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Research Article

Mass or Energy: On Charge of Gravity

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The gravitational charge should be the energy instead of the mass. This modification will lead to some different results, and the experiments to test the new idea are also presented. In particular, we figure out how to achieve the negative energy and repulsive gravitational force in the lab.

1. Introduction

A gauge theory requires the conserved charge. The mass m_0 is an invariant in relativity and some alternative theories where c^2 is replaced by another constant K [1–4] but not conserved in the creation, annihilation, etc. Consequently, it is impossible to get the charge of gravitation. Indeed, a photon in free space can be pulled towards the star and Earth [5] although m_0 is zero. In spite of momentum conservation, the momentum p is not the gravitational charge either because the stationary objects in Cavendish's torsion-balance experiment can attract each other. We tend to regard the gravitational interaction as arising from conservation of energy E and predict some novel effects which cannot be explained by traditional theories.

2. New Form

Newton's law of universal gravitation states that every mass attracts any other mass by a force. It takes the form

$$G\frac{m_1 m_2}{r^2}, \tag{1}$$

where $G = 6.674 \times 10^{-11}\,\mathrm{Nm^2\,kg^{-2}}$ is the gravitational constant and r is the distance. If the charge of the gravitational interaction is energy, the new form of the force should be

$$G'\frac{E_1 E_2}{r^2}, \tag{2}$$

and the potential

$$\varphi = -\frac{G' E}{r}, \tag{3}$$

is a dimensionless quantity to indicate the deviation from the flat space-time in general relativity (Equation (49)). The Poisson equation is replaced by

$$\nabla^2 \varphi = 4\pi G' \aleph, \tag{4}$$

where $\aleph$ is the energy density of the source. It is reduced to

$$\nabla^2\left(\varphi c^2\right) = 4\pi G \rho, \tag{5}$$

once the relation between $\aleph$ and the mass density ρ of the source is

$$\aleph = \rho c^2. \tag{6}$$

At a low speed ($v \ll c$),

$$E = \frac{m_0 c^2}{\sqrt{1 - v^2/c^2}} \approx m_0 c^2,$$
$$G'\frac{E_1 E_2}{r^2} \approx G'\frac{m_{01} m_{02}}{r^2} c^4. \tag{7}$$

In comparison to Equation (1), the new gravitational constant G' is

$$G' = \frac{G}{c^4} = 8.262 \times 10^{-45}\,\mathrm{N}^{-1}. \tag{8}$$

For instance, the energies of the Earth and a massless photon are $E = Mc^2 \approx M_0c^2$ and hf (Planck constant h times the frequency f), respectively. The gravitational force

$$G' \frac{Mc^2}{r^2} hf \approx G' \frac{M_0c^2}{r^2} hf = G\frac{M_0}{r^2}\frac{hf}{c^2}. \tag{9}$$

is nonzero. Equation (2) can be rewritten as

$$G' \frac{E_1E_2}{r^2} = G\frac{\left(E_1/c^2\right)\left(E_2/c^2\right)}{r^2}. \tag{10}$$

Here, E/c^2 plays the role of the so-called gravitational mass m_G. From now on, the concept m_G is redundant, and the physical meaning of the principle of equivalence $m_i = m_G$ is just $m = E/c^2$. Einstein claimed that "The calling force of the earth depends on the gravitational mass. The answering motion of the stone depends on the inertial mass." [6]. It should be revised to "The calling force of the earth depends on the energy. The answering motion of the stone depends on the mass".

3. Negative Energy and Repulsion

In Newton's theory, the gravitational force is always attractive. Now, we use the new form to examine a bound system. The rest energy of a deuteron is 1875.6×10^6 eV, and the force between the Earth should be

$$G' \frac{M_0c^2}{r^2} 1875 \cdot 61 \times 10^6\,\mathrm{eV} = G\frac{M_0}{r^2} 1875 \cdot 61 \times 10^6\,\frac{\mathrm{eV}}{c^2}. \tag{11}$$

Nevertheless, the deuteron is composed of one proton and one neutron. Their rest energies are 938.27×10^6 eV and 939.57×10^6 eV. The resultant of forces

$$\begin{aligned} &G' \frac{M_0c^2}{r^2} 938.27 \times 10^6\,\mathrm{eV} + G' \frac{M_0c^2}{r^2} 939.57 \times 10^6\,\mathrm{eV} \\ &\quad = G' \frac{M_0c^2}{r^2} 1877.84 \times 10^6\,\mathrm{eV}, \end{aligned} \tag{12}$$

is larger than (11). Actually, the gravitational force between the negative binding energy -2.23×10^6 eV and the Earth should be repulsive and Equation (11) is equal to

$$\begin{aligned} &G' \frac{M_0c^2}{r^2} 938.27 \times 10^6\,\mathrm{eV} + G' \frac{M_0c^2}{r^2} 939.57 \times 10^6\,\mathrm{eV} \\ &\quad - G' \frac{M_0c^2}{r^2} 2.23 \times 10^6\,\mathrm{eV}. \end{aligned} \tag{13}$$

Like the Coulomb force, gravity can be not only pulling but also repelling.

4. Gravitational Effect of a Potential Energy

The total energy in the above example is still positive. Let us consider an object whose total energy can be negative. The wave function of a free particle is

$$\begin{aligned} \psi &\sim \exp \frac{i}{\hbar}(Et - \mathbf{px}) = \exp \frac{i}{\hbar}\left(mc^2t - \mathbf{px}\right), \\ m &= \frac{m_0}{\sqrt{1 - v^2/c^2}}. \end{aligned} \tag{14}$$

In a Faraday cage, the electrostatic field $\mathbf{E}$ is absent even though an electric scalar potential φ_E is applied. In practice, φ_E is usually the voltage relative to ground. The velocity $\mathbf{v}$ or momentum $\mathbf{p}$ of a particle electrically charged q does not change while the total energy is

$$E = mc^2 + q\varphi_E. \tag{15}$$

Generally speaking, energy is related to the momentum, and the energy shift is accompanied by the change of momentum. However, this is a special state whose momentum and velocity remain unchanged as the electrostatic field strength is zero. The feature is decisive to the success of the experiment to detect an effect caused by the force of gravity which is much weaker than other forces. The wave function is now

$$\psi \sim \exp \frac{i}{\hbar}(Et - \mathbf{px}) = \exp \frac{i}{\hbar}\left(mc^2t + q\varphi_E t - \mathbf{px}\right), \tag{16}$$

and the particle gains an extra phase [7]

$$\frac{q}{\hbar}\varphi_E t. \tag{17}$$

It is the evidence of Equation (15). In classical mechanics, the gravitational force between the Earth is

$$\begin{aligned} G\frac{M_0}{r^2} m_0 &\approx m_0 g, \\ g &\approx \frac{GM_0}{r^2} = 9.8\,\mathrm{ms}^{-2}. \end{aligned} \tag{18}$$

Using the new law (Figure 1),

$$\begin{aligned} G' \frac{M_0c^2}{r^2}\left(mc^2 + q\varphi_E\right) &= \frac{GM_0}{r^2}\left(m + \frac{q\varphi_E}{c^2}\right) = \frac{GM_0m}{r^2}\left(1 + \frac{q\varphi_E}{mc^2}\right) \\ &= mg\left(1 + \frac{q\varphi_E}{mc^2}\right), \end{aligned} \tag{19}$$

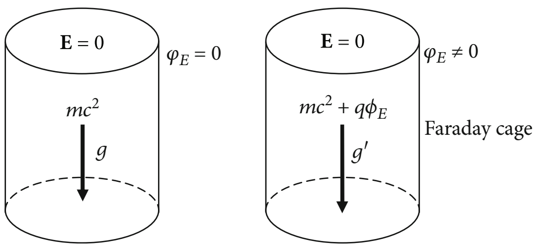

Figure 1: Gravitational accelerations.

$$g' = \frac{G'\left(M_0c^2/r^2\right)\left(mc^2 + q\varphi_E\right)}{m} = \frac{\left(GM_0/r^2\right)\left(m + q\varphi_E/c^2\right)}{m} = g\left(1 + \frac{q\varphi_E}{mc^2}\right). \tag{20}$$

It is against common sense that the gravitational acceleration of a freely falling body is independent of the mass, which has lodged itself in the public mind since the anecdotal Galileo's Leaning Tower of Pisa experiment. We should measure the gravitational accelerations of electrically charged particles [8, 9] in a region where $\varphi_E \neq 0$ and $\nabla\varphi_E = 0$. For example, the electric charge of an electron is $q = -e$ and the force

$$mg\left(1 - \frac{e\varphi_E}{mc^2}\right), \tag{21}$$

can be zero on condition that

$$\varphi_E = \frac{mc^2}{e}. \tag{22}$$

The critical potential of a slow electron is

$$\frac{mc^2}{e} \approx \frac{m_0c^2}{e} = 0.51 \times 10^6 \text{ volts}. \tag{23}$$

It must be said that we get a negative total energy (15), repulsive force of gravity (21), and reversed acceleration g' (20) of an electron if

$$\varphi_E > \frac{mc^2}{e} \approx 0.51 \times 10^6 \text{ volts}. \tag{24}$$

5. Influence on the Mass

A hypothesis to avoid a nonconstant acceleration (Equation (20)) is that m is changed to

$$m \longrightarrow m + \frac{q\varphi_E}{c^2}, \tag{25}$$

simultaneously. Under the circumstances, the gravitational acceleration is

$$\frac{G'\left(M_0c^2/r^2\right)\left(mc^2 + q\varphi_E\right)}{m + q\varphi_E/c^2} = \frac{\left(GM_0/r^2\right)\left(m + q\varphi_E/c^2\right)}{m + q\varphi_E/c^2} = g = 9.8\,\text{ms}^{-2}, \tag{26}$$

as before, and the gravitational interaction is still equivalent to a "geometric effect." It is difficult to test Equation (20) directly in normal labs [8, 9], and one can reexamine the physical quantities involving m or m_0 to speculate on the gravitational acceleration. For instance, the specific heat C_v of the electron gas is proportional to the temperature T and m_0, i.e.,

$$C_v = \gamma T \propto T, \quad \gamma \propto m_0. \tag{27}$$

In a Faraday cage, the specific heat will be

$$C_v \propto \left(m_0 - \frac{e\varphi_E}{c^2}\right)T, \tag{28}$$

in the event that

$$m_0 \longrightarrow m_0 - \frac{e\varphi_E}{c^2}. \tag{29}$$

Now, we discuss the spectra emitted by hydrogen atoms in a cage. The electric potential energy of an electron in this atom is

$$-\frac{e^2}{4\pi\varepsilon_0 R} - e\varphi_E \quad (R \text{ is the distance to the proton}). \tag{30}$$

The electric force as the gradient of Equation (30) is still

$$\frac{e^2}{4\pi\varepsilon_0 R^2}. \tag{31}$$

Hence,

$$\frac{e^2}{4\pi\varepsilon_0 R^2} = m\frac{v^2}{R}. \tag{32}$$

Due to Bohr's quantization condition,

$$mvR = n\hbar \quad (n = 1, 2, 3 \cdots), \tag{33}$$

the total energy of an electron is

$$E = mc^2 - \frac{e^2}{4\pi\varepsilon_0 R} - e\varphi_E \approx m_0 c^2 - \frac{e^4}{32\pi^2\varepsilon_0^2\hbar^2 n^2} m_0 - e\varphi_E, \tag{34}$$

whereby the frequency of the spectrum should be

$$hf = E_1 - E_2 = \frac{e^4}{32\pi^2\varepsilon_0^2\hbar^2} m_0 \left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) = 13.6\,\text{eV}\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right). \tag{35}$$

In my opinion, m or m_0 is unaffected; otherwise, we shall discover a new effect in spectroscopy

$$\begin{aligned} hf &\longrightarrow \frac{e^4}{32\pi^2\varepsilon_0^2\hbar^2} m_0 \left(1 - \frac{e\varphi_E}{m_0 c^2}\right)\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) \\ &= 13.6\,\text{eV}\left(1 - \frac{e\varphi_E}{m_0 c^2}\right)\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right). \end{aligned} \tag{36}$$

6. Superconducting Interferometry Gravimeter

The electrostatic field within a superconductor vanishes as well. Inspired by the COW experiment of the neutron [10], we design a superconducting circuit (Figure 2) to detect the phase shift caused by the weight of the carrier.

At point 1, the incident supercurrent is split into two parts on a horizontal plane 1234. They follow the path $\overline{124}$ and $\overline{134}$, and the relative phase at point 4 where they recombine is

$$\frac{p_0}{\hbar}(L + H) - \frac{p_0}{\hbar}(H + L) = 0. \tag{37}$$

$p_0 = mv_0 \approx m_0 v_0$ is the initial momentum. By rotating the interferometer about the line $\overline{12}$, the difference between the lower path $\overline{124'}$ and upper path $\overline{13'4'}$ is

$$\vartheta = \frac{p_0 - p}{\hbar} L. \tag{38}$$

The height of $\overline{3'4'}$ is H and the momentum p should be

$$\frac{p^2}{2m_0} = \frac{p_0^2}{2m_0} - m_G g H. \tag{39}$$

In the COW experiment,

$$\begin{aligned} &\frac{p_0^2}{2m_0} \gg m_G g H, \\ &p \approx p_0 - \frac{2m_0 m_G g H}{p_0} = p_0 - \frac{2m_G g H}{v_0}. \end{aligned} \tag{40}$$

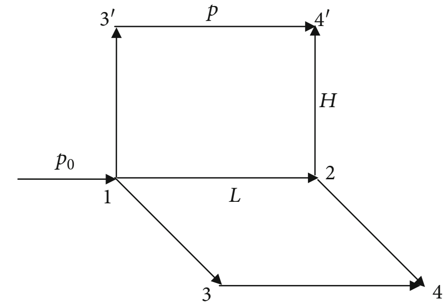

Figure 2: Schematic diagram.

The phase shift

$$\vartheta = \frac{p_0 - p}{\hbar} L = \frac{2m_G g H}{\hbar v_0} L \propto m_G g, \tag{41}$$

is proportional to the gravitational force $m_G g \approx m_0 g$. The experiments suggested in Sections 4–5 are to determine the gravitational acceleration and mass, respectively. This proposal is to weigh a superconducting carrier. It should be multiplied by a factor

$$m_0 g \longrightarrow m_0 g\left(1 + \frac{q\varphi_E}{m_0 c^2}\right) \tag{42}$$

after an electric scalar potential φ_E is applied. In Einstein's elevator, the inertial force is inadequate to compensate for the gravitational force (Equation (42)) and the phase shift is nonzero.

7. Physical Significance

The gravitational acceleration (20) is at variance with not only Newton's theory but also Einstein's general relativity whose motion equation

$$\frac{d^2 x^\mu}{ds^2} + \Gamma^\mu_{\alpha\beta}\frac{dx^\alpha}{ds}\frac{dx^\beta}{ds} = 0, \tag{43}$$

is independent of the mass. Actually, a geometric description holds true for the constant gravitational charge-to-mass ratios. In relativity, it is $m_G/m_i = 1$. We point out that the gravitational charge is E and $m_G/m_i = 1$ is equivalent to $E/m = c^2$. However, the ratio in the above counterexample

$$\frac{E}{m} = \frac{mc^2 + q\varphi_E}{m} = c^2 + \frac{q\varphi_E}{m}, \tag{44}$$

is not constant.

8. Geometric Theories of Gravity

To a constant K, there are [1–4]

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu, \tag{45}$$

$$dx^{\mu}dx^{\nu} = Kt^2 + dx^2 + dy^2 + dz^2, \quad (46)$$

$$g_{\mu\nu} = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad (47)$$

to describe an inertial reference frame. In a gravitational field, Equations (45) and (46) are still tenable, and $g_{\mu\nu}$ is given by Einstein's field equation

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = 8\pi G' T_{\mu\nu} \quad \left(G' = 8.262 \times 10^{-45}\ \mathrm{N}^{-1}\right). \quad (48)$$

For the sake of convenience, we consider the simplest case

$$g_{\mu\nu} = \begin{pmatrix} -(1+2\varphi) & 0 & 0 & 0 \\ 0 & \frac{1}{1+2\varphi} & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & r^2 \sin^2\theta \end{pmatrix}. \quad (49)$$

In view of $E \approx M_0 c^2$ of the source, another expression of Equation (49)

$$g_{\mu\nu} = \begin{pmatrix} -\left(1 - \frac{2GM_0}{c^2 r}\right) & 0 & 0 & 0 \\ 0 & \frac{1}{1 - 2GM_0/c^2 r} & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & r^2 \sin^2\theta \end{pmatrix}, \quad (50)$$

is familiar to us, and Equation (45) can be written as

$$ds^2 = -\left(1 - \frac{2GM_0}{c^2 r}\right) K dt^2 + \frac{dr^2}{1 - 2GM_0/c^2 r} + r^2 d\theta^2 + r^2 \sin^2\theta\, d\phi^2. \quad (51)$$

Suppose $K = c^2$, it is the well-known Schwarzschild solution

$$ds^2 = -\left(1 - \frac{2GM_0}{c^2 r}\right) c^2 dt^2 + \frac{dr^2}{1 - 2GM_0/c^2 r} + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2. \quad (52)$$

As to the gravitational field produced by the electrically charged particle in Section 4, there is an extra term $2G' q\varphi_E / r = 2Gq\varphi_E / c^4 r$ in the Reissner-Nordström solution.

The approximation of the motion equation is

$$\frac{d^2 x^i}{K dt^2} + \nabla\varphi = 0, \quad (53)$$

and the acceleration should be

$$a = \frac{d^2 x^i}{dt^2} = -K\nabla\varphi. \quad (54)$$

On the Earth,

$$\varphi = -G' \frac{E}{r} = -\frac{G}{c^4}\frac{M_0 c^2}{r} = -\frac{GM_0}{c^2 r}, \quad (55)$$

$$a = \frac{K}{c^2}\frac{GM_0}{r^2}. \quad (56)$$

In the age of Newton, the energy-mass equations of all experimental objects satisfy $K = c^2$. Thus,

$$a = \frac{GM_0}{r^2}. \quad (57)$$

This is just Newton's law

$$m_0 a = \frac{GM_0}{r^2} m_0. \quad (58)$$

$K \neq c^2$ is conducive to construct MOND (modified Newtonian dynamics).

9. Negative Mass and Attraction

A negative mass was inconceivable in Newton's time, whereas scientists can make anomalous waves in metamaterials now whose wave vectors are reversed. The phenomena imply that the masses of quanta of these waves are less than zero [4]. In the light of Newton's formula (Equation (1)), the gravitational force between the quanta and Earth should be repulsive. However, the energy hf of such a quantum is positive and the force

$$G' \frac{M_0 c^2}{r^2} hf, \quad (59)$$

is still attractive. The sign of gravity depends on the product of energies rather than masses. Interestingly, the gravitational acceleration

$$\frac{G' \left(M_0 c^2 / r^2\right) hf}{m} \quad (m < 0), \quad (60)$$

should be in the opposite direction. From another angle, it is because $K < 0$ [4] in Equation (56). In Section 4, the force is repulsive and mass is positive. Conversely, here are the attractive force and negative mass. Both the accelerations turn towards outer space. They are two types of antigravity propulsion.

10. Metric Tensor and Noninertial Effect

In a rotating frame,

$$ds^2 = -\left(1 - \frac{\Omega^2 r^2}{K}\right) K dt^2 + dr^2 + r^2 d\theta^2 + dz^2 + 2\Omega r^2 d\theta dt. \tag{61}$$

Ω is the angular frequency of the rotation. The relation between frequencies f_1 and f_2 at different distances should be

$$f_1 \sqrt{1 - \frac{\Omega^2 r_1^2}{K}} = f_2 \sqrt{1 - \frac{\Omega^2 r_2^2}{K}}. \tag{62}$$

When $K = c^2$,

$$ds^2 = -\left(1 - \frac{\Omega^2 r^2}{c^2}\right) c^2 dt^2 + dr^2 + r^2 d\theta^2 + dz^2 + 2\Omega r^2 d\theta dt, \tag{63}$$

$$f_1 \sqrt{1 - \frac{\Omega^2 r_1^2}{c^2}} = f_2 \sqrt{1 - \frac{\Omega^2 r_2^2}{c^2}}. \tag{64}$$

It was verified long ago [11]. In fact, there are following similarities between the photon and phonon (quantum of sound) (Table 1):

Space and time are not physical realities. They are tools to reflect nature, and one can attempt different space-time structures to fit the data. For example, the coefficient K in Equation (46) should be C_s^2 to describe the flat space-time

$$ds^2 = -C_s^2 dt^2 + dr^2 + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2, \tag{65}$$

of sound [1]. In a rotating system,

$$ds^2 = -\left(1 - \frac{\Omega^2 r^2}{C_s^2}\right) C_s^2 dt^2 + dr^2 + r^2 d\theta^2 + dz^2 + 2\Omega r^2 d\theta dt, \tag{66}$$

$$f_1 \sqrt{1 - \frac{\Omega^2 r_1^2}{C_s^2}} = f_2 \sqrt{1 - \frac{\Omega^2 r_2^2}{C_s^2}}. \tag{67}$$

Neither classical mechanics nor relativity where K is fixed as c^2 and the factor is $\sqrt{1 - v^2/c^2} \ll \sqrt{1 - v^2/C_s^2}$ can interpret Equation (67) which was predicted in 2000 [1]. Nonetheless, it was observed in 2011 [12]. $K = c^2$ of light is much greater than $K = C_s^2$ of sound, so the noninertial shift of light [11] is much less than that of sound [12].

Table 1

	Photon	Phonon
Speed	$c = 1/\sqrt{\varepsilon_0 \mu_0}$ (constant)	$C_s = \sqrt{\text{modulus/density}}$ (constant)
Energy	$E = \hbar\omega$	$E = \hbar\omega$
Momentum	$p = \hbar k$	$p = \hbar k$
Energy-momentum relation	$E = pc$ (linear)	$E = pC_s$ (linear)
Mass	$m_0 = 0$ (massless)	$m_0 = 0$ (massless)

11. Comparison between the Gravitational Field and Noninertial Frame

$K = C_s^2$ in Equation (51) yields the equations of sound in a gravitational field

$$ds^2 = -\left(1 - \frac{2GM_0}{c^2 r}\right) C_s^2 dt^2 + \frac{dr^2}{1 - 2GM_0/c^2 r} + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2. \tag{68}$$

$$f_1 \sqrt{1 - \frac{2GM_0}{c^2 r_1}} = f_2 \sqrt{1 - \frac{2GM_0}{c^2 r_2}}, \tag{69}$$

The gravitational frequency shift is as small as that of light. The result can be derived from a nongeometric theory too. Equation (9) is valid no matter whether it is a photon or phonon, and the potential energy should be

$$-G' \frac{M_0 c^2}{r} hf = -\frac{GM_0}{r} \frac{hf}{c^2}. \tag{70}$$

In this sense, the photon and phonon behave as if they have the same "gravitational mass" hf/c^2, though the inertial mass of the latter is hf/C_s^2 [1, 12]. The total energy in a gravitational field should be

$$hf - \frac{GM_0}{r} \frac{hf}{c^2}. \tag{71}$$

It is conserved

$$hf_1 - \frac{GM_0}{r_1} \frac{hf_1}{c^2} = hf_2 - \frac{GM_0}{r_2} \frac{hf_2}{c^2}, \quad f_1 \left(1 - \frac{GM_0}{c^2 r_1}\right) = f_2 \left(1 - \frac{GM_0}{c^2 r_2}\right). \tag{72}$$

We have the Mössbauer effect to measure the gravitational frequency shift of light [5] but no technologies to detect such a tiny change of sound so far. In contrast, the gravitational shift of sound ought to be observable by substituting the mass hf/C_s^2 of a phonon determined by the noninertial experiment [12] into Newton's law. The potential energy and total energy near the surface of the Earth are

$$-\frac{GM_0}{r}\frac{hf}{C_s^2}, \tag{73}$$

$$hf - \frac{GM_0}{r}\frac{hf}{C_s^2} = hf\left(1 - \frac{GM_0}{C_s^2 r}\right). \tag{74}$$

Namely,

$$f_1\left(1 - \frac{GM_0}{C_s^2 r_1}\right) = f_2\left(1 - \frac{GM_0}{C_s^2 r_2}\right). \tag{75}$$

Nevertheless, there is no need to test Equation (75) experimentally because it does not agree with the acoustooptic effect [13]. An incident photon hf_i can absorb the energy hf of a phonon, and the relation between the diffracted photon hf_d is

$$hf_i + hf = hf_d, \tag{76}$$

$$f_i + f = f_d. \tag{77}$$

Equation (76) does not allow for the gravitational interaction. According to Equation (71) of the photon and Equation (74) of the phonon, their energies in this process are

$$hf_i\left(1 - \frac{GM_0}{c^2 r}\right) + hf\left(1 - \frac{GM_0}{C_s^2 r}\right) = hf_d\left(1 - \frac{GM_0}{c^2 r}\right). \tag{78}$$

Owing to $GM_0/c^2 r \ll 1$,

$$hf_i + hf\left(1 - \frac{GM_0}{C_s^2 r}\right) = hf_d. \tag{79}$$

A typical speed in the acoustooptic material is $C_s = 5000$ ms^{-1}, and the total energy of a phonon is

$$hf\left(1 - \frac{GM_0}{C_s^2 r}\right) \approx hf\left(1 - \frac{gr}{C_s^2}\right) = hf\left(1 - \frac{9.8\,\text{ms}^{-2} \times 6.4 \times 10^6\,\text{m}}{5000^2\,\text{m}^2\text{s}^{-2}}\right) \approx -1.5hf. \tag{80}$$

Therefore, Equation (79) is

$$\begin{aligned} hf_i - 1.5hf &= hf_d, \\ f_i - 1.5f &= f_d. \end{aligned} \tag{81}$$

It is inconsistent with the experimental fact (77). We have to conclude that both the photon and phonon are subject to Equation (71) and the law of energy conservation in a gravitational field is

$$hf_i\left(1 - \frac{GM_0}{c^2 r}\right) + hf\left(1 - \frac{GM_0}{c^2 r}\right) = hf_d\left(1 - \frac{GM_0}{c^2 r}\right). \tag{82}$$

In a geometric theory, it is

$$hf_i\sqrt{1 - \frac{2GM_0}{c^2 r}} + hf\sqrt{1 - \frac{2GM_0}{c^2 r}} = hf_d\sqrt{1 - \frac{2GM_0}{c^2 r}}. \tag{83}$$

The gravitational shifts of light and sound are the same, but their noninertial shifts (Equations (64) and (67)) are unequal. That is to say, in a geometric description, $g_{\mu\nu}$ of the gravitational field only depends on the source and has nothing to do with K of the test particle while $g_{\mu\nu}$ of a noninertial frame is associated with not only the acceleration but also K. A gravitational field cannot be equated with the noninertial system, unless $K = c^2$.

12. Conclusions

Newton's law of universal gravitation is not universal. The charge of gravity should be the energy whose concept became mature in the 19th century, about 100 years after his death. For this reason, the electromagnetic radiation and neutrinos in the cosmos participate in the gravitational interaction no matter if they are massive or not. In general, the mass-energy equation of common objects is $E/m = c^2$, whereby Newton's law is applicable to most cases. Likewise, Einstein's general relativity is effective under the same premise of $E/m = c^2$. We came up with some exceptions which can be divided into two types. One is $E/m = \text{constant} \neq c^2$ [1–4] corresponding to a geometric description (Sections 8–11). The other is $E/m \neq \text{constant}$ [14, 15], and this paper proposes a new counterexample that the energy as the gravitational charge is changed by the potential (Equation (15)) which has no effect on the mass (Section 5) and the gravitational charge-to-mass ratio is no longer c^2 (Equation (44)). We hope the experiments in Sections 4–6 can be carried out as soon as possible.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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