteristic quantity, the relative mass defect, is

$$\Delta_A^{MD} = (\mathrm{A}\boldsymbol{m} - \mathrm{m}_A)/\mathrm{A}\boldsymbol{m} = \Delta \mathrm{m}_A / \mathrm{A}\boldsymbol{m} \quad (6)$$

and can be calculated for every isotope with the uncertainty of its components. Because measurements of G are available with an uncertainty less than 20 ppm, Ref. **[4]** the measurement of the Newtonian constant $\boldsymbol{G}$ and of G_{AB} can be performed for any composition of test bodies with a similar accuracy. The composition dependency of G in the range of 7400 ppm can be verified with much less accurate measurements.

The hydrogen isotopes with the smallest value of (6) are left out in this paper because hydrogen does usually not occur in the composition of test bodies. The relative mass defect, calculated from Ref. **[8],** varies in the case of the most frequent isotopes between 0.441% in case of ${}^{7}_{3}\mathrm{Li}$ and 0.784% at ${}^{56}_{26}\mathrm{Fe}$. According to (3), this results in a deviation of 7000 ppm for $\mathrm{G}_{AB}/\boldsymbol{G}$ with a measurement of the gravity if lithium ${}^{7}_{3}\mathrm{Li}$ and iron ${}^{56}_{26}\mathrm{Fe}$ are used. This fits very well into the overall range of observed values of the gravitational constant G which is 7400 ppm.

In the course of the paper, the uncertainty of 10 ppm of Δ_{TB} (0.001%) will be used for the test bodies, which corresponds to a 20 ppm uncertainty of G. This uncertainty is appropriate since the frequencies of different isotopes of chemical elements in test bodies are often not more precisely known and the isotope masses from Ref. **[8]** have also to be corrected in this order. See the additional remark to **Tab. 1**.

In recent measurements of gravity, the elements with A < 12, Li, Be, B, and gaseous elements are usually not used in the composition of test bodies. Therefore, the boundary of the range for the gravitational constant G_{AA} can be calculated with the largest value of Δ_{TB} at iron, Δ_{Fe} = 0.784%, and with the smallest value at uranium, Δ_{U} = 0.647%. The range is 2800 ppm = 2x1400 ppm and fits very well with the confident interval of the CODATA value of G which is 2x1500 ppm. Therefore, the literature value of G should be interpreted as an average value over all used compositions of test bodies.

In both cases, the composition dependency of G fits in very well with the prediction. Therefore, a further search or the presumption of any systematic error in the gravity measurement is not plausible. The uncertainties of recently published values of G are in each case much less than 1500 ppm, typically 100 ppm, but the values are not in close accordance with each other. The composition dependency of G is difficult to verify with known experimental results because the compositions of test bodies are frequently not published. Therefore, an **Appeal** of the author on **CODATA** goes out to remove this lack in publishing.

Now, the material independent Newtonian gravitational constant ***G*** has to be determined from the measured values G_{AB} under the mentioned circumstances. The value of ***G*** can be determined from independent experiments with copper as frequently used main material for test bodies**.** Kleinevoß, for instance used two masses (each 576 kg) with 90% Cu and 10% Zn, Ref. **[11]**. The measurement of Quinn, Ref. **[5]**, was also carried out with copper metal as the main part of the external mass with 15.5 kg. Schlamminger, Ref. **[2]** in his measurements used mercury in two stainless steel tanks ($\approx$800 kg) as the field mass (FM$\approx$13,521 kg) and two different test bodies, copper and tantalum as test masses (TM$\approx$1.1 kg)**.**

At first, we will turn to the measurement of Schlamminger, because he experimented with two different kinds of test bodies. For the mercury isotopes the evaluated deviation of Δ_A is 0.003%, with 0.685% at $^{198}_{80}$Hg and 0.682% at $^{204}_{80}$Hg, which means 61 ppm for the gravitational constant G_{HgHg} for both Hg isotopes. The difference between the Δ_A values of copper and of tantalum is 0.082%, with 0.779% at $^{63}_{29}$Cu and with 0.697% at $^{181}_{73}$Ta. Tantalum is consisting of 99.98% out of $^{181}_{73}$Ta and the copper metal consists of approximately 69.17% of this copper isotope, the remainder is $^{63}_{29}$Cu with $\Delta^{Isotope,A}$ = 0.780%. Mercury consists of seven stable isotopes. Therefore Δ_{Hg} = 0.683% is taken for the natural mercury metal. 5.5% of FM can be attributed to the stainless steel tanks with Δ_{Fe} = 0.784%, which levels Δ_{FM} to 0.689%. However, the accurate mass distribution of the tanks relative to Hg mass is unrecorded. Therefore we will use the Hg value for the FM without correction.

The result of the measurement of Schlamminger et al., Ref. **[2]** with the mercury/copper combination is used first to determine the value ***G***. For mercury and for copper metal, the values Δ_{Hg} = 0.683% (FM without the steel tanks) Δ_{Cu} = 0.779% re taken in order to calculate ***G*** from (3).

With the measured value $6.67407(22) \text{x} 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$ the following value for the Newtonian constant ***G*** is obtained as the material independent gravitational constant

$$\boldsymbol{G = 6.576(6) \text{x} 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}}. \tag{7}$$

The uncertainty will be explained later. The value

$$\text{G}_{CuCu} = 6.6797\ \text{x} 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2},$$

calculated with ***G*** (7) and with (3) is to compare with the value of Quinn,

$$\text{G} = 6.67565(45) \text{x} 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2},$$

performed mainly with copper metal as test bodies. The calculated value is 600 ppm higher than the measured value, but it is compatible with

$$\text{G}^{CODATA} = 6.673(10) \text{x} 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2},$$

and it tends toward the value measured by the PTB in 1995, Ref. **[3]**.

With the value of ***G*** from (7) and with Δ_{Ta} = 0.697% the gravitational constant can also be calculated for the mercury/tantalum combination of Schlamminger as

$$\text{G}_{Hg,Ta} = 6.6677\ \text{x} 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}.$$

The deviation of calculated value $G_{Hg,Ta}$ from the second measured value of Schlamminger is 900 ppm.

At this point a remark is appropriate: During the measurement, a mass comparator was used to determine the gravitational force. To convert the balance of the comparator reading in a force, the same value of the local acceleration

$b = 9.8072335(6)\ \mathrm{m/s^2}$,

was taken for both test masses. Furthermore, the equivalence of inertial and gravitational mass for both bodies, consisting of copper and of tantalum was also used in the data evaluation. This process can be understood on the basis of the validity of the accepted UFF. But the proceeding is questioned if the validity of UFF is not presumed for the data evaluation. Notwithstanding, the experiment can contribute to the proof the composition dependency of G with two different kinds of test bodies. But because the data evaluation of the measurement has used the accepted theories, but not the theory of gravity proposed in this paper, this should be considered for the interpretation of the result. In this sense an uncertainty of 900 ppm has to be assigned to the results of Schlamminger which leads to the given uncertainty of $\boldsymbol{G}$ in (7).

On the other hand, if one takes Schlamminger's mercury/tantalum combination for a calculation of the material independent $\boldsymbol{G}$, the result would be

$$\boldsymbol{G} = 6.582 \mathrm{x} 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}. \qquad (8)$$

Since other independent measurements were also carried out with test masses consisting mainly of copper, the value in (7) has a greater probability to be the correct value of $\boldsymbol{G}$ than those in (8).

As far as the material dependency of the gravitational constant G_{AB} is concerned, not very much can be stated quantitatively from the other experimental results, because the isotope compositions of the test bodies were not recorded sufficient and precise manner. At first, the experiments with copper will be used to get other $\boldsymbol{G}$ values in order to increase the accuracy. From the other measurements, without copper composition, only qualitative indications can be made - perhaps in the expected area, where the measured values of G_{AB} would be considered to be (FM = field mass, TM = test mass).

Kleinevoß / Uni. Wuppertal FM and TM brass (90% Cu, 10% Zn), Ref. **[11]**

With Δ_{Zn} = 0.776% as well as with the value Δ_{TB} = 0.777% for the test bodies, the measured value of

$G = 6.67422(98) \mathrm{x} 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}$,

leads to the value of the Newtonian gravitational constant

$\boldsymbol{G} = 6.571 \mathrm{x} 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\ \mathrm{s}^{-2}$.

This calculated value fits with the value of the Newtonian constant in (7).

Quinn / BIPM: FM and TM of Cu and of Cu with 0.7% Te, Ref. **[5]**

The observed gravitational constant is a little bit larger than the measured value of Kleinevoß. If pure natural copper is considered, Δ_{Cu} = 0.779%, and Te is not included in the calculation, than one obtains

$\boldsymbol{G} = 6.570 \mathrm{x} 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}$.

From the measurements with copper, Refs. **[2]**, **[5]**, **[11]** all calculated values of the Newtonian $\boldsymbol{G}$ are within the uncertainty of 900 ppm. In this range of uncertainty, the experiments prefer the lower values of $\boldsymbol{G}$.

In the following measurements either iron was used at least in one of the test bodies or different materials were used with unknown isotope composition.

Karagioz / AIM: FM Steel/brass (Cu, Zn?), TM unknown (?), Ref. **[7]**

The isotope composition of the test bodies is not sufficiently known. The measured value is G = 6.6729(5) x10^{-11} m^{3} kg^{-1} s^{-2}.

Luo / HUST: FM chromium steel (?), TM of copper (?), Ref. **[6]**

The Cr contribution and other components of steel are unknown. Therefore, Cr (Δ_{Cr} = 0.781%) was omitted from the consideration. With Δ_{Fe} = 0.784%, Δ_{Cu} = 0.779% and with the value of ***G*** from (7) the calculated value,

G_{FeCu} = 6.6797(60) x10^{-11} m^{3} kg^{-1} s^{-2},

is significantly larger than the measured value

G = 6.6699(7) x10^{-11}m^{3} kg^{-1} s^{-2}.

Michaelis / PTB: FM wolfram/zerodur(?), TM Zerodur, Ref. **[3]**

The calculation of $\Delta_{zerodur}$ for the glass ceramics material is difficult, because it consists of many oxides of Si, Al, P, Li, Ti Zr, Zn, Mg and so on. Moreover, the contribution of wolfram with Δ_{W} = 0.695% is unknown. Therefore, nothing can be stated, except that the measured value is

G = 6.7154(8) x10^{-11}m^{3} kg^{-1} s^{-2}.

Gundlach /Seattle, FM stainless steel 316, pendulum pyrax, Ref. **[4]**

Also, concerning the measured value of

G = 6.67421(92) x10^{-11} m^{3} kg^{-1} s^{-2},

with the smallest uncertainty (14 ppm), nothing can be stated regarding the determination of the Newtonian constant ***G*** due to the unknown isotope composition with the stainless steel (68-63% Fe) and with Pyrax (the special glass consisting of many oxides, see comments to zerodur). The theoretical estimation of the uncertainty of ***G*,** due to the range of Fe occurrence in the composition, is certainly greater than 100 ppm, which has to be compared with the published experimental uncertainty of 14 ppm. One can conclude that the best ever measured value of G, corresponding to the actual composition, is fortuitous. Furthermore, the publication, Ref. **[4]** does not allow any estimation of the uncertainty due to an effect of the possible time variation observed by Karagioz, Ref. **[15]**.

If one tries to calculate an average value for all the observed G with the really used chemical elements for test bodies, the value

$G^{Theory} = (G_{Fe,Fe} + G_{U,U})/2$,

could serve with $\Delta_{Fe} = 0.784\%$, $\Delta_U = 0.647\%$,

$\boldsymbol{G} = 6.576 \mathrm{x} 10^{-11}\ m^3 kg^{-1} s^{-2}$,

and with the occurrence range of G_{AB} 2x1400 ppm. The value would be

$G^{Theory} = 6.6707(93) \mathrm{x} 10^{-11}\ m^3\ kg^{-1} s^{-2}$

The value G^{Theory} fits very well with the CODATA value and with its uncertainty

$G^{CODATA} = 6.6730(100) \mathrm{x} 10^{-11}\ m^3 kg^{-1} s^{-2}$.

Therefore, the literature value G^{CODATA} has to be interpreted as the average value of G for all the used compositions and not as a value of a constant quantity with the given uncertainty.

The mass number dependence of the relative mass defect (6) is shown in **Tab. 1**.

The hydrogen isotopes are left out in **Tab.1**, because they seldom occur in the composition of test bodies. It is known that the mass defect of deuteron is less than half of the mass defect of a ${}^{7}_{3}Li$. The calculated variation of G between A = 28 and 140 is relatively small; it is about 2x300 ppm. Most of the isotopes ever used are in this mass number interval; therefore an apparent independency of composition of G was assumed in the 300 years history of gravity experiments. The confident interval of G^{CODATA}, 2x1500 ppm, covers the gravitational constant of all elements with exception of the elements with A $\leq$ 11. The composition dependency of G between Li, Fe and U is 7000 ppm. This fits with the observed range of 7400 ppm. See **Fig. 1** and **Fig. 2** further below.

Two additional smaller corrections have to be made for the usage of (3) with values from Ref. **[8]** and with those from **Tab. 1**. One relates to the calculation of the isotope masses, from the measurements with a mass spectrometer. The measurements are performed with ionised isotopes. In order to get the mass of the electric neutral isotopes the electron mass is added to the measured mass of the ionised isotopes.

The relative mass defect of hydrogen can be calculated from the binding energy of the ground state of H atom and $\boldsymbol{m}$ as $1.4x10^{-8}$.

According to the negative gravitational charge of electrons, the electron mass has to be subtracted from the positive gravitational charge of ionised isotopes which are measured as isotope masses. The correction in the case of one time ionised isotopes is $m_A^{corrected} = m_A (1-2m_e/m_A)$

leading to a smaller neutral isotope masses than shown in the **Tab. 1**.

Tab.1 The gravitational charges of electric neutral isotopes is $g_A = Ag(m_p - m_e)$ with $g_p = gm_p$, for p^+, $g_e = -gm_e$ for e^- and $g_n = g(m_p - m_e)$ for n. The second column shows the gravitational masses $A(m_p - m_e)$ in atomic mass units. The isotope masses of the most frequent isotopes are taken from Ref. **[8]**; they are inertial masses of isotopes. The mass number dependent Eq. (6) is shown in column five with 10ppm uncertainty. The formula of Δm and the used mass defect in nuclear physics $\Delta m_{n.ph.}$ is also given, expressed with the proton, electron and neutron masses.

Composition of the nuclei	Gravitational mass [amu]	Isotope mass [amu]	Isotope	Relative mass defect [%]	Mass number
[p^+ + e^-	1.006727885		n^0		1]
$2p^+$ + 2n	4.026911540	4.002603250	$^{4}_{2}He$	0.607	4
$3p^+$ + 4n	7.047095195	7.016004049	$^{7}_{3}Li$	0.441	7
$4p^+$ + 5n	9.060550965	9.012182135	$^{9}_{4}Be$	0.534	9
$5p^+$ + 6n	11.074006735	11.009305466	$^{11}_{5}B$	0.584	11
$6p^+$ + 6n	12.080734620	12.000000000	$^{12}_{6}C$	0.668	12
$7p^+$ + 7n	14.094190390	14.003074005	$^{14}_{7}N$	0.647	14
$8p^+$ + 8n	16.107646160	15.994914622	$^{16}_{8}O$	0.700	16
$9p^+$ + 10n	19.127829815	18.998403205	$^{19}_{9}F$	0.677	19
$10p^+$ + 10n	20.134557700	19.992440176	$^{20}_{10}Ne$	0.706	20
$11p^+$ + 12n	23.154741355	22.989769675	$^{23}_{11}Na$	0.713	23
$12p^+$ + 12n	24.161469240	23.985041898	$^{24}_{12}Mg$	0.730	24
$13p^+$ + 14n	27.181652895	26.981538441	$^{27}_{13}Al$	0.736	27
$14p^+$ + 14n	28.188380780	27.976926533	$^{28}_{14}Si$	0.750	28
$15p^+$ + 16n	31.208564435	30.973761512	$^{31}_{15}P$	0.752	31
$16p^+$ + 16n	32.215292320	31.972070690	$^{32}_{16}S$	0.755	32
$17p^+$ + 18n	35.235475975	34.968852707	$^{35}_{17}Cl$	0.757	35
$18p^+$ + 22n	40.269115400	39.962383123	$^{40}_{18}Ar$	0.762	40
$19p^+$ + 20n	39.262387515	38.963706861	$^{39}_{19}K$	0.761	39
$20p^+$ + 20n	40.269115400	39.962591155	$^{40}_{20}Ca$	0.761	40
$21p^+$ + 24n	45.302754825	44.955910243	$^{45}_{21}Sc$	0.767	45
$26p^+$ + 30n	56.376761560	55.934843937	$^{56}_{26}Fe$	0.784	56
$79p^+$ +118n	198.325393346	196.96655131	$^{197}_{79}Au$	0.685	197
$80p^+$ +122n	203.359032770	201.97062560	$^{202}_{80}Hg$	0.683	202
$82p^+$ + 208n	209.399400080	207.97663590	$^{208}_{82}Pb$	0.679	208
$92p^+$ +146n	239.601236630	238.05078258	$^{238}_{92}U$	0.647	238

$m_{Isotope} = A(m_p - m_e) - \Delta m = N_p m_p + N_n m_n - \Delta m_{n.ph.} = Am_p + 2.531150482 N_n m_e - \Delta m_{n.ph.}$

→

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→

Fig. 1 The relative mass defect Δ_A of the most frequent isotopes with a mass number A compared to that of iron Δ_{Fe} .

The correction factor is the smaller the larger m_A is. The correction $(1\text{-}2m_e/m_A)$ is for lithium 0.99985, for beryllium 0.99988 and for iron 0.999981. Therefore, the corrected relative mass defects are Li: 0.456%, Be: 0.546% and Fe: 0.786% instead of 0.441%, 0.534% and 0.784% as given in **Tab. 1**. Because of the posterior unknown ionisation degree of the isotopes, the original data from Ref.

[8] has to be used. The corrections are omitted in **Tab. 1**. The uncertainty of the relative mass defects is given with 10ppm.

Another correction of (3) arises from the binding energy of isotopes in the solid state. This second correction is certainly much smaller than the one discussed above. Therefore, an investigation is left out here.

Finally, a comparison of the lowest and highest calculated and observed value of the gravitational constant has to be done.

In comparison to all other elements the relative mass defect is especially small for lithium and beryllium. With the corrected values Δ_{Li} = 0.456%, Δ_{Be} = 0.546% and with

$\boldsymbol{G} = 6.576(6) \times 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}$

the predicted values are

$G_{Li,Li} = \boldsymbol{G} / (1-0.00456)^2 = 6.636(6) \times 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}$

$G_{Be,Be} = \boldsymbol{G} / (1-0.00546)^2 = 6.648(6) \times 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}$.

They are far from the lower border of the confidential interval of the CODATA value. All the values $G_{Li,Li}$, $G_{Be,Be}$; $G_{X,Li}$ and $G_{X,Be}$ are significantly smaller than $G_{X,Y}$ for all other elements X and Y. Therefore, the measurements with lithium and beryllium are very informative for gravity, although these metals have low specific weights.

The highest values of G_{AA} can be calculated for iron and for cobalt. With the corrected values Δ_{Fe} = 0.786%, Δ_{Co} = 0.782% and with $\boldsymbol{G}$, the G_{AA}'s are at the upper border of the confidential interval of the CODATA value:

$G_{Fe,Fe} = \boldsymbol{G} / (1\text{-}0.00786)^2 = 6.681(6)\text{x}10^{-11}\ m^3\,kg^{-1}\,s^{-2}$

$G_{Co,Co} = \boldsymbol{G} / (1\text{-}0.00782)^2 = 6.680(6)\text{x}10^{-11}\ m^3\,kg^{-1}\,s^{-2}$.

Results of G experiments are shown in **Fig. 2** compared with ***G*** and $G_{Fe,Fe}$. Since 1998, the lowest and highest measured values of G taken from the data base **[13]**

$G_{Luo} = 6.6699(7)\text{x}10^{-11}\ m^3\,kg^{-1}\,s^{-2}$ Ref. **[6]**

$G_{Schw} = 6.6873(94)\text{x}10^{-11}\ m^3\,kg^{-1}\,s^{-2}$ Ref. **[12]**

→

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Fig 2. Results of G experiment since Cavendish compared with the literature value $G^{(CODATA,1998)}$, the gravitational constant ***G*** and $G_{Fe,Fe}$. The last two values are calculated in this paper.

Conclusion until now: From (3), the 1500 ppm uncertainty, and the value itself, of the CODATA value for G, as well as the occurrence of all measured values of the laboratories with different material are derivable with the Newtonian constant

$\boldsymbol{G} = 6.576(6)\text{x}10^{-11}\text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$.

The values of characteristic quantity Δ_{TB} lead to the deviations of $G_{FM,TM}$ with the correct order of magnitude. ***G*** is significantly smaller than the literature value

$G^{CODATA} = 6.673(10)\ \text{x}10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$.

However, the comparison of some observed single values of G with calculated values $G_{FM,TM}$ shows partly a larger deviation. This is influenced by the frequently unrecorded isotope composition, the inadequate data evaluations and in some cases probably through experimental errors. From available experiments ***G*** can be determined better than 100 ppm. In order to increase the certainty of ***G***, test bodies with chemical elements with only one stable isotope should be selected. Chemical elements, e.g. the Be, Al, Ta or Nb should be used, because they consist (almost) to 100% of one stable isotope. In particular, zero-experiments (or compensation experiments) can also be used in order to minimize experimental errors. The isotope frequency of chemical elements with several stable isotopes is often not known with the necessary accuracy. Therefore, they should be avoided at the beginning of the calculation for the determination of ***G***. In the evaluation of experimental data the composition dependent G and the non equivalency of inertial and gravitational mass must be taken into account. Sometimes, Ref. **[11]**, the meaning occurs that the most recent experiments are in close accordance with each other and the uncertainties are much smaller than the revised CODATA error. But with these measurements it is not shown that the used compositions of the test bodies span the range from Li/Be to Fe/Co/Ni. The possible systematic error explanations of the observed 7400 ppm range will lack any realistic basis. There are no treatments of systematic errors available in the literature which would essentially allow the reduction of this range. The often quoted Kuroda effect corrects the range of uncertainty only about 200 ppm, see the published G values in *The Newtonian Gravitational Data Base*, Ref. **[13].** The Kuroda effect can neither explain the large deviation between the value of Michaelis, Ref. **[3]** and Luo, Ref. **[6]** nor the observed time variation of G reported by Karagioz et al. Ref. **[13]**. Therefore the explanation of the deviation of measured G with the Kuroda correction is left out in this paper.

The summary of the perceptions obtained so far, allows the conclusion that the composition dependency of G is determined by the equation (3). It is founded on the empirically known mass number dependent of relative mass defect Δ^{MD} and on the gravitational charges of particles.

The Gravitational Charges of Elementary Particles

The formula (3) for the usage of compositions dependent G_{AB} expressed with the Newtonian constant ***G*** emerges from the author's work about the fundamental field. The theory of the fundamental field is a theory of Unified Field (UF), Ref. **[9]**. The UF connects the gravitational field and the electromagnetic field within a covariant field theory. The equation (3) is valid in the context of very fundamental considerations. Here, only some aspects of the UF will be mentioned concerning the gravitational charges and only to the extent as it is required for the understanding of (2b), (3) and the above defined mass defect.

The similarity of the static Coulomb law and the static law of gravitational force, together with general mathematics (the Gaussian divergence theorem and the theorem of Stokes), see e.g. Ref. **[10]**, provides that the four stable particles e^-, e^+, p^+ and p^-, with the elementary electric charges $q_i = \pm q$, can also be also equipped with elementary gravitational charges g_i without any discrepancy. The static gravitational force between these four particles is described as follows:

The Elementary Particles (EP) with the same electric charges exert an attracting gravitational force to each other and the Elementary Particles with opposite electric charges exert a repulsive gravitational force against each other.

The four elementary gravitational charges g_i with a positive sign convention for the proton $g_3 = +gm_p$ and with the electron mass m_e and proton mass m_p are:

$$e^- : g_1 = -gm_e, \quad e^+ : g_2 = +gm_e, \quad p^+ : g_3 = +gm_p, \quad p^- : g_4 = -gm_p \qquad (9)$$

The same specific gravitational charge g of all four particles is an additional assumption. Within the UFT it is shown that the two elementary charges and the particle number n_{EP} of the four particles are Lorentz invariant quantities. Therefore, all three quantities q_i, g_i and n_{EP} remain the same in all frames. Since n_{EP} is conserved, the particles e^-, e^+, p^+ and p^- never decay as observed in nature. Obviously it must be assumed that they are not composed of any other fundamental particles; they are indeed Elementary Particles. The four EP with two different Maxwell charges are the sources of the electromagnetic and the covariant gravitational field and more than these four particles are not needed to generate the fundamental field UF.

On the other hand, one can argue that all gravitational charges of the four particles could have the same sign. But first, such an assumption can not explain the observed properties of G. Beside of this; several serious basic problems would arise if the gravitational charges of all particles would have the same sign, Ref. **[9]**. Therefore, this assumption is rejected and the proposal (9) is accepted. The repulsive gravitational force, for instance between p^+ and e^- reduces the force between electric neutral particle systems due to the reduced gravitational charges. The reduced gravitational force is proportional to $g^2(m_p\text{-}m_e)^2$. The effect of reduction through m_e is small because of the large mass difference $m_p >> m_e$. The condensed (electric neutral) material has always the same number of positive and negative electric charges. Therefore, the repulsive character of gravity between proton and electron can never be observed with known macroscopic bodies: the gravitational force is always attractive. The UF explains the key role of p^- which is never observed as decay product of unstable nuclei. Beside the Planck's constant h, a second fundamental constant

$$h^0 = \pi q^2/\sqrt{2}\, c = h/387,$$

exists also, Ref. **[9]**, in the microscopic physics, which causes the estimated size of the electron neutrino of $7.03\text{x}10^{-14}$ cm and the proton neutrino of $3.83\text{x}10^{-17}$ cm. The proton neutrino, considered as the υ_p = (p^+,p^-)-system, is by a factor

$\sim 5x10^{-4}$ smaller than nuclei. Since the interaction sphere of υ_p is in the order of its own size, it can not be built in nuclei. The explanation of the absence of p^- in the condensed material depends also essentially on the different sign of the gravitational charges as in (9). The same sign of all g_i will not correspond with these observations in nuclear physics. But this is beyond the scope of this paper and will be treated later in a separate paper, Ref. **[9]**.

The gravitational charge of an electric neutral isotope with the mass number A is

$$\mathrm{g}_A = g\mathrm{A}(m_p - m_e) = g\mathrm{A}\boldsymbol{m} \tag{10}$$

and can also be considered as a new "Ansatz". Within the UF theory, the equation (10) is strongly justified because the gravitational charge of the neutron g_n is the same as that of the (e^-,p^+) system. The same g_n appears for the neutron if it is either considered as a two particle system (e^-,p^+) or as a four particle system $(e^-,p^+,(e^-,e^+))$. The subsystem (e^-,e^+) does not contribute to net charges, neither to the gravitational charge nor to the gravitational charge of an electric neutral isotopes. The net gravitational charge of an electric neutral isotope is independent of the number of the subsystems (e^-,e^+) in the nuclei. Therefore, the gravitational charge of a neutral isotope depends only on the number of p^+ and is given in (10). The number of p^+ is equal to the generally used mass number A.

The bound subsystem (e^-,e^+) can be considered as the electron neutrino υ_e which is detected as a decay product of a free neutron. The explanation of the "mass-less" neutrinos with gravitational charges of the four EP according to (9) is very simple and straightforward. Since the neutrinos are consisting of two EPs, their velocity is less than the velocity of light c.

Since the "Ansatz" of the gravitational charge of an electric neutral isotope (10) is reasonable and within the UF theory, it is deduced as a generally valid equation.

Now, the two material independent constants, $\boldsymbol{G}$ and $\boldsymbol{m}$, in (2b) and (3) can be explained. In the formula of the gravitational force between two isotopes with the mass numbers A and B,

$$F_{AB} = -(g\mathrm{A}\boldsymbol{m})(g\mathrm{B}\boldsymbol{m})/4\pi r^2 = -\boldsymbol{G}\mathrm{AB}\boldsymbol{m}^2/r^2,$$

they have the following meaning:

$$\boldsymbol{G} = g^2/4\pi, \qquad \boldsymbol{m} = m_p - m_e. \tag{11}$$

$\boldsymbol{G}$ is the "true" Newtonian constant. The quantity $g\boldsymbol{m}$ is the gravitational charge of a proton reduced by an electron and of a neutron

$$g_n = g(m_p - m_e).$$

The mass defect Δm_A for an isotope with the mass number A can be defined according to the formula

$$m_A = A(m_p - m_e) - \Delta m_A = A\boldsymbol{m}(1 - \Delta m_A/A\boldsymbol{m}). \tag{12}$$

This is a new definition and it differs from the one defined in nuclear physics:

$$m_A = Zm_p + Nm_n - \Delta m_{n.ph.}.$$

This formula is used with the help of proton and neutron masses m_p and m_n. The equation (12) supplies approximately 1.5 MeV smaller binding energy of the nuclei than it is known in nuclear physics until now.

The Equation of Motion in the Gravitational Field

The Newtonian law of gravitational force

$$F \sim M_1^g \; M_2^g / r^2 , \tag{13}$$

published 1687 in Principia is a static law. Together with the Lex Secunda - the equation between acceleration and force that was used first consequently by Euler – it led to two fundamental assumptions in physics: The independence of gravity of the composition of bodies and the equivalence of inertial mass and gravitational mass. The second fundamental assumption is not valid for mass particles, except the four Elementary Particles. Putting the gravitational charges

$G_1 = gM_1^g$ and $G_2 = gM_2^g$

of the bodies in the right side of (13), one obtains

$$F = -G_1 G_2 / 4\pi r^2 = -g^2 M_1^g M_2^g / 4\pi r^2 = -\boldsymbol{G}\, M_1^g M_2^g / r^2 . \tag{14}$$

The coefficient of $M_1^g M_2^g$ is really a constant and it is the "true" Newtonian constant $\boldsymbol{G}$. The static law of gravitational force (14) is independent of the material composition indeed as declared by Newton (13). The gravitational mass of an arbitral body is given by the equation

$$M^g = \sum_A N_A A(m_p - m_e). \tag{15}$$

M^g is proportional to the reduced gravitational charge of the protons through the electrons and to the number of protons in the body. The inertial mass of a body is the sum of the inertial masses of isotopes m_A, measured in mass spectrometers,

$$M^i = \sum_A N_A m_A = M^g - \sum_A N_A \Delta m_A = M^g (1 - \Delta^{MD}). \tag{16}$$

The inertial and the gravitational mass of a body differ by the mass defect term $\sum_A N_A \Delta m_A$. The following quantity gives the relative size of the deviation

$$(M^g - M^g)/M^g = \Delta^{MD} = (\sum_A N_A \Delta m_A)/M^g = (\sum_A N_A A \Delta_A^{MD})/\sum_A N_A A.$$

It depends on the composition of the body and is less than 0.785% for each body. From the Lex Secunda in the static gravitational field of a mass M_0^g follows

$$M^i a = F = -\boldsymbol{G} M_0^g M^g / r^2 . \qquad (17)$$

This equation of motion in the gravitational field can be expressed either with the inertial or with the gravitational isotope masses. The simpler equation is

$$M^i a = M^g (1-\Delta^{MD}) a = -\boldsymbol{G} M_0^g M^g / r^2 . \qquad (18)$$

If the equation (17) is to be expressed with the inertial masses, the inertial masses of isotopes have to be weighted with different G_{AB} according to (4) on the right side. Because of the mass number dependent Δ^{MD}, the acceleration in the gravitational field depends on the composition of the bodies. Therefore, an iron body falls quicker than a lithium and uranium body, and a uranium body falls quicker than a lithium body. The iron kernel of the earth is a manifestation of this fact in nature. The material dependent Δ^{MD} violates the UFF.

The difference of fall times in a vacuum can be easily calculated from a given height under the assumption that *the influence of the electric charges can be neglected*. In the following, only bodies are considered consisting of Li respectively Be and are compared with an iron body with the corrected relative mass defects of Li: 0.456%, Be: 0.546% and Fe: 0.786%. With

$$M^i = M^g (1-\Delta^{MD}),$$

the relative differences of the acceleration are

$$\Delta a_{Li}/a \approx \Delta_{Fe} - \Delta_{Li} = 0.33\%, \qquad \Delta a_{Be}/a \approx \Delta_{Fe} - \Delta_{Be} = 0.24\%. \qquad (19)$$

The relative fall time difference, Δt, after a time of fall t_0, with $\Delta t << t_0$, follows from the equation

$s = ½a\, t^2$.

According to (19) and expressed with $\Delta a/a$ it is

$$\Delta t_{Li}/t_0 \approx ½\Delta a_{Li}/a \approx 0.165\%, \qquad \Delta t_{Be}/t_0 \approx ½\Delta a_{Be}/a \approx 0.120\%. \qquad (20)$$

The difference of distances between two bodies falling from a height s_0 and after the time t_0 expressed with $\Delta a/a$ is

$$\Delta s_0 \approx at_0 \Delta t = at_0^{\ 2} \Delta t/t_0 = s_0 \Delta a/a. \qquad (21)$$

From a fall height of s_0 = 110m and with a = 980.7 cm/s^2, the times of fall is t_0 = 4.736 s. In the case of Li/Fe the corresponding time difference due to the different acceleration is Δt = 7.8ms and the fall distance difference is Δs_0 = 36.3 cm. In the case of Be/Fe one gets Δt = 5.6 ms and Δs_0 = 26.4 cm. Such a mass dropping experiment is in preparation for execution by the author.

Historical Review and Foresight

In the early 6th century B.C. Philoponus declared the UFF. An experimental evidence for the UFF was first given by Galileo in the 17th century within the experimental errors and formulated by him as a fundamental hypothesis. The experimental errors of measurements of Galileo and Newton ranged in the order of 10^{-3}. The chemical elements were not yet discovered in their time. A composition dependency of Kepler's third law was not recognised. The hypothesis of UFF led to the Equivalence Principle (EP) by Einstein (1907). At the beginning of the 20^{th} century isotope masses were still unknown and Li and Be were not available as test bodies. Only for about 50 years the material dependent Δ^{MD} is empirically known and only since then a larger violation of the UFF could have been predicted and detected at all. Today, the non equivalency of the inertial and gravitational masses can be calculated with the required accuracy. The violation of UFF can also be understood as a consequence of the proposed UFT with the gravitational charges (9) of the Elementary Particles.

The attraction of the earth to different materials was first measured in 1889. The attraction measurement with the precision of $5x10^{-3}$ ppm due to an improved device was published in 1922. Eötvös' lecture on January 20^{th}, 1890 at the MTA, Budapest, was entitled "A föld vonzása különbözö anyagokra" ("The attraction of the earth on different materials"). In 1890, he presented his first experimental results having used copper, glass, antimonite and cork. The difference in the gravity of these bodies with the same masses was smaller than 1/20 000 000. The one of air and copper was smaller than 1/100 000, Ref. **[14]**. With his measurements Eötvös confirmed the most important thesis of the Newtonian theory of gravitation: The attraction of the earth, e.g. the force of the earth on different material is proportional to the "mass of the body" and independent of the material constitution. His precise measurement seemed to confirm the possible zero value of his parameter η for two bodies, A and B,

$$\eta = \frac{2[(m^g / m^i)_A - (m^g / m^i)_B]}{[(m^g / m^i)_A + (m^g / m^i)_B]} = \frac{2[(1-\Delta_A^{MD})^{-1} - (1-\Delta_B^{MD})^{-1}]}{[(1-\Delta_A^{MD})^{-1} + (1-\Delta_B^{MD})^{-1}]}, \qquad (22)$$

and one believes till today, that η is also able to check the equivalency of inertial and gravitational mass. Using the expressions (15) and (16) and setting

$\Delta_A^{MD} = \Delta_B^{MD}$,

for two appropriate chosen bodies it follows $\eta = 0$, but not the equivalency of inertial and gravitational mass and therefore not the validity of the Weak Equivalence Principle. The equation

$\Delta_A^{MD} = \Delta_B^{MD}$,

respectively $\eta = 0$, means only the same acceleration of the two bodies. In accepted gravity theories, Ref. **[15, 17]** the expression

$\Delta a_{AB}/a = \eta$,

is used and here is

$\Delta a_{AB}/a \approx \Delta_A - \Delta_B$,

explicitly derived**.** The relative difference between inertial and gravitational mass is Δ^{MD} as given in (16). The Eötvös parameter η is not a reliable parameter to check the equivalence of inertial and gravitational mass and therefore the Equivalence Principle. The review article by Nobili, Ref. **[15]** collects the relevant gravity experiments and tests of UFF. Due to the previously shown behaviour of the Eötvös parameter, a revision of the reliability of all these tests has to be checked with the non-equivalence of inertial and gravitational mass as background.

In this situation one remembers the words of Einstein: Physics should only use such a concept and comprehension for the description of phenomenon of nature which is measurable, at least principally. The Newtonian constant

$$\boldsymbol{G} = g^2/4\pi \, ,$$

and the composition dependent G_{AB} are measurable quantities with an uncertainty of approximately 20 ppm up to now, Ref. **[4]**. Within the proposed theory, the equations (15)-(17) represent the equation of motion of a body in the gravitational field. The inertial and gravitational mass of bodies is not equal. The violation of UFF is directly measurable with the chemical elements Li/Be/B/C/Al/Fe/Pb and this experiment is in preparation by the author. If the awaited results of the experiment demonstrate the non-equivalence of inertial and gravitational mass, the validity of the proposed UF has to be proved further with experiments. The UF theory is a complete covariant unified field theory and describes the fundamental non-conservative field consisting of the electromagnetic and the gravitational field. The gravitational field is a covariant field in a Euclidian space with the propagation velocity c which seems to be confirmed with recent measurements, Ref. **[18]**. The equivalence of inertial and gravitational mass is only valid for the four Elementary Particles. The Elementary Particles are the sources of the electromagnetic and gravitational field. They are the four kinds of Quanta of the Fundamental Field. For composite particle systems the gravitational mass is not equal to the inertial mass.

The proposed UF theory, together with a variation principle for open and non-conservative physical systems discussed in Refs. **[9, 19],** opens probably a consistent and much simpler way for particle physics, for microscopic field theory as well as for astrophysics. However, since the oldest and most fundamental assumptions in physics, the UFF and the equality of inertial mass and gravitational mass, is most probably not valid in nature, many of the accepted and nowadays successful hypotheses in these areas are up to revision, Ref. **[9].** Such hypotheses and assumptions are

- The mass-energy equivalence relation $E = mc^2$,
- The existence of photons as the quanta of the electromagnetic field,
- The universality of the Planck's constant and its interpretation,
- The existence of intrinsic angular momentum of the stable Elementary Particles,
- The existence of other than the electromagnetic and gravitational interaction,
- The existence of other particles as the four Elementary Particles,
- The space curvature of universe within the General Relativity Theory.

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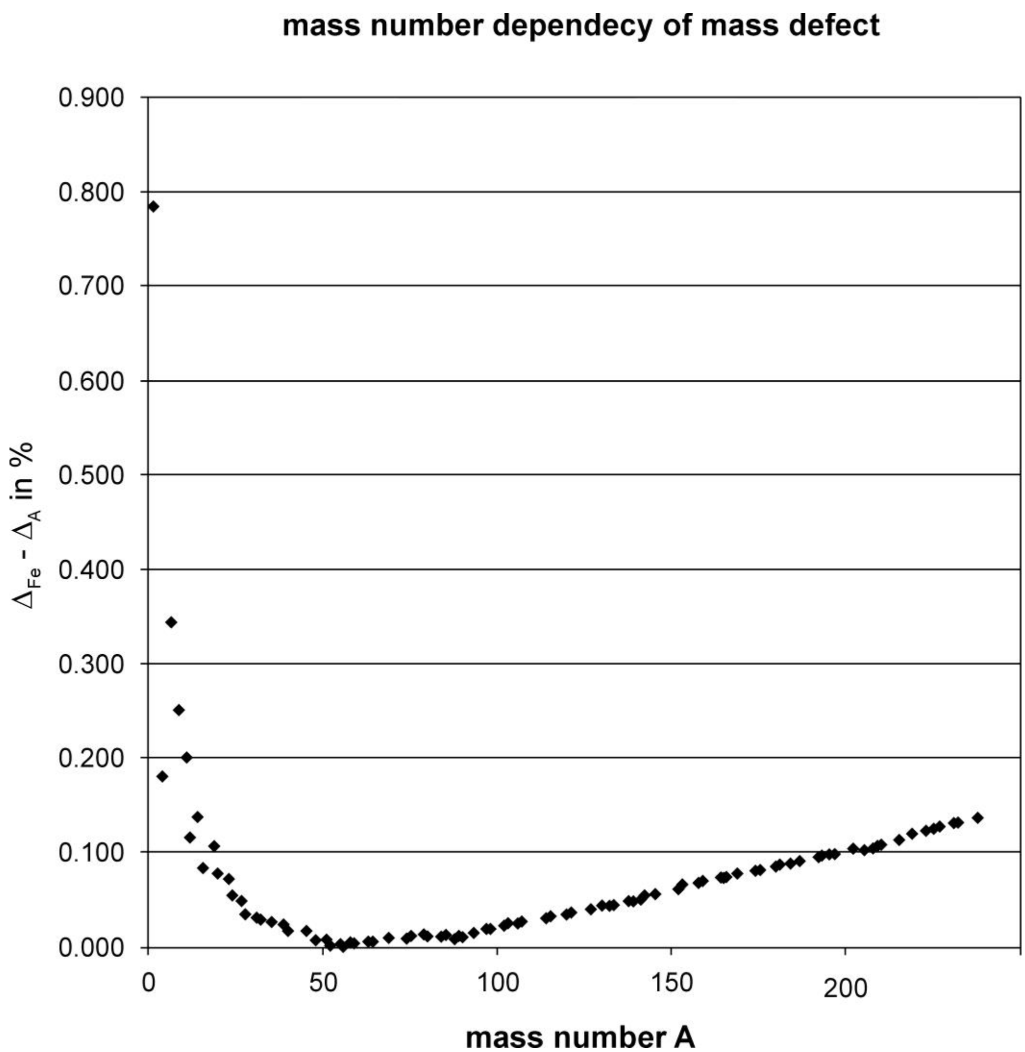
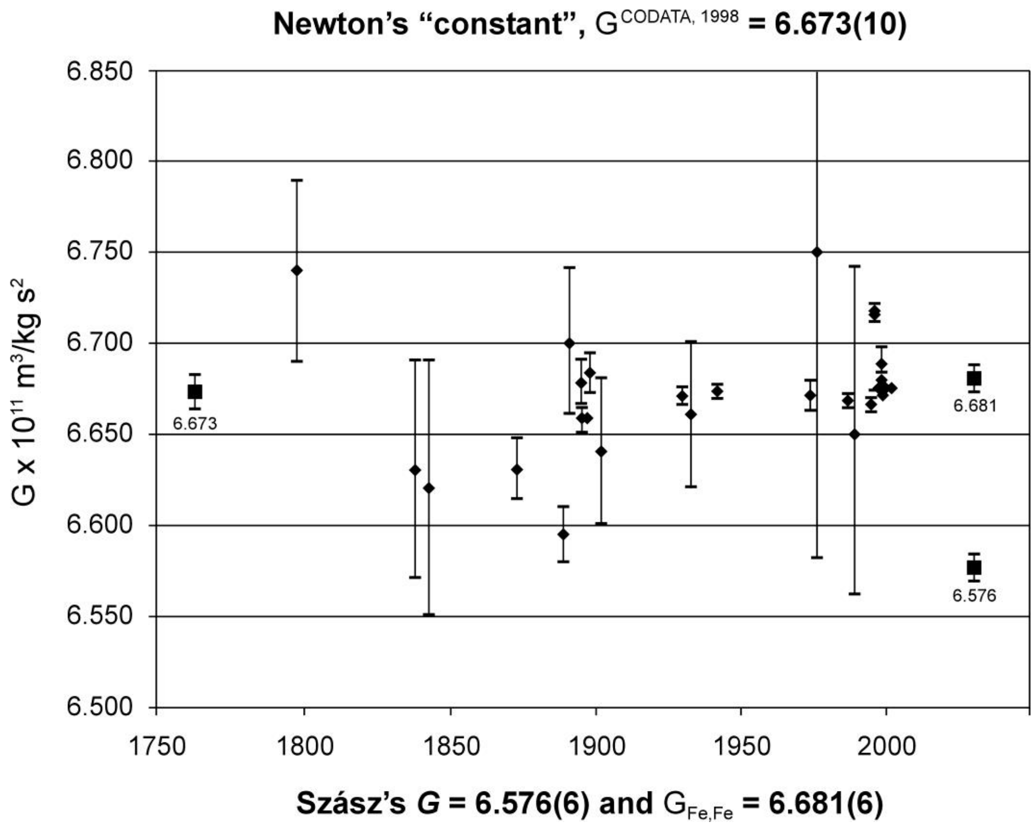
References

[1] CODATA, Journal of Physical and Chemical Reference Data **28**, 1713 (2000), Rev. of Mod. Phys. **72**, 351 (2000).
[2] St. Schlamminger, E.Holzschuch, W.Kuendig, Phys.Rev.Lett. **89**, 161102 (2002).

[3] W.Michaelis et al., Metrologia **32**, 267 (1995/1996).
[4] J.H.Gundlach, S.M.Merkowitz, Phys.Rev.Lett. **85**, 2869 (2000).
[5] T.J.Quinn et al., Phys.Rev.Lett. **87**, 111101 (2001).
[6] J.Luo et al., Phys.Rev. **D59**, 42001 (1999).
[7] O.V.Karagioz, V.P.Izailov, Meas. Tech. **39**, 979 (1996).
[8] G.Audi, A.H.Wapsta, Nuclear Physics, **A598**, 409 (1995).
[9] Gy.I.Szász, *Principles of Physics*, (2004).
[10] Sandra C. Chapman, *Core Electrodynamics,* First Edition, (Taylor & Francis, London, 2000).
[11] U.Kleinevoß, Ph.D. thesis, Universality Wuppertal, Germany, Report No. WUB-DIS 2002-2 (2002).
[12] J.P. Schwarz et al., Science **282**, 2230 (1998).
[13] O.V. Karagioz, V.P.Izailov, *The Newtonian Gravitational Constant Data Base*, last update June 15. 2001, Internet; and J.P.Mbalek, M.Lachièze-Rey, preprinp arXiv: gr-qc/0204061 v1 (2002).
[14] L.Eötvös, Akadémiai Értesitö **1**, 108 (1890), Math. und Naturw. Ber. aus Ungarn, **8**, 65 (1890); L Eötvös et al., Ann. Phyik, **68**, 11 (1922).
[15] A.M.Nobili, *Precise gravitation measurements on earth and in space: Test of the Equivalence Principle*, Published in Proc. of the Internat. School of Phys. "Enrico Fermi", Course CXLVI, Societa' Italiana di Fisica, IOSS Press, 509, (2001).
[16] Intenet page of the Eöt-Wash Group, Seattle, *The Controversy over Newton's Gravitational Constant*, http://www.npl.washington.edu/eotwash/gconst.html.
[17] C.Will, *Theory and experiment in gravitational physics*, Revised Edition (Cambridge University Press, Cambridg 1993), R.H.Dicke, *The theoretical significance of experimental relativity*, Third Printing (Gordon and Breach, New York – London – Paris, 1968).
[18] S.Kopeikin, E.Fomalont presented the measurement of the propagation of gravity at the Meeting of AAS, in Seattle, on 01/08/2003. The measured value in comparison with the propagation of light is 1.06 with 20% uncertainty. On 08/09/2002 Jupiter passed a quasar. This alignment offered the chance to measure the propagation of gravity, CQG, **21**, 3251 (2004).
[19] Gyula I. Szász, thesis, *Zur quantenmechanischen Beschreibung von Resonanzphänomenen*, Johannes Gutenberg University Mainz, Germany (1975), Gy. I. Szász, Z. Phys., **A275**, 403 (1975), Gy. I. Szász, Z. Phys., **A278**, 165 (1976), Gy. I. Szász, Fortschr. Physics, **24**, 405 (1976), Gy. I. Szász, Phy. Lett. **A55**, 327 (1976), Gy. I. Szász, Phy. Lett. **A62**, 313 (1977), V. Marigliano Ramaglia, G.P. Zucchelli, Phy. Lett. **A67**, 9 (1978).


mass number dependecy of mass defect
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
$\Delta_{Fe} - \Delta_A$ in %
0
50
100
150
200
mass number A


Newton's "constant", $G^{CODATA,\ 1998}$ = 6.673(10)
6.850
6.800
6.750
6.700
6.650
6.600
6.550
6.500
G x 10^{11} $m^3/kg\ s^2$
6.673
6.681
6.576
1750
1800
1850
1900
1950
2000
Szász's G = 6.576(6) and $G_{Fe,Fe}$ = 6.681(6)