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Gravitational-magnetic-electric interaction in controlling relative permittivity and permeability

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Abstract: Appling the controlling relative permittivity and permeability in the equations for the gravitational-magnetic-electric field interaction, a very large variation of the gravitational acceleration of the Earth by electric/magnetic field could be arrived at. This conclusion may be supported by some of the experiments for the gravitational effect of superconductor.

Key words: Gravitational-electric/magnetic interaction; Controlling permittivity and permeability; Superconductor

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The possible relation of gravity to electricity was first tested by Michael Faraday[1]in 1985 as the theory for the electromagnetic field was being developed. In recent, it was reported that the gravitational effect of electric/ magnetic field was observed.[2 -13] But, the effect is very little which is difficult to be observed. And, for different hypotheses and different experimental design, the observed results are different. Therefore, the effect is disputed experimentally and theoretically.[14-19] Here, we present that, the gravitational effect of superconductor[2-5] could be understood and explained with the equations for the gravitational-electric-magnetic interaction.[21] Further, we theoretically demonstrate that a very large effect that the gravitational acceleration of the Earth varied by the controlling permittivity and permeability could be arrived at.

The gravitational acceleration of the Earth varied by a strong electric/magnetic field can be easily understood from Figure 1. In a volume above the surface of the Earth, a body is gravitated by a gravitational acceleration g. g is related with the gravitational energy in this volume. As the volume is filled with photons, the energy of the photons is varied by the gravitational redshift. From the law of conservation of energy, it is easy to known that the energy of the gravitational field in the volume is correspondently varied by the light.

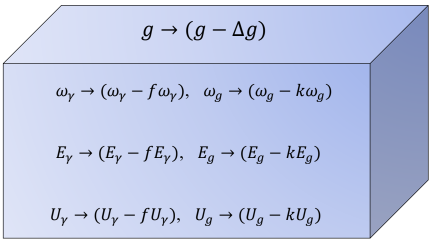

Figure 1. The variations of both electric/magnetic field and gravitational field in a volume. ω_γ and ω_g are the frequency of the photon and graviton, E_γ and E_g are the total energy of the electric/magnetic field and the gravitational field in the volume, f is the gravitational redshift parameter and k is the shift parameter of the frequency of the graviton by the electric/magnetic field (now, k has not been know.). U_γ is the energy density of electromagnetic field, for the electric and magnetic field, there is $U_e = \frac{\varepsilon_0 E^2}{2}$ or $U_m = \frac{B^2}{2\mu_0}$; for the gravitational field there is $U_g = \frac{g^2}{2G}$, where B is the magnetic flux density, E is the electric field intensity, g is the gravitational acceleration of the Earth; G, μ_0 and ε_0 are gravitational, magnetic and electric constant.

This conclusion is based on the well-known experiments: The gravitational redshift/blueshift, the bending of light by gravity and Shapiro time delay. In Pound–Rebka experiment [22,23], for gravitational redshift, the frequency of a photon is varied by gravity for that this photon can absorb a unit energy of the gravitational field. Therefore, as an electric/magnetic field is filled in a volume, both the gravitational field and electric/magnetic field in the volume are varied by each other in three aspects: 1) The frequencies of the photons are varied by gravitational redshift and the frequencies of the gravitons are varied by that a unit of energy is absorbed by the photons. 2) The total energy with the energy density of electric/ magnetic field and that of the gravitational field are varied by the variations of the frequencies of the photons and that of gravitons. 3) The two variations should make the gravitational acceleration g in the volume varied.

From the law of conservation of energy, we know, in this volume, the variation of the total energy of the electric/magnetic field is equal to that of the gravitational field. Therefore, there is

$$\begin{cases} k\frac{g^2}{2G} = f\frac{B^2}{2\mu_0} \\ k\frac{g^2}{2G} = f\frac{\varepsilon_0 E^2}{2} \end{cases} \tag{1}$$

From Equation (1), writing $\sqrt{k}g = \Delta g$, we have:

$$\begin{cases} \Delta g = \sqrt{fG/\mu_0}B \\ \Delta g = \sqrt{fG\varepsilon_0}E \end{cases} \tag{2}$$

From Figure 1, the experimental design to test Eq.(2) is clear. That the gravitational acceleration g in the volume is varied with Δg just means that the gravitational force of the Earth on a body with the mass M inside the volume is varied with $\mathrm{F} = \mathrm{M}\Delta g$. Correspondently, the weight of the body shall be varied:

$$\Delta M = M\frac{\Delta g}{g} \tag{3}$$

Therefore, this design is simple. Putting a body in a strong electric/magnetic field, as the variation of the weight of the body is measured, Eq.(2) shall is confirmed. Therefore, this experiment can be designed as shown in Figure 2.

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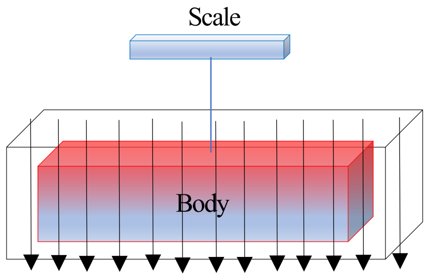

Figure 2. **The design to test the variation of the weight of the body in strong electric/magnetic field.** The red body is inside a strong electric/magnetic field. The weight of the body can be measured with the scale.

From the Figure 2, it is easy to know, for different materials, the relative permittivity ε_r and the relative permeability μ_r are different which determines that the energy density of the electric/magnetic field is different. Therefore, Eq.(1) can be rewritten as

$$\begin{cases} k\frac{g^2}{2G} = f\frac{B^2}{2\mu_r\mu_0} \\ k\frac{g^2}{2G} = f\frac{\varepsilon_r\varepsilon_0 E^2}{2} \end{cases} \tag{4}$$

Correspondently, Eq.(3) can be rewritten as

$$\begin{cases} \Delta g = \sqrt{fG/\mu_r\mu_0}B \\ \Delta g = \sqrt{fG\varepsilon_r\varepsilon_0}E \end{cases} \tag{5}$$

Eq.(5) shows that as $\varepsilon_r \to \infty$, there is $\Delta g = \sqrt{fG\varepsilon_r\varepsilon_0}E \to \infty$, and as $\mu_r \to 0$, there is $\Delta g = \sqrt{fG/\mu_r\mu_0}B \to \infty$. We know, now, the material with $\varepsilon_r \to \infty$ and $\mu_r \to 0$ not only were studied theoretically, but applied in many areas.[24-30] The variation of the gravitational acceleration by the relative permittivity ε_r and the relative permeability μ_r can be expressed in Figure 3. Therefore, making use of the materials, we could make a very large variation of the gravitational acceleration of the Earth in a small volume. It means that a way to use the gravity should be possible.

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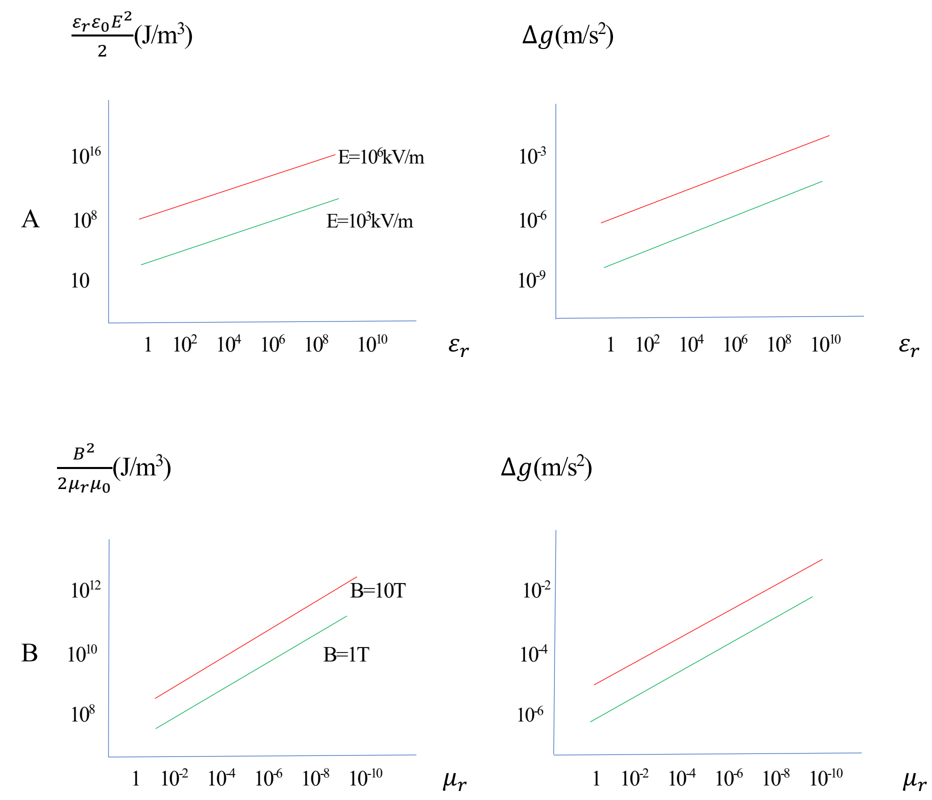

Figure 3. The variation of the relative permittivity and permeability and the variation of gravitational acceleration. A. The variation of energy density of electric field by ε_r and the variation of the gravitational acceleration by ε_r. **B.** The variation of energy density of electric field by μ_r and the variation of the gravitational acceleration by μ_r.

Figure 3 shows, for electric field, $U_e = (\frac{\varepsilon_0 E^2}{2})\varepsilon_r$ is corresponding to $\Delta g = (\sqrt{fG\varepsilon_0}E)\sqrt{\varepsilon_r}$. For magnetic field, $U_m = (\frac{B^2}{2\mu_0})\frac{1}{\mu_r}$ is corresponding to $\Delta g = (\sqrt{f\frac{G}{\mu_0}}B)\sqrt{\frac{1}{\mu_r}}$. It indicates that a lager energy is needed to make the gravitational acceleration varied. In mathematics, there are $U_e = (\frac{\varepsilon_0 E^2}{2})\varepsilon_r \to \infty$, as $\varepsilon_r \to \infty$ and $U_m = (\frac{B^2}{2\mu_0})\frac{1}{\mu_r} \to \infty$, as $\mu_r \to 0$. But, in fact, it is impossible to have a material that its energy density is infinite large. So, it is need to studied that what is the limit of the energy density of a material. After this limit is known, the limit of Δg shall be known.

The design in Figure 2 seems very simple. But, it is very important for arriving at right result. It further clarifies that our conclusion is that the gravitational acceleration of the Earth in a small volume is varied by an electric/

magnetic field. Therefore, the necessary condition to measure the variation of the gravitational acceleration is that the whole body is inside the electric/magnetic field. In this case, from Eq.(3) we know, the gravitational force on the body is not $\mathrm{F} = \mathrm{M}g$. Instead, it is $\mathrm{F} = \mathrm{M}(g - \Delta g)$. So, Figure 2 is helpful to further constraint our work. And, from Figure 2, the condition and device to detect Δg from Eq.(2), (5) or (6) can be known exactly. Therefore, in Supplementary Material 1, we give the detailed device for the experiment and predict the precision possible experimental result.

The gravitational effect of superconductor was reported[2-8] while it was disputed experimentally and theoretically.[14-20] Now, there has not been an accepted theoretical explanation for it. But, from our work, if Eq.(4) should be valid, for the superconductor, there is $\mu_r = 0$, a very large Δg should be produced. Therefore, the results in Refs.[2-5] may can be explained with Eq.(5). In Refs.[2-5], because of their theory, their experimental design is different from ours in Figure 2. The tested body is not wholly in a uniform magnetic field which results in that they cannot obtain the largest variation of gravitational effect. And, the position of the tested body relative to the magnetic field is different in different experiment, so the observed effect is different in different experiment.

In Refs.[2,3], the gravitational effect is related with the variation of the magnetic field. And, in Refs.[6, 13], it is related with discharge. We know, as an initial current produced from that a switch is on or off is used to produce an electric/magnetic field, a very large instantaneous initial electric/magnetic field can be produced. It could results in that, in Eq.(2) or (5), a very large instantaneous gravitational effect could be produced. Discharge is also related with the varying electric/ magnetic field while it is a complicated process. Therefore, Eq.(5) can be rewritten as

$$\begin{cases} \partial g = \sqrt{fG/\mu_r\mu_0}\,\frac{\partial B}{\partial t} \\ \partial g = \sqrt{fG\varepsilon_r\varepsilon_0}\,\frac{\partial E}{\partial t} \end{cases} \tag{6}$$

Different from the Maxwell equation, Eq.(6) only means that, as an electric/magnetic field is varied, the gravitational acceleration is correspondently varied. Now, we know, the gravitational acceleration of the Earth only is a single direction which cannot be affected by the electric/magnetic field. Therefore, in Eq.(6), the relation between the directions of the electromagnetic fields and the variation of the gravitational acceleration has not been known. It only can be known with further experiment.

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ε_r and μ_r are affected by the frequency of the electron in the material.[24] Because the polarized direction of the electron is determined with the direction of the electric/magnetic field, the ∂g should be affected by the direction of the body moving relative to that of the field.

The relationship between the initial electric/magnetic field and ε_r or μ_r is unknown. The value of the gravitational effect by a varying ε_r or μ_r only can be measured with experiment.

Ivanov[31] obtained the equation $F_g = \sqrt{G\varepsilon_r\varepsilon_0}E$ and $F_g = \sqrt{G\mu_r\mu_0}H$ in 2004. But, it is noted that, Ivanov's equations are different from our Eq.(5) physically and mathematically. In physics, in Ivanov's[31] equations, it is that a gravity is induced or produced from an electric or magnetic field. In our equations, it is that the local gravitational acceleration of the Earth is changed by a magnetic or electric field. In mathematics, in our equation, there is a gravitational redshift factor $f \approx 6.95 \times 10^{-10}$. This factor makes that the possible measurable force in our equations is much less than that in Ivanov's. And, in our work, the gravitational field is just varied by the gravitational redshift. So, the $f \approx 6.95 \times 10^{-10}$ is not only a mathematic constant, but expresses a process of physical interaction.

In our work, the graviton-photon interaction is studied.[21] In [21] the equation (12) was presented to unify the gravitational, electric and magnetic constant. Therefore, our work is related with the Grand Unified Theory. But, it is noted that, our work is not for the current Grand Unified Theory. Our work is just an effort trying to explain another aside of the experiment of gravitational redshift.[22,23] Just as a coin has two sides, one side of the experiment showed that the light was redshift by the gravity, which was well studied and understood; while another side could show that, at the same time, the gravity is changed by the light, which has not been noticed before our work.[21] Even if Eqs. (2), (5) and (6) had been experimentally confirmed, it should not mean that this is a resolution of the Grand Unified Theory. For example, the spin of the graviton and photon is not studied. But, the gravitational effect to the electromagnetic field need be included in the Grand Unified Theory. We think, the best way to detect the graviton is the graviton-photon interaction. Some work was done to understand the quantum gravity through bending of light[32] and gravitational redshift[33]. Therefore, our work may be a new possible to understand some aspects of graviton.

It is stressed that, the basic conditions to obtain a measurable result is that the electric field is $\mathrm{E} \geq 10^6 kV/m$ and the magnetic field is $\mathrm{B} \geq 10\mathrm{T}$ as presented in Table 1 and 2 in Ref.[21]. It is noted that, the analogous conditions was noted by Solomon.[20] He pointed out that, in the experiments with the zero result, the magnetic and electric is too small for a possible result. And, in the Supplementary Material 2, the experiments[2-5] on the gravitational effect of superconductor are reviewed. It is shown that, in a very rough standard, the experimental results in [2-5] is accordant with the prediction in Eq.(5) and Figure 3. These experiments may be the supporter of our work. It should imply that the gravitational effect of superconductor or electric/magnetic field is possible. For the two reasons, we think, it is worth further experiment to test the gravitational effect of electric/magnetic field.

Eq.(6) should be crucial if the gravitational effect only could be produced from that the field is varying analogous to the Faraday's law of induction. And, in Refs.[2,3,6,13], the effect was observed as the field is varying. So, Eq.(6) need be tested specially.

It is the feature of our work that, the predicted results with the conditions for the possible measurable results are exact, the conclusion in our work can be exactly observed with experiment. And, we have a detailed experimental design in the Supplementary Material 1. Very high precision measured result can be obtained from the experimental design. Therefore, the conclusion can be certainly and clearly assessed. These conclusions can be easily tested: 1) To test Eq.(2) with static electric/magnetic field. In Ref.[21], it was shown that, the variation of the gravitational acceleration varied by a strong magnetic field could be observed. Here, we presented that, $\triangle \mathrm{g} = \sqrt{fG\varepsilon_r\varepsilon_0}E$ can be tested with static electric field. As $\varepsilon_r = 34000$ which is the known largest relative electric permittivity, under the condition of $V = 100kV$ and $\mathrm{d} = 10^{-2}m$, there should be $\triangle \mathrm{g} = 1.18 \times 10^{-6}ms^{-2}$. In current technology, it is easy to be measured. We have a detailed experimental design in the Supplementary Material 1 for measuring it. 2) To test Eqs.(5) and (6) with varying electric/magnetic field and superconductivity. Superconductivity is a prior choice because there is $\mu_r = 0$ for superconductivity. A very large initial magnetic field can be produced from that an initial current is produced by that a switch is on/off. Therefore, a very large instantaneous $\partial g = \sqrt{fG\varepsilon_r\varepsilon_0}\frac{\partial E}{\partial t}$ could be correspondently produced. It is noted that the external magnetic field has an action on the superconductivity. Making the optimized combination of B and μ_r need be studied. 3) To test Eq.(6) with the moving body in the strong electric/magnetic field. 4) To explore the materials with controlling ε_r and μ_r which could produce large gravitational effect of electric/magnetic field. For the materials of $\varepsilon_r \to \infty$, because the external electric/magnetic field has action on ε_r,[24] how to make the combination of E and ε_r optimized need be studied.

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Supplementary Material 1

Experimental design

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The configuration is as the Figure 1. It is noted that the body need be inside in the electric/magnetic field.

1. Device and condition

1) For magnetic field

A Stable uniform magnetic field with $B \geq 20\ \text{Tesla}$; A magnetic insulation body with 50g; A scale with the precision of 10^{-6}g.

2) For electric field

An uniform electric field with $E \geq 10^4 kV/m$; A body of 50 g with $\varepsilon_r = 34000$; A scale with the precision of 10^{-6}g.

3) It is noted that, as the electric/magnetic field is not uniform, the energy density of the field need be revised according to Eq.(1) or (3).

2. **Method**

To measure the difference of the weight of the body between inside and out of an electric/magnetic field.

3. **Possible measured result**

1) For the magnetic field

According to Eq.(2) or the Table 1 in Ref.[], in a magnetic field with 20T, the gravitational acceleration of the Earth should be varied $\Delta g = 1.2 \times 10^{-5} \text{m}s^{-2}$. It should make the weight of a body with 50g varied almost $6 \times 10^{-5} g$.

2) For the electric field

According to Eq.(4), there should be $\triangle \text{g} = 1.18 \times 10^{-6} ms^{-2}$ as the weight of the body is 50g.

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4. **Modern technology for the experiment**

1) For the magnetic field, there are the stable magnetic field with 40 T in Hefei of China and in American. For the electric field, $E \geq 10^4 kV/m$ need $V \geq 10^2 kV$ and $d = 10^{-2} m$.

2) Modern gravity meter is with the precision of $10^{-8} ms^{-2}$, so the variation of gravitational acceleration of $\triangle g = 1.18 \times 10^{-6} ms^{-2}$ can be easily measured. The METTLER-TOLEDO precision balance is with a range from $10^{-6}\text{g} - 52\text{g}$. So, the variation of $6 \times 10^{-5}\text{g}$ of a body with 50g can be easily measured.

5. **Difficulty for the experiment**

The difficulty is to avoid the interference of the electric/magnetic field on the device.

1) The magnetic insulation materials are usually produced with Ni-Fe Alloy. It is a well-developed technology now.

2) The strong magnetic field has an interference on the scale. We can use a long magnetic insulation line to pend the sphere into the magnetic field.

3) The scale need be specially designed and manufactured.

6. **Further test for Eqs. (5) and (6)**

To test Eq.(5), the body in the electric/magnetic field can be replaced with superconductivity and the materials of $\varepsilon_r \to \infty$ and $\mu_r \to 0$. For example, put a superconductivity inside a magnetic field.

To test Eq.(6), there two ways. First, making the electric/magnetic field varied. Second, let the body moved in the electric/magnetic field.

An instantaneous large $\triangle g$ may be observed for that a very large initial electric/magnetic field can be produced by that a switch is on or off.

It is noted that, an instantaneous initial electric/magnetic field is unknown. It need be measured immediately.

7. **Conclusion**

This is a simple experiment. Modern device and instruments can make the measured result with very high precision.

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Supplementary material 2

A simple review on the experiments for the gravitational effect of electric/magnetic field

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It was reported that the gravitational effect of electric/magnetic field was observed in experiments.[2-17] There are these features in these experiments: 1) The hypotheses for the reasons to produce the gravitational effect are different; 2) The experimental designs with the device and instruments are different; 3) The values of the electric/magnetic fields are different. 4) The operations of the experiments are different; therefore, 5) The observed results are different. At the same time, the experiments of null results were reported.[17-19] Therefore, it is very difficult to assess whether or not this effect does exist and what is the exact express of this effect.

Many hypotheses are presented to explain these experiments. However, these hypotheses are difficult to be generally accepted.

We think, the key is to clarify whether or not there is the gravitational effect of electric/magnetic field.

From the gravitational redshift, it can be concluded that, the gravitational acceleration of the Earth could be affected by the strong electric/magnetic field. Theoretically, as the energy of the photons is shifted by gravitational field through gravitational redshift, the energy of the gravitational field is of course shifted correspondently by the photons. For the reason, we think, the experiments in Refs.[2-5] could be understood and explained with our Eqs.(2), (5) and (6).

For Eq.(5), the gravitational effect of superconductivity should be possible. For superconductivity, there is $\mu_r = 0$. As $\mu_r \to 0$, from Eq.(5), there is $\Delta g = \sqrt{fG/\mu_r\mu_0}B \to \infty$. From Figure 3 we know, a Δg close to the value that was observed in the experiments of [2-5] may be possible.

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For Eq.(6), the varying electric field was used in 4 experiments.[2,3,6,13] First is Podkletnov and Modanese's [2,3] experiment. It was observed that the gravitational effect is varied with the varying electric field. Second is experiment [6, 13]. In their experiment, the effect is varied with the discharge. As pointed out, a very large initial electric/magnetic field can be produced by that a switch is on or off. Therefore, a large gravitational effect may be produced in these experiments.[2,3,6,13]

We noticed that, in 5 experiments[15-19] the null result was reported. But, the conditions, such as the value of the electric/magnetic field, in these experiments are different. For Ref.[15], in the Supplementary Materials 3, it is shown that the effect of the superconductor cannot be measured. Therefore, it may be the gravitational effect of the strong magnetic field with B=2T was measured which is roughly accordant with the prediction in the Table 1 of Ref.[21]. In Ref.[16], it is claimed that, the condition in the experiment[16] is the same as that in [2,3]. But, it is found that there is not a magnetic field with a certain position in the experiment setup[16]. This makes that the experiment condition in [16] is different from [2,3]. And, in the Supplementary Materials 4, it is shown that the conclusion in Ref.[19] is simply and clearly wrong.

In Ref.[20], after reviewing the experiments and theories for the gravitational effect of superconductivity, Solomon had a conclusion for the conditions that need to be met for any future experiments. Of his 7 conditions, there are: "First, an electrical field with surface field strength on the order of 10^7 N/C. Second, a magnetic field on the order of 15T." The analogous conditions are also listed in the Table 1 and 2 in Ref.[21] Therefore, we think, the experiments in Refs.[2-5] may be the supporters of our work and in Refs.[15-19] the magnetic field is omitted. So, it is too arbitrary to claim that the gravitational effect of the electric/magnetic field has been unproven from these experiments[15-19].

From Eq.(5) and Figure 3, we know, to arrive at $\triangle \mathrm{g} = 1 \times 10^{-3} ms^{-2}$, it is needed that $\mathrm{B} = 1\mathrm{T}$ and $\mu_r = 10^{-10}$, or $\mathrm{B} = 10\mathrm{T}$ and $\mu_r = 10^{-8}$. In this case, the weight of a body may be changed on the level about 0.01%. In the Table 1, the experimental results related with the magnetic fields in Refs.[2-5] was listed. Therefore, in a very rough standard, the conditions and predicted results in Figure 3 are accordant with the conditions and experimental results in Refs.[2-5].

For these reasons, we have the conclusions: 1) The current experiments could show that, in a high probability,

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the gravitational effect of electric/magnetic field is possible. 2) These experiments may be understood and explained with the equations in our works. Therefore, these experiments may be supporter of our work. 3) So, further experiment is needed. 4) As pointed out in Refs.[20,21], in future experiment, these conditions need be stressed: the electric field need be $E \geq 10^6 kV/m$, the magnetic field $B \geq 10T$. Considering Eqs.(5) and (6), as $\varepsilon_r \to \infty$ and $\mu_r \to 0$, less E and B can be possible. Therefore, superconductivity may be a prior choice. The possible result can be known from Eqs.(5) and (6) and Figure 3. It is noted that, it is difficult to know the value of ε_r and μ_r which need be measured immediately.

Table 1.

Experiments about gravitational effect of superconductivity

Name	Podkletnov & Nieminen	Podkletnov	Rounds	Tajmar et al
magnetic field		2T	0.5T	20mT
Weight variation (%)	0.05-0.3	0.3-2.1	0.05-0.1	10ug

Note: These are the experimental results with magnetic fields in Refs.[2-5].

Supplementary Material 3

A simple investigation of "Static test for a gravitational force coupled to type II YBCO superconductors" by Li and coworkers

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In 1977, Li and coworkers published "Static test for a gravitational force coupled to type II YBCO superconductors".[1] They claimed that they detected the effect "coupling between static superconductors and gravity".

It was presented that the variation of gravitational field of the Earth varied by strong electric/magnetic field could be measured.[2] And, in a superconductor, because of the relative permeability $\mu_r \to 0$, in theory, this effect could be enlarged infinitely.[3]

The effect produced from $\mu_r \to 0$ is only inside the superconductor. But, in Li and coworkers' experiment,[1] the effect is measured with a gravimeter. Thus, the effect inside the superconductor cannot be measured in [1]. So, it is thought, the effect that measured in [1] only is that the gravitational field is varied by the strong magnetic field with B=2T as presented in [2]. In a rough standard, the measured result in [1] is accordant with the prediction in the Table 1 of Ref.[2]. Therefore, in Ref.[1], the measured result is not related with the gravitational effect of the superconductor.

It is clear, the effect measured by Li and coworkers[1] is different from that in Refs[4-7] in which the variations of the weight of the superconductors were measured. Therefore, according to Refs[2,3], the gravitational effect inside the superconductors was measured in [4-7]. And, the measured results in Refs.[4-7] are roughly accordant with the prediction in Ref.[3].

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Supplementary Material 4

Comment on "Put Strong Limits on All Proposed Theories so far Assessing Electrostatic Propulsion: Does a Charged High-Voltage Capacitor Produce Thrust?"

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Abstract: Prof. Tajmar and co-worker claimed that, our result in the paper "Gravitational-magnetic-electric field" was ruled out by their experiment. But, factually, their conclusion about our work is simply and clearly wrong.

In the paper "Put Strong Limits on All Proposed Theories so far Assessing Electrostatic Propulsion: Does a Charged High-Voltage Capacitor Produce Thrust?",[1] Prof. Tajmar and co-worker claimed that, our result[2] was ruled out by their experiment. But, factually, their conclusion about our work is simply and clearly wrong.

First, it is clear wrong that Tajmar and co-worker classified our work into the Ivanov's model. Our work is radically different from Ivanov's although Ivanov's equations[3] are $F_g = \sqrt{G\varepsilon_r\varepsilon_0}E$ and $F_g = \sqrt{G\mu_r\mu_0}H$ while our equations are $\Delta g = \sqrt{fG\varepsilon_0}E$ and $\Delta g = \sqrt{fG/\mu_0}B$. But, it is noted that, Ivanov's equations are different from ours physically and mathematically. In physics, Ivanov's equations[3] means that "Strong gravitational force induced by static electromagnetic fields." Our equations means that the local gravitational acceleration of the Earth could be changed by a magnetic or electric field. In mathematics, in our equation, there is a gravitational redshift factor $f \approx 6.95 \times 10^{-10}$. This factor makes that the possible measurable force in our equations is much less than that in Ivanov's.[3] And, in our work, the variation of the gravitational field is just because of the gravitational redshift. So, the factor $f \approx 6.95 \times 10^{-10}$ is not only a mathematic constant, but an description of the process of physical interaction.

Second, in the Table 2 of our paper[2], we clearly showed, to test our work, the electric field need be

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E=1×10⁶kV/m to make a measurable variation of $\Delta g = 1 \times 10^{-7} m s^{-2}$. But, in Tajmar and co-worker's experiment[1], there is only $E \le \frac{1}{7} \times 10^4$kV/m. According to our work, as $\varepsilon_r = 4200$ is considered, Tajmar and co-worker's electric field is still too little to make the variation of $\Delta g = 1 \times 10^{-7} m s^{-2}$.

Third, Tajmar and co-worker's[1] balance cannot measure the variation of the gravitational acceleration on the level of $\Delta g = 1 \times 10^{-7} m s^{-2}$ which is correspondent to that the variation of the weight of 1kg is 1×10^{-5}g. But, Tajmar and co-worker's balance only can measure the variation of the weight larger than 0.3$\times$ 10^{-3}g and the weight of the body they used only is 2$\times$ 5.8g.

It seems that Tajmar and co-worker misunderstood the physics and mathematics in our equations and neglected the gravitational redshift factor $f \approx 6.95 \times 10^{-10}$ in our equations. It is clearly shown that their conclusion[1] "Put Strong Limits on All Proposed Theories so far Assessing Electrostatic Propulsion" is not true.

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