Unification of electric and gravitational interaction in classical physics

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Abstract

This paper challenges the quantum-focused search for a unified theory of fundamental interactions by exploring the potential unification of electric and gravitational forces within classical physics. Highlighting the similarities between Coulomb's law and Newton's law of universal gravitation, it suggests that signs of unification should be observable on a macroscopic scale. The concept of gravitomagnetic fields, akin to magnetic fields in electromagnetism, is introduced, supported by experimental evidence from rotating masses and a notable experiment with a superconducting disk. This experiment hinted at the generation of a powerful gravitomagnetic field, suggesting a gravitational analogue to electromagnetic phenomena.

The discussion extends to gravitational synchrotron radiation, proposing that celestial bodies in orbit emit this radiation, influencing their orbital dynamics. This concept is used to explain the observed mergers of black holes and neutron stars detected by gravitational wave observatories, framing these events as influenced by gravitational waves rather than spacetime vibrations.

A central argument for unification is the treatment of rest mass as the true invariant gravitational charge, challenging the current understanding of black holes and suggesting they are states of matter with finite density without traditional event horizons. The paper concludes with a reevaluation of the Schwarzschild radius and event horizons, proposing thought experiments that question established interpretations and advocate for a classical physics approach to unifying gravitational and electric interactions.

The unification of all interactions in nature is considered an obvious matter to all physicists. The sought-after theory that will combine all interactions in a coherent manner is called the Theory of Everything. The search for the Theory of Everything is pursued at the quantum level. So far in quantum physics, three of the four fundamental interactions have been unified, leaving gravity as the only interaction that has not been unified. It is believed that once a quantum theory of gravity is formulated, unification of all interactions will be achieved. However, there is only one doubt: electrical and gravitational interactions are similar, both being long-range interactions, and therefore are easy to investigate at the level of classical physics. Coulomb's law and Newton's law of universal gravitation are practically identical. If there is unification between these two interactions, it should also be visible on a macroscopic scale.

The electric interaction is much stronger than the gravitational interaction. (The gravitational force between two protons is 36 orders of magnitude weaker than the electric interaction). Nevertheless, nowadays we have very precise measurement methods, so it is possible to search for effects in gravitational interaction that occur in the electric interaction.

In the theory of electric fields, two basic vectors are distinguished: the electric field intensity vector $\vec{\boldsymbol{E}}$ and the magnetic induction vector $\vec{\boldsymbol{B}}$, which characterizes the so-called magnetic field. The vector $\vec{\boldsymbol{E}}$ can be called the static aspect of the electric field, while the vector $\vec{\boldsymbol{B}}$ represents its dynamic property.

In electricity, there are two types of charges, denoted by a plus and a minus sign. When two charges of the same absolute value but opposite signs are in the same location, the electric field disappears. In gravitational interaction, there is only one type of charge, and this is the fundamental difference between these two interactions. As long as there are any gravitational charges (mass) in space, the static gravitational field cannot be turned off.

In an electric conductor carrying current, electrons from the conduction band move with respect to stationary positive charges, resulting in no net electrostatic field in the conductor. However, a magnetic field arises as a dynamic aspect of the electric field. In gravitational interaction, due to the existence of only one type of charge, there is no way to separate the static and dynamic effects of the gravitational field. Nevertheless, if unification between these two interactions exists, such dynamic effects should also appear for the gravitational field, although they are heavily masked by the static effect (gravitational force).

A coil carrying an electric current produces a magnetic field. Rotating masses such as the Earth, Sun, and other celestial bodies should produce a similar field, which we can call the gravitomagnetic field. How can we detect the gravitomagnetic field of the Earth? One way is to insert another gravitomagnetic coil and measure the precise forces acting on it. This coil could be a rotating mass, such as a disk made of a material that does not produce any magnetic field that could interfere with the measurement. Ideally, the disk would be made of a superconductive metal to ensure that it is not a source of a magnetic field.

The strangest thing is that such an experiment was carried out. On March 21, 2006, at the European Space Research and Technology Centre in the Netherlands, the European Space Agency announced the results of an experiment in which a superconducting disk was spun up to 6500 revolutions per minute, and precise measurements showed an increase in the disk's weight. The conclusion of this experiment was as follows: "The experiment demonstrated that a superconducting gyroscope is capable of generating a powerful gravitomagnetic field and is therefore the gravitational analogue of a magnetic coil. Although it is one millionth of the acceleration caused by the Earth's gravitational field, the measured field is astonishingly a hundred billion billion times larger than predicted by Einstein's general theory of relativity".

Unfortunately, the experiment was not carried out to completion because the disk was not spun in the opposite direction. In that case, measurements should have shown a slight decrease in the weight of the disk, by the same amount that it increased during the previous rotation. This experiment was conducted in the Netherlands (approximately **51°** north latitude), where the angle between the Earth's axis and the disk's axis was about **39°**. The greatest difference in weight between the resting disk and the spinning disk would have been observed at the pole, where both gravitational magnetic coils, namely the disk and the Earth, would be coaxial. However, it should be noted that in electrical interactions, like charges repel each other, while in gravitational interactions, they attract each other. Therefore, when such a disk is spun at the pole in the same direction as the rotation of the Earth, an additional repulsive force will occur, while spinning in the opposite direction will result in an additional attractive force.

Another evidence that a gravitomagnetic field exists around rotating celestial bodies are the rings of Saturn. Such rings, although more diffuse, are also present around other planets such as Jupiter or Uranus. Exoplanets with such rings have also been observed. A characteristic feature of these rings is that they always lie perfectly in the plane of the planet's equator and are very thin.

Using currently accepted theories, it is not possible to explain the properties of these rings. However, when gravitational-magnetic forces are taken into account, everything becomes clear. Of course, the rings must orbit the planet in the opposite direction to the rotation of the parent planet, because then forces are present that press the ring material into the equatorial plane. There has never been any information published about observations that would determine the direction of Saturn's ring rotation. It seems that everyone assumes *a priori* that the directions of the planet's and rings' rotations are consistent. A thorough analysis of data obtained from the Cassini-Huygens mission could provide an answer to the question of which direction Saturn's rings rotate.

Recently, a similar situation was observed in the galaxy NGC 3147, where a very thin disk was detected revolving around the central supermassive black hole. In this case, the disk and black hole are also rotating in opposite directions. However, when a relativistically rotating accretion disk falls onto a supermassive black hole also rotating at relativistic speeds in the same direction, the formation of matter jets can be explained as a result of the action of, among others, gravitomagnetic forces. Simply put, these forces tear apart the material of the accretion disk, directing it along the axis of the black hole in two opposite directions. The magnetic field generated by such a relativistic black hole likely also plays a significant role in shaping the jets.

The second experiment, which also measured effects originating from Earth's gravitomagnetic field, was a NASA-funded space project called Gravity Probe B. It began in 2004, and the final results were announced in 2011. The goal of the project was not to measure Earth's gravitomagnetic field, but rather to measure the curvature of spacetime around Earth and the effect of "dragging" spacetime caused by the rotation of the Earth. In this experiment, four gyroscopes (gravitomagnetic coils) with perfectly spherical shapes and spherically distributed mass were placed on a satellite (any deviation from these parameters could have introduced an additional moment of force on the gyroscope axes). Deviations in the gyroscopes' axes from their initial positions were measured using a telescope directed at the binary star system IM Pegasi. The satellite's orbit had an inclination of **90°**, so it flew over the poles with an orbital period of 97.6 minutes. This orbit configuration caused a variable moment of force from Earth's gravitomagnetic field to act on the gyroscopes' axes with a frequency equal to the orbital period. This moment of force arises from the fact that Earth's gravitomagnetic field tries to align the gyroscopes' axes parallel to the lines of force of the field.

The interpretation of the measurement results was very challenging if one wanted to justify the existence of the space-dragging effect (the analysis of the results took about four years). If the concept of the Earth's gravitomagnetic field were taken into account, the experimental results would have been easier to interpret.

Much better results would have been obtained if the satellite had been placed in an equatorial orbit, or two satellites, one of which orbited in the same direction as the Earth's rotation, while the other in the opposite direction. In that case, if the gyroscopes' axes were set at an angle (preferably **45°**) to the Earth's axis, a constant torque would act on these axes, causing them to precess uniformly. The gravitational-magnetic field of the Sun would also have some effect on the precession of these gyroscopes' axes. (The gravitational-magnetic field of the Sun also affects the precession of the Earth's axis.)

Another phenomenon that is very characteristic of the electric interaction is synchrotron radiation. It is observed when an electrically charged particle is subjected to an acceleration perpendicular to its velocity. This radiation occurs with high intensity in synchrotrons, where electric charges are accelerated along circular paths to relativistic speeds, hence its name. It is asymmetric and causes a reduction in the speed of the charged particle, which is why such pseudo-hydrogen atoms, where an electron would orbit a proton around the center of mass along any circular or elliptical orbit, are not observed in vacuum. Simply put, the electron loses energy due to synchrotron radiation and falls onto the proton.

If there is unification between the gravitational and electric fields, then there must exist a gravitational version of synchrotron radiation, which means that any two celestial bodies orbiting a common center of mass should emit such radiation and ultimately fall towards each other.

Immediately, the question arises as to why the Moon does not fall towards the Earth, but rather moves away from it. Firstly, the gravitational interaction is very weak, so at non-relativistic velocities, this phenomenon is almost imperceptible. Secondly, the Moon orbits the Earth in the same direction as the Earth rotates, and due to tidal forces, part of the Earth's angular momentum is transferred to the Moon. As a result, the Moon moves away from the Earth by an average of 38mm per year, and the sidereal day is systematically lengthened. (1.4 billion years ago, a day on Earth lasted about 18 hours, and the average radius of the Moon's orbit was much smaller). If the Moon orbited the Earth in the opposite direction, it would "fall" towards it, because this time it would be transferring part of its angular momentum to the Earth. However, the rate of this fall would be much, much greater than the rate of fall due to gravitational synchrotron radiation.

In our immediate vicinity, all large celestial bodies such as stars, which mutually orbit each other, move at non-relativistic speeds, therefore the gravitational synchrotron radiation emanating from them has very low frequency and amplitude, and is practically immeasurable. However, recently, with the help of the LIGO and Virgo observatories, the final stage of the merger of black holes or neutron stars has been detected. Quite a few such events have been recorded so far. The small diameter and large mass of these objects allow them to achieve relativistic speeds, making their gravitational synchrotron radiation very intense and of high frequency. Despite significant distances, it is detected by the sensitive equipment of these observatories. We are not dealing with the vibration of space here, but with the vibration of instruments (mirrors) under the influence of gravitational wave, just as electrons vibrate under the influence of electromagnetic wave.

The unification of these two interactions also requires that the charges of electric and gravitational interactions have similar properties. The characteristic feature of electric charges is that they are invariant under Lorentz transformations, that is, they have the same value in all reference frames. In this situation, in order to meet the requirements of unification, the gravitational charge, which is mass in Newton's formula, should also be an invariant of this transformation. Currently, it is assumed that total energy is the gravitational charge, but the total energy of a body depends on the reference frame. Such an approach to gravitational charge makes it impossible to unify gravitational interaction with electric interaction. Rest mass fulfills this condition, it is an invariant of Lorentz transformation, so rest mass is the gravitational charge.

One should note that the inertial mass in the equation of the second law of Newton's dynamics is not the same as the rest mass. Therefore, the problem that troubled physicists for some time has disappeared. The inertial mass in the second law of dynamics is not the same as the mass that appears in Newton's universal law of gravitation. So, what is the inertial mass in the second law of dynamics? After the announcement of Einstein's the special theory of relativity, the second law of dynamics has been modified. Its relativistic version looks as follows:

$$\vec{a} = \frac{\sqrt{1 - \frac{|\vec{v}|^2}{c^2}}}{m_r} \left[\vec{F} - \frac{1}{c^2} \left(\vec{F} \cdot \vec{v} \right) \vec{v} \right] \tag{1}$$

where m_r is the rest mass of the body, $\vec{v}$ and $\vec{a}$ are its velocity and acceleration, $\vec{F}$ is the force acting on the body, c is the speed of light, and a dot denotes the scalar product of vectors.

If we take into account that the total energy (E_t) of a body is given by:

$$E_t = \frac{m_r c^2}{\sqrt{1 - \frac{|\vec{v}|^2}{c^2}}} \tag{2}$$

then equation (1) can also be written as:

$$\vec{a} = \frac{c^2}{E_t} \left[\vec{F} - \frac{1}{c^2} \left(\vec{F} \cdot \vec{v} \right) \vec{v} \right] \tag{3}$$

Formula (2) for the total energy applies to a body at absolute zero temperature and without angular momentum. Formula (1) also applies under these same conditions. Therefore, formula (3) is appropriate, where the total energy of the body can include not only the rest mass, but also the temperature and the kinetic energy resulting from the velocity and angular momentum.

Formula (3) can be transformed to give the force vector in terms of the acceleration vector:

$$\vec{F} = \frac{E_t}{c^2}\left(\vec{a} + \frac{\vec{a}\cdot\vec{v}}{c^2 - |\vec{v}|^2}\vec{v}\right) \tag{4}$$

In equations (3) and (4), we see that the concept of inertial mass has become ambiguous. It is not possible to unambiguously indicate the proportionality coefficient between the acceleration vector and the force. We have a complex relationship related to the directions of acceleration, force, and velocity vectors. Therefore, the equivalence of gravitational mass and inertial mass is only an apparent equivalence resulting from subjective (local) feelings of the internal observer.

Relativistic formulas for the first and second cosmic velocity

Accepting the assumption that gravitational mass is rest mass requires a change in stance regarding relativistic formulas for the first and second cosmic velocities.

The first cosmic velocity is the velocity of a satellite moving in a circular orbit with a radius of R around a central body, where R is also the radius of that body. In such a circular motion with velocity v, the centripetal acceleration is given by the formula:

$$a = \frac{v^2}{R} \tag{5}$$

The centripetal force acting on a body moving in such an orbit, according to the relativistic form of the second law of dynamics (4), is given by:

$$F = \frac{E_t}{c^2}a \tag{6}$$

(As velocity and acceleration vectors are perpendicular in this case, the second term in parentheses in formula (4) equals zero). If we neglect the temperature and any possible angular momentum of a satellite with rest mass m_r, then formula (6) can be written as:

$$\boldsymbol{F} = \frac{\boldsymbol{m_r}}{\sqrt{\boldsymbol{1 - \frac{v^2}{c^2}}}}\,\boldsymbol{a} \tag{7}$$

After substituting the acceleration from (5) into (7), we obtain the relativistic form of the formula for the centripetal force:

$$\boldsymbol{F} = \frac{\boldsymbol{m_r\, v^2}}{\boldsymbol{R}\sqrt{\boldsymbol{1 - \frac{v^2}{c^2}}}} \tag{8}$$

On the other hand, from Newton's law, it follows that the force acting on a satellite moving in a circular orbit of radius $\boldsymbol{R}$ around a central body of rest mass $\boldsymbol{M_r}$ is given by:

$$\boldsymbol{F} = \frac{\boldsymbol{G M_r m_r}}{\boldsymbol{R^2}} \tag{9}$$

where $\boldsymbol{G}$ is the gravitational constant, equation (8) and (9) yield the following equation:

$$\frac{\boldsymbol{m_r\, v^2}}{\boldsymbol{R}\sqrt{\boldsymbol{1 - \frac{v^2}{c^2}}}} = \frac{\boldsymbol{G M_r m_r}}{\boldsymbol{R^2}} \tag{10}$$

The solution of this equation is the relativistic formula for the first cosmic velocity:

$$\boldsymbol{v_I} = \frac{\boldsymbol{G M_r}}{\boldsymbol{\sqrt{2}\, c\, R}}\sqrt{\sqrt{\boldsymbol{1 + \frac{4c^4 R^2}{G^2 M_r^2}}} - \boldsymbol{1}} \tag{11}$$

It is necessary to verify what value this formula gives for Earth. Assuming the mass of Earth to be $5.97219 \times 10^{24}\,[kg]$, the average radius of Earth to be $6\,371\,008\,[m]$, the gravitational constant to be $6.67428 \times 10^{-11}\left[\frac{m^3}{kg\, s^2}\right]$, and the speed of light to be $299\,792\,458\,[m/s]$, equation (11) yields the value:

$$\boldsymbol{v_I = 7909.7898257\,[m/s]}$$

On the other hand, according to the previously used non-relativistic formula:

$$\boldsymbol{v_I} = \sqrt{\frac{\boldsymbol{GM}}{\boldsymbol{R}}} \tag{12}$$

$$\boldsymbol{v_I = 7909.7898271\,[m/s]}$$

We obtained a result that differs just in the tenth significant digit. If the same calculations are performed, for example, for a neutron star with a mass of two solar masses and a radius of $\mathbf{12\,000}\,[\boldsymbol{m}]$, according to formula (11): $\boldsymbol{v_I} = \mathbf{139\,868\,400}\,[\boldsymbol{m/s}]$, while the traditional calculation yields - formula (12): $\boldsymbol{v_I} = \mathbf{148\,720\,918}\,[\boldsymbol{m/s}]$. This time, the first cosmic velocity calculated using formula (11) is nearly $\mathbf{6\%}$ smaller than that calculated using the currently used formula.

The function given by formula (11) is a continuously decreasing function in the range of $\boldsymbol{R} \in \langle \mathbf{0}, \boldsymbol{\infty})$, and the limit of this function for $\boldsymbol{R} \to \mathbf{0}$ is $\boldsymbol{c}$. Therefore, it can be observed that for any massively compact black hole with a radius greater than zero, there exists a first cosmic velocity smaller than $\boldsymbol{c}$.

> *Attention! For the Schwarzschild radius* $\boldsymbol{R_{Sch}} = \frac{\mathbf{2}\boldsymbol{GM}}{\boldsymbol{c^2}}$*, the first cosmic velocity according to formula (11) is* $\boldsymbol{v_I} = \mathbf{187\,313\,486}\,[\boldsymbol{m/s}]$*, while according to the non-relativistic formula (12):* $\boldsymbol{v_I} = \mathbf{211\,985\,280}\,[\boldsymbol{m/s}]$.

On the other hand, in order to find the relativistic formula for the second cosmic velocity, one needs to calculate the energy that must be expended to move a test body with a rest mass $\boldsymbol{m_r}$ from the surface of a celestial body with a rest mass $\boldsymbol{M_r}$ and radius $\boldsymbol{R}$ to infinity.

> *Attention! The second cosmic velocity is the velocity that must be imparted to a test body on the surface of a celestial body to allow it to escape to infinity, assuming that only these two bodies are present in space.*

The work $\boldsymbol{W}$ required to move a test body to infinity is determined by the formula:

$$\boldsymbol{W} = \frac{\boldsymbol{G M_r m_r}}{\boldsymbol{R}} \tag{13}$$

The relativistic formula for kinetic energy $(\boldsymbol{E_k})$ is as follows:

$$\boldsymbol{E_k} = \boldsymbol{E_t} - \boldsymbol{m_r c^2} \tag{14}$$

After substituting the expression from formula (2) for $\boldsymbol{E_t}$:

$$\boldsymbol{E_k} = \boldsymbol{m_r c^2} \left(\frac{\mathbf{1}}{\sqrt{\mathbf{1} - \frac{|\vec{v}|^2}{c^2}}} - \mathbf{1} \right) \tag{15}$$

Therefore, one needs to solve the equation:

$$\frac{\boldsymbol{G M_r m_r}}{\boldsymbol{R}} = \boldsymbol{m_r c^2} \left(\frac{\mathbf{1}}{\sqrt{\mathbf{1} - \frac{|\vec{v}|^2}{c^2}}} - \mathbf{1} \right) \tag{16}$$

We have obtained the relativistic formula for the second cosmic velocity:

$$\boldsymbol{v_{II} = c\sqrt{1 - \frac{R^2c^4}{(GM_r + Rc^2)^2}}} \tag{17}$$

According to the equation, it follows that as the radius of the central body approaches zero, the second cosmic velocity approaches the speed of light regardless of the central body's mass. So, it is similar to the case of the first cosmic velocity: for any massive black hole with a radius greater than zero, there exists a second cosmic velocity smaller than $\boldsymbol{c}$.

The second cosmic velocity for Earth calculated according to equation (17) is:

$$\boldsymbol{v_{II} = 11\,186.1320431\,[m/s]}$$

Calculated using the non-relativistic formula:

$$\boldsymbol{v_{II} = \sqrt{\frac{2GM}{R}}} \tag{18}$$

is:

$$\boldsymbol{v_{II} = 11\,186.1320489\,[m/s]}$$

This time the difference appeared on the eleventh significant digit.

Note! For the Schwarzschild radius, the second cosmic velocity according to the relativistic formula (17) is $\boldsymbol{v_{II} = 223\,452\,105\,[m/s]}$, *while according to the formula (18):* $\boldsymbol{v_{II} = c}$.

The conclusion that black holes have their own escape velocities may seem surprising, but there is nothing unusual about this when one considers that there are no limits to the kinetic energy of massive objects. As the velocity of a massive object, in the reference frame of the central object, approaches the speed of light, its kinetic energy approaches infinity, while its gravitational charge (rest mass) remains constant. Therefore, one should ask oneself what black holes are, if they have no event horizon. **Black holes are another state of matter with an extremely high, but finite density**, and are a manifestation of the Universe's tendency to achieve maximum entropy.

Regarding the Schwarzschild radius – let's consider the following thought experiment. Suppose we have a very massive object gathered in a certain place, for which the Schwarzschild radius is half a light-year, i.e., 4,730,365,236,290,400 meters. Using the formula for the Schwarzschild radius, this mass $\boldsymbol{M = \frac{R_{Sch}c^2}{2G} \approx 3.185 \times 10^{42}[kg]}$. If it were a gas uniformly distributed in a sphere of that radius, its density would be approximately $\mathbf{7.183 \times 10^{-6}} \left[\frac{kg}{m^3}\right]$, which is five orders of magnitude less than the density of air at sea level. (*Note! The gravitational field intensity, when approaching the center of this sphere, would decrease from about* $9.5 \left[\frac{m}{s^2}\right]$ *to zero*). Let's construct from this mass a perfectly symmetric spherical shell with a radius 3 meters shorter than half a light-year. It must be symmetric so that we can apply the Schwarzschild metric to it. The gravitational acceleration on the surface of this shell will be less than that on the surface of the Earth and will be approximately $\frac{GM}{R_{Sch}^2} \approx \mathbf{9.5} \left[\frac{m}{s^2}\right]$. However, inside this shell, the gravitational field intensity will be zero. When we stand on this shell, about a meter above our heads, there should be an event horizon stretching out. Let's consider what will happen when we throw a stone or a ball or aim a laser light upwards. Will all these objects shatter against some invisible "glass ceiling" called the event horizon?

The strange situation presented above arises from the fact that the gravitational field strength is directly proportional to the mass of the central object, but inversely proportional to the square of the distance from that object. Meanwhile, the Schwarzschild radius is directly proportional to the mass of the central object. Therefore, when the mass of the central object increases, for example, twice, the Schwarzschild radius also increases twice, but the gravitational field strength for this new radius decreases twice. Thus, when the mass of the central object approaches infinity, according to the General Theory of Relativity, the gravitational field strength at the event horizon approaches zero. In this situation, it is difficult to find a reason why crossing the event horizon from the inside is impossible.

Bibliography

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