Chapter 3

Is Gravitation A Results Of Asymmetric Coulomb Charge Interactions?

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Abstract

Many attempts have been made to equate gravitational forces with manifestations of other phenomena. In these remarks we explore the consequences of formulating gravitational forces as asymmetric Coulomb charge interactions. This is contrary to some established theories, for the model predicts differential accelerations dependent on the elemental composition of the test mass. The predicted differentials of acceleration of various elemental masses are compared to those differentials that have been obtained experimentally. Although the model turns out to fail, the construction of this model is a useful intellectual and pedagogical exercise.

Introduction

The similarities in the expressions for Newtonian gravitation and Coulomb electrostatic interactions,

$$\begin{cases} \vec{F}_{\rm g} & = & -G\,\frac{m_1 m_2}{r^2}\,\hat{r} \\ \vec{F}_{\rm c} & = & k\,\frac{q_1 q_2}{r^2}\,\hat{r} \end{cases}$$

are apparent, particularly the inverse-square nature of both forces and the binary product of the masses and charges. Based on this similarity, and the physicists' goal to unify all fundamental forces of nature, it is reasonable to conjecture that gravitation is some manifestation of electrostatic phenomena.

With these considerations in mind, we construct a simple gravity model; however, the model fails. The model predicts differential accelerations dependent on the elemental composition of the test mass. This is in keeping with various Fifth-Force (Hypercharge) hypotheses and re-evaluations of the Eötvös experiments which postulate the existence of non-Newtonian and baryon-dependent forces over short ranges. Such hypotheses are presently controversial, at best. T.M. Niebauer *et al.* have shown that the differential acceleration Δg, of two different materials, is less than 5 parts in 10^{10} of the gravitational acceleration $g = 980.67$ cm/s^2. Experiments verifying the Equivalence Principle have been performed by Dicke *et al.*, demonstrating that gravitational mass and inertial mass are equivalent to within 1 part in 10^{12}. These experiments rule out Fifth-Force hypotheses as well as our simple gravity model. Our model will show that the calculated differential acceleration Δg_{calc}, for the same materials, is on the order of 8.37 cm/s^2, in clear contradiction to the limits established by the experiments of Niebauer *et al.*

The original motivation for this formulation of gravitation was to calculate the approximate change δk, of the electrostatic constant $k = 1/4\pi\epsilon_0 = 8.9876\ \times 10^9$ Nm^2/C^2, in an asymmetric Coulomb charge interaction, necessary to account for gravitational forces. By this we mean that forces between like charges are expressed as

$$\vec{F}_{1,2} = k\,\frac{q_1 q_2}{r^2}\,\hat{r}\ , \tag{3.1}$$

while forces between unlike charges are expressed as

$$\vec{F}_{1,2} = (k + \delta k)\,\frac{q_1 q_2}{r^2}\,\hat{r}\ , \tag{3.2}$$

with $\delta k > 0$. We will show that $\delta k/k$ is on the order of 10^{-37}.

The idea of expressing gravity as a Coulomb interaction is not new; it had been explored by Wilhelm Weber (1804–1891) of Göttingen and Friedrich Zöllner (1834–1882) of Leipzig. Because Weber and Zöllner performed their "gedanken" experiment before the discovery of atomic particles, they were unable to foresee the consequences of combining charges in a densely packed nucleus. In these remarks we take into account the mass defects due to the binding energies of nuclei.

Asymmetric Coulomb Charge Interactions

Suppose two spherical masses, m_1 and m_2, are separated by a distance r connecting their centers of mass. Each mass m_i is composed of p_i positive charges and e_i negative charges.

Let F_{++} denote the force between the positive charges of mass m_1 and the positive charges of mass m_2; then the three remaining forces F_{+-}, F_{-+}, and F_{--} are labelled appropriately to represent the type of interaction between the charges of m_1 and m_2. We express the positive fundamental charge as q and negative fundamental charge as $-q$ in order to maintain the proper orientation of these central forces [1].

The forces on one of the masses are

$$\begin{cases} \vec{F}_{++} & = & -k \, \frac{q^2 p_1 p_2}{r^2} \, \hat{r} \\ \vec{F}_{--} & = & -k \, \frac{q^2 e_1 e_2}{r^2} \, \hat{r} \\ \vec{F}_{+-} & = & (k + \delta k) \, \frac{q^2 p_1 e_2}{r^2} \, \hat{r} \\ \vec{F}_{-+} & = & (k + \delta k) \, \frac{q^2 e_1 p_2}{r^2} \, \hat{r} \quad . \end{cases} \tag{3.3}$$

If we combine these forces [2],

$$\vec{F}_{\text{tot}} = -k \, \frac{q^2 (p_1 p_2 + e_1 e_2)}{r^2} \, \hat{r} + (k + \delta k) \, \frac{q^2 (p_1 e_2 + e_1 p_2)}{r^2} \, \hat{r} \ , \tag{3.4}$$

or, upon rearranging the terms, we find that

$$\vec{F}_{\text{tot}} = -k \, \frac{q^2 (p_1 - e_1)(p_2 - e_2)}{r^2} \, \hat{r} + \delta k \, \frac{q^2 (p_1 e_2 + e_1 p_2)}{r^2} \, \hat{r} \ . \tag{3.5}$$

An examination of the first term of equation (3.5) reveals that it is a reformulation of the Coulomb force equation. Note that this term vanishes if either mass is electrically neutral.

The last term,

$$\delta k \, \frac{q^2 (p_1 e_2 + e_1 p_2)}{r^2} \, \hat{r} \ , \tag{3.6}$$

does not change sign, regardless of the p_i and e_i; like gravity, it is always attractive.

Next we wish to find what the p_i and e_i are for each mass. This is simplified if we assume that m_1 and m_2 are electrically neutral masses. This implies that $e_1 = p_1$ and $e_2 = p_2$, and that

$$\vec{F} = 2 \delta k \, \frac{q^2 p_1 p_2}{r^2} \, \hat{r} \ . \tag{3.7}$$

When charges are combined, a very small fraction of the constituent particle masses is lost to the binding energy; this is referred to as a mass defect. We denote the actual mass of an atom by m_i, and its mass defect by B_i. The relationships of these quantities to the constituent particle masses are

$$\begin{aligned} m_1 + B_1 &= Z_1(m_p + m_e) + n_1 m_n \\ m_2 + B_2 &= Z_2(m_p + m_e) + n_2 m_n \ . \end{aligned} \tag{3.8}$$

Here Z_i represents the number of protons, and n_i represents the number of neutrons contained in the electrically neutral mass m_i; the quantities m_p, m_e, and m_n represent the masses of protons, electrons, and neutrons, respectively.

It is crucial to our model that each neutron is composed of one positive and one negative charge as indicated in the disintegration: $n \to p + e^- + \overline{\nu}_{e^-}$. This implies that

$$\begin{aligned} p_1 &= Z_1 + n_1 \\ p_2 &= Z_2 + n_2 \ . \end{aligned} \tag{3.9}$$

The number of neutrons can be expressed as a function of the number of protons [3], that is, $n_i = \mu_i Z_i$, where $\mu_i = (A_i - Z_i)/Z_i$. Substituting $\mu_1 Z_1$ for n_1 and $\mu_2 Z_2$ for n_2 in equations (3.9), we find

$$\begin{aligned} p_1 &= Z_1(1 + \mu_1) \\ p_2 &= Z_2(1 + \mu_2) \ . \end{aligned} \tag{3.10}$$

By replacing n_i with $\mu_i Z_i$ in equations (3.8), we have

$$\begin{aligned} m_1 + B_1 &= Z_1(m_p + m_e + \mu_1 m_n) \\ m_2 + B_2 &= Z_2(m_p + m_e + \mu_2 m_n) \ . \end{aligned} \tag{3.11}$$

Solving for Z_i in equations (3.11), and substituting these, in turn, into equations (3.10), we have

$$\begin{aligned} p_1 &= \tfrac{(m_1+B_1)(1+\mu_1)}{(m_p+m_e+\mu_1 m_n)} \\ p_2 &= \tfrac{(m_2+B_2)(1+\mu_2)}{(m_p+m_e+\mu_2 m_n)} \ . \end{aligned} \tag{3.12}$$

Finally, equation (3.7) becomes

$$\vec{F} = \frac{2\delta k q^2}{(m_p + m_e)^2} \left[\frac{(1+\sigma_1)(1+\sigma_2)(1+\mu_1)(1+\mu_2)}{(1+\mu_1\Delta)(1+\mu_2\Delta)} \right] \frac{m_1 m_2}{r^2} \hat{r} \ , \tag{3.13}$$

where $\sigma_i = \frac{B_i}{m_i}$, $\mu_i = \frac{N_i - Z_i}{Z_i}$, and $\Delta = \frac{m_n}{m_p + m_e} = 1.000833$.

If we assume the binding energies are negligible, that is, $\sigma_i = 0$, and that $\Delta \approx 1$, then equation (3.13) becomes

$$\vec{F} = \frac{2\delta k q^2}{(m_p + m_e)^2} \frac{m_1 m_2}{r^2} \hat{r} \ . \tag{3.14}$$

This allows us to equate the constant, $\frac{2\delta k q^2}{(m_p+m_e)^2}$, with the gravitational constant, $G = 6.672 \times 10^{-11}$ Nm^2/kg^2, to find

$$\delta k = G \cdot \frac{(m_p + m_e)^2}{2q^2} = 3.639 \times 10^{-27} \ \frac{Nm^2}{C^2} \ . \tag{3.15}$$

Dividing this value by k, we conclude that $\Delta k/k \sim 10^{-37}$.

Differential Accelerations

Unlike Newtonian or Einsteinian gravitation, our model predicts small differences in the accelerations of different test masses. These relative differences in g are dependent on the mass defects B_i, and the neutron/proton ratios, μ_i.

The force exerted by the earth, M_{earth}, on a test mass m_1, is

$$\vec{F} = \frac{2\delta k q^2}{(m_p + m_e)^2} \left[\frac{(1+\sigma_{earth})(1+\sigma_1)(1+\mu_{earth})(1+\mu_1)}{(1+\mu_{earth}\Delta)\,(1+\mu_1\Delta)} \right] \frac{M_{earth} m_1}{r^2} \, \hat{r} \ . \tag{3.16}$$

If another test mass, m_2, of differing composition, is accelerating under the same conditions, the ratio of the accelerations of masses m_1 and m_2 is

$$\frac{|\vec{a}_1|}{|\vec{a}_2|} = \left(\frac{1+\sigma_1}{1+\sigma_2}\right) \left(\frac{1+\mu_1}{1+\mu_2}\right) \left(\frac{1+\mu_2\Delta}{1+\mu_1\Delta}\right) \ . \tag{3.17}$$

In the freefall experiment of Niebauer *et al.*, the test masses represented extremes in elemental composition. One test mass was 40.0 grams of copper ($^{63}_{29}Cu$) and the other was 102.5 grams of depleted Uranium ($^{238}_{92}U$). The following table for σ_i and μ_i is derived from these data [4]:

Table I.

	Copper ($^{63}_{29}Cu$)	Uranium ($^{238}_{92}U$)
test mass (m)	40.0 gm	102.5 gm
atomic mass (m_a)	63.546 amu	238.0289 amu
σ	-.000384989	.008217874
μ	1.1724	1.5870

Substituting the values of Table (I) into equation (3.17), we find

$$\frac{|\vec{a}_1|}{|\vec{a}_2|} = 1.00854 \ , \tag{3.18}$$

so that $\Delta g_{calc}/g = .00854$.

Next we construct the following table for the elements aluminum (Al) and gold (Au) used in the experiments of Dicke *et al.*

Table II.

	Aluminum ($^{27}_{13}Al$)	Gold ($^{197}_{79}Au$)
atomic mass (m_a)	26.9815 amu	196.9665 amu
σ	.008951882	.008499650
μ	1.0769	1.4937

The differential acceleration of aluminum and gold predicted by our model is $\Delta g_{calc}/g = .000515$. Both values of Δg_{calc}, namely .00854 cm/s^2 and .000515 cm/s^2, far exceed the limit $\Delta g < 4.9033 \times 10^{-7}$ cm/s^2 experimentally found by Niebauer *et al.*

Conclusion

The model predicts differential accelerations that cannot be reconciled with those obtained by experiment. This does not preclude some relation or unification of gravitation and electromagnetism, but it does show that the simple model of Coulomb asymmetry is not viable.

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Notes

1. The magnitudes of the fundamental positive and negative charges are equivalent to within 1 part in 10^{20}.

2. Note that we have not taken into account any Coulombic shielding that would occur.

3. Typical values of $\mu = (A - Z)/Z \sim 1$–1.5, where A is the baryon number and Z is the atomic (or proton) number.

4. 1 amu (atomic mass unit) $= 1.661 \times 10^{-24}$ grams.

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