Interrelations between electrodynamics and gravitation

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Abstract

Many physical phenomena are connected by cause and effect relationships, even if they belong to different fields. The fragmentation of the science, along with a compensating abundance of postulates, results in theoretical constructions that have great complexity.

The existence of such a problem is evidenced by a large number of postulates and paradoxes in electrodynamics and the theory of relativity. Examples include Faraday's homopolar generator, discovered back in the 1820's, and the twin paradox. So far they have no satisfactory explanation within the Standard Model.

The situation in these fields could improve significantly if we were to use two interrelated theories, which have undeservedly been superseded by others. One of them is Paul Gerber's generalized force of gravitation. Gerber correctly predicted the anomalous advance of the Mercury perihelion, 17 years before publication of the general theory of relativity, and without using curved space and time dilation. Gerber's law has no *ad hoc* constants, and it has not been refuted.

The second theory is Wilhelm Weber's force law. This resolves paradoxes and reduces the number of postulates in electrodynamics. Some doubts arose with regard to Weber's theory as to whether his force formula guarantees the energy conservation of moving electric charges.

Here we show that Weber's force does guarantee the conservation of energy, and the proof is based on Gerber's method. This discovery allows us to take the two theories as the basis for an alternative paradigm.

Our analysis of Gerber's approach to the derivation of the generalized gravitational potential provides a perspective for understanding the nature of gravitation. The phenomenon is based on two interrelated processes, whereas previously proposed theories of gravitation were based on a single process or on the space-time curvature without specifying any physical cause of it.

Introduction

Modern electrodynamics abounds with paradoxes. Particularly noteworthy among these is Faraday's homopolar generator [1], discovered back in the 1820's. So far this has no satisfactory explanation within the standard paradigm. Only with the help of Weber's theory [2] has this paradox found explanation [3][4].

We consider interrelations between Wilhelm Weber's theory and that of Paul Gerber [5][6]. The two theories are similar in that they proceed from the same assumption about the dependence of the force on the relative velocity of two bodies. Weber addressed the interaction of electric charges, while Gerber addressed the gravitational interaction of masses. The original idea about the dependence of the interaction force between moving charges on their relative velocity belongs to Carl Gauss [7].

Weber continued and developed Gauss' idea and published his fundamental force law in 1846. On the basis of the same idea, Gerber proposed a modified gravitational law for two moving masses in 1898.

Weber's theory has many advantages [3][4]: first, his force formula includes only the relative velocity of the two charges, so that uniform motion of the observer cannot affect the force between the charges. From Weber's formula the empirical formula of Ampere for the interaction of currents is derived [8], as well as the law of electromagnetic induction, but it lacks the physical model that is present in Gerber's theory. The purpose of this article is to eliminate this shortcoming.

Many different formulas for the force between two moving masses were proposed (see [9]). We have chosen Gerber's theory because it has three advantages over other theories: 1) to deduce his force law Gerber used a model of the physical process in which the action propagates through the medium; 2) Gerber's results gave excellent agreement with the experimental data to account for Mercury's perihelion advance; 3) Gerber's law has no *ad hoc* constants (or no free parameter to be determined from the data).

N.T. Roseveare, a historian of science and the author of the review book on Mercury's perihelion [9], admitted that "the Gerber force formula is mathematically identical to Albert Einstein's formula for general relativity." In another citation from the same book: Gerber's theory "faded from view rather than being publicly refuted" (p144). Nevertheless Roseveare himself tried to refute Gerber's theory: "Gerber's formula doesn't include the velocity-dependence of mass implicit in any viable theory of dynamics. **Lacking any reason for excluding it,** this effect, which adds 7 arcseconds per century to the perihelion precession of Mercury, must be added to Gerber's formula." There exists such a reason and it will be presented in the Discussion section.

Roseveare's criticism was criticized by the anonymous author of the mathematical notes [10]. Here is his/her remark regarding the logic: Roseveare's conclusion is "somewhat incongruous with the pre-relativistic foundations of Gerber's theory… the derivation must be without introducing any special relativistic features."

When writing about the deflection of light near a gravitating body, Roseveare applies the non-relativistic formula to the photon, treating it like a stone, and he comes to the conclusion that Gerber's force law gives an incorrect deviation of the rays from distant stars. Such misuse of the formula is just as irrelevant as it would be to apply Newton's second law to calculate the acceleration of a photon.
Thus Roseveare could not reasonably refute Gerber's theory.

General hypotheses

The gravitational and electrical forces are not contact forces - their action is transmitted from one body to the other by some medium or field. The force source generates a deviation from the equilibrium state of the medium or field. The propagation speed of these deviations is finite; therefore there is a delay in the action transmission which does not have to be the same for different phenomena. The medium state can be described by a "potential function." In Coulomb's and Newton's laws the potential depends only on the distance r between the bodies ($V=\mu/r$), but such an approach is valid only for stationary states, whereas for moving bodies it is necessary to use a modified potential taking into account its retardation.
Hence the force between the bodies depends, in part, on their relative velocity.

Initially Weber did not provide the potential from which his force law could be derived. He began from the force expression having empirical origin – its integral along electrical currents is equal to Ampere's formula for the force between the electric currents [8].
Helmholtz forced Weber to present a suitable potential (see [11]) and then Weber suggested the electric potential in the following form:

$$V = \frac{e\, e'}{r}\left[1 - \frac{1}{c^2}\left(\frac{dr}{dt}\right)^2\right],$$

where r is the distance between the interacting charges e and e'. This potential function was selected in such a way that its derivative gave Weber's force expression.

But Maxwell rightly argued that if the potential includes v^2 with a minus sign, then this leads to an increase in energy of a body acted on by a force like friction:

"This impossible result is a necessary consequence of assuming any formula for the potential which introduces negative terms into the coefficient of v^2." [11] p.431.

This was a damning verdict for Weber's theory, but the correction to Weber's potential, presented below, leads to a positive coefficient in the term with v^2, thus removing Maxwell's objection. This correction follows from application of Gerber's approach to the derivation of the electric potential for the case of moving charges.

Gerber's gravitational potential

52 years after Weber published his force law, another physicist, Paul Gerber, drew an analogy between the interaction of electric charges and the gravitational interaction of masses (see [6]). Following Weber, Gerber assumed a dependence of the gravitational force on the velocity of the body, but instead of choosing an expression for the generalized gravitational potential, Gerber deduced the potential from the static one taking into account its retardation. The delay is a consequence of the finite propagation speed of the medium state.

The objective was to derive the force from the generalized gravitational potential for the case of moving masses. Let the mass M be stationary, and the other body with mass m' moves away from it with a radial velocity v = dr/dt, so the negative value of v means the masses approach each other (Fig. 1).

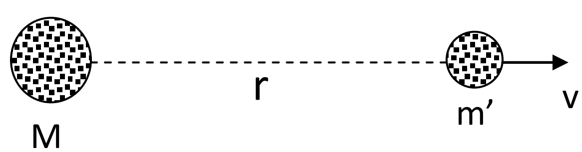

Fig.1. Interaction of moving masses.

It is necessary to determine the potential at m' at the moment t, when the distance between the masses is r. At this moment, the mass m' experiences the action of the potential that was emitted by the mass M at an earlier time t' = t- Δt = t -r/c. Here c is the propagation velocity of the gravitational potential in the solar system.

At time t' the distance r' between the masses was different from r. Let us compute r' using the current distance r(t) between the masses and its derivatives. Expanding to a series in the small quantity Δt, we get

$$r'=r(t-\Delta t)=r(t)+\dot{r}(-\Delta t)+\ddot{r}\Delta t^2/2+\ldots \simeq r\left(1-\frac{\dot{r}}{c}+\frac{r\,\ddot{r}}{2c^2}\right). \qquad (1)$$

(Note: if the time instant is not explicitly specified in (1), then the moment t is implied.)

Gerber restricted the series to the linear terms only $r' \simeq r\left(1 - \frac{\dot{r}}{c}\right)$.

The other correction factor reflects the variable "density" of the incoming potential as a result of the mass m' motion ([6] Gerber, p.435). Gerber did not give a detailed description of the process, but we can imagine this process by analogy with the Doppler effect [12], where the motion of the receiver affects the apparent frequency of the wave. For a moving observer and a stationary source, due to the motion, the rate at which the observer receives waves is changed so that the apparent frequency is equal to $f = f_0 \frac{1}{1-v/c}$.

On the whole, the generalized gravitational potential is equal to $V = \frac{\mu}{r} / \left(1 - \frac{\dot{r}}{c}\right)^2$, and neglecting powers of $\frac{\dot{r}}{c}$ greater than the second, Gerber obtained the potential

$$V \simeq \frac{\mu}{r}\left(1 + 2\frac{\dot{r}}{c} + 3\frac{\dot{r}^2}{c^2}\right), \qquad (2)$$

where μ is a constant.

The derivation of Gerber's force formula is presented in the left column of Table 1.

What is remarkable is that the expression obtained for the generalized gravitational force allowed Gerber to correctly predict the anomalous advance of the Mercury perihelion, 17 years before the publication of the general theory of relativity and without curved space-time.

Correction to Weber's electric potential

Following Gerber, we apply his method to derive a formula for the generalized electric potential taking into account the motion of charges. We start from the static electric potential $\frac{ee'}{r}$ which resembles its gravitational equivalent. The retardation of the electric potential is taken into account in the same way that Gerber did, i.e. dividing the static potential by $\left(1 - \frac{\dot{r}}{c}\right)$, but now c denotes the propagation velocity of the electric potential. Next, we must take into account the influence of the relative velocity of the charges on the apparent potential density.

Table1.Comparison of the derivations of the two generalized force laws.

Gerber's derivation of his generalized gravitational force between two moving masses	Our derivation of Weber's force law for two moving electric charges
Gerber used the retarded potential $V=\frac{\mu}{r}/\left(1-\frac{\dot r}{c}\right)\left(1-\frac{\dot r}{c}\right)$, where the second bracket is a consequence of a change in the "density" of the potential in a unit of time due to the relative velocity of the charges.	The retardation of the potential gives the correction factor $1/\left(1-\frac{\dot r}{c}\right)$, as in the case of gravity. But the second correction factor is equal to $1/\left(1+\frac{\dot r}{c}\right)$.
Gerber's approximation of the gravitational potential to the terms of the order $\frac{\dot r^2}{c^2}$: $V=\frac{\mu}{r}/\left(1-\frac{\dot r}{c}\right)^2 \simeq \frac{\mu}{r}\left[1+2\frac{\dot r}{c}-\frac{\dot r^2}{c^2}+\left(2\frac{\dot r}{c}-\frac{\dot r^2}{c^2}\right)^2\right] \simeq \frac{\mu}{r}\left(1+2\frac{\dot r}{c}+3\frac{\dot r^2}{c^2}\right)$	Approximation of the corrected gravitational potential to the terms of the order $\frac{\dot r^2}{c^2}$: $V=\frac{e\,e'}{r}\frac{1}{\left(1-\frac{\dot r}{c}\right)\left(1+\frac{\dot r}{c}\right)} \simeq \frac{e\,e'}{r}\left(1+\frac{\dot r^2}{c^2}\right)$
Applying the Lagrange formula for Gerber's force calculation $F=\frac{d}{dt}\left(\frac{\partial V}{\partial \dot r}\right)-\frac{\partial V}{\partial r}= \frac{d}{dt}\left[\frac{\mu}{r}\left(\frac{2}{c}+6\frac{\dot r}{c^2}\right)\right]+ \frac{\mu}{r^2}\left(1+\frac{2\dot r}{c}+3\frac{\dot r^2}{c^2}\right)= \frac{\mu}{r^2}\left(1-3\frac{\dot r^2}{c^2}+6\frac{r\ddot r}{c^2}\right)$	Applying the Lagrange formula for Weber's force calculation $F=\frac{d}{dt}\left(\frac{\partial V}{\partial \dot r}\right)-\frac{\partial V}{\partial r} =\left(2\frac{\dot r}{c^2}\right)\frac{d}{dt}\frac{ee'}{r}+\frac{e\,e'}{r}2\frac{\ddot r}{c^2} +\frac{ee'}{r^2}\left(1+\frac{\dot r^2}{c^2}\right) =\frac{ee'}{r^2}\left(1-\frac{\dot r^2}{c^2}+2\frac{r\ddot r}{c^2}\right)$

When the charges are moving away from each other ($\dot{r} > 0$), the density of the incoming potential is reduced by a factor of $1 + \frac{\dot{r}}{c}$. Therefore, it is necessary to further subdivide the generalized potential by $1 + \frac{\dot{r}}{c}$ (see the right column in Table 1). As a result, we get

$$V = \frac{ee'}{r} / \left(1 - \frac{\dot{r}^2}{c^2}\right) \simeq \frac{ee'}{r}\left(1 + \frac{\dot{r}^2}{c^2}\right), \qquad (3)$$

which differs from the potential that was chosen by Weber: the plus sign appears where Weber’s potential has minus.
As we already mentioned, the minus sign in the coefficient of v^2 does not guarantee the energy conservation. The corrected potential (3) has a plus sign in the term of v^2, thus Maxwell's requirement is satisfied.

Gerber derived his force from the gravitational potential using Lagrange’s formula. In contrast, Weber took the total derivative of the electric potential with respect to r. Furthermore details of the method are presented in the next section.

Choice of the method of force derivation from the generalized potential

Gerber used Lagrange’s formula [13] to calculate the gravitational force on a moving body. Such a choice is justified by the fact that Lagrange’s equation for the motion of a body under the action of the force F follows from Newton's 2nd law:

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{r}} - \frac{\partial T}{\partial r} = F \qquad (4)$$

where T is the kinetic energy of the body. If there exists a potential energy function V(r, dr/dt) that depends on position and velocity, such that the force F can be derived from a potential V so that

$$F = \frac{d}{dt}\frac{\partial V}{\partial \dot{r}} - \frac{\partial V}{\partial r} \qquad (5)$$

then the system with L=T-V satisfies the Euler–Lagrange equation of motion [13]

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{r}} - \frac{\partial L}{\partial r} = 0. \qquad (6)$$

This ensures compliance with the principle of energy conservation E = T + V = constant during the motion.

In contrast, Weber calculated the force on the charge by taking the total derivative of the potential with respect to r:

$$F_W = \frac{dV}{dr} = \frac{\partial V}{\partial r} + \frac{\partial V}{\partial \dot{r}}\frac{\partial \dot{r}}{\partial r}. \qquad (5')$$

But such a force does not ensure the conservation of energy in the case of moving charges.

We wrote above (see Eq.3) that in deriving the formula for the electric force on a moving charge according to Gerber's method, we must replace the minus sign by plus in Weber's potential $\frac{ee'}{r}\left(1 - \frac{\dot{r}^2}{c^2}\right)$. Now we have shown that it is also necessary to calculate the force by Lagrange's formula (5).
These two corrections lead to the same force that was initially published by Weber in 1946. That is, Weber's formula for the electric force on a moving charge was correct, and all attacks on it were erroneous.

Thus Weber's force law, based solely on Ampere's empirical force, is consistent with the principle of energy conservation and can be derived from the physical model.

On the nature of gravitation

If the electric and gravitational potentials were identical, we would obtain the same coefficients in the expressions for electric and gravitational forces. But Gerber obtained the force formula with coefficients which differ from Weber's force. This difference occurs due to the different correction factors of the potential density: $1/\left(1 + \frac{\dot{r}}{c}\right)$ for the electric potential vs. $1/\left(1 - \frac{\dot{r}}{c}\right)$ for the gravitation. Such a difference cannot be related to attraction or repulsion, because the electric charges have both. Proceeding from the analogy with the Doppler effect, at v> 0 the correction factor $1/\left(1 - \frac{\dot{r}}{c}\right)$ is greater than one, which means that the mass m' moves against the density potential stream. That is, the retarded potential moves away from mass M, while the density potential moves towards mass M, in the opposite direction.

The counter-movement of two opposite streams seems impossible, but if everything relating to the nature of gravitation were simple, physicists would have come up with a conceivable explanation for this phenomenon long ago.

To demonstrate the possibility of oncoming movement of two potentials, we propose an analogy with another phenomenon in which cold and heat flow towards each other.

Imagine a closed room with air in a state of thermodynamic equilibrium. A refrigeration unit starts operating in the room, which violates the equilibrium. This distortion begins to propagate (with delay) to an ever greater distance, which causes a counter-flow of heat. In the end, the dynamic equilibrium of the two counter flows is established, so that they become stationary. But these are not two independent flows - the heat flow is the reaction of the medium to the distortions resulting from the cold flow.

The described dual process may serve as an analog to the gravitational process.

Discussion

There are many unresolved paradoxes in physics. Among the most famous are the twin paradox and Faraday's homopolar generator, discovered back in the 1820's, and so far this has no satisfactory explanation within the Standard Model.

This fact, as along with a large number of postulates, indicates the need to create an alternative paradigm, which would include a consistent set of theories that would reduce the number of postulates and unresolved paradoxes.

The theories of Weber and Gerber are parts of the new paradigm, but they are not the only ones. Costa de Beauregard wrote in his book "Time, the Physical Magnitude" [14] : "Each physical magnitude constitutes a feature of some physical carrier." Bakman and Pogorelsky [15] showed that the time in the relativity theory is detached from its carrier; therefore time dilation has no physical meaning.

Eliminating the postulate of the constancy of the light speed enables the evident explanation for the retardation of radar echo from the planets in the Shapiro experiment [16] by slowing down the light speed near the sun, instead of by time dilation (Fig.2). In addition, a simple explanation is obtained for the deflection of a light ray near the sun [17], [18]. L.Okun also presented the gravitational redshift of photons in the most elementary way [17]. Together with Gerber's correct prediction of the advance of the Mercury perihelion, all the four pieces of evidence for general relativity have simple interpretations.

According to special relativity, the mass of a body depends on its absolute velocity, but the absolute velocity of a body is the speed relative to the observer. It turns out that the mass of a body depends on the observer, which is a paradox. A quote from [19], [20]: "It has been increasingly recognized that relativistic mass is a troublesome and dubious concept."

V.Bush [21] showed, that Weber's theory, when applied to interpretation of the experiments with fast electrons, "involves an invariant mass" (see also [3] [4]). In other words, Weber's force law does not need the hypothesis of the variable mass of the electrons. Thus, with the inclusion of Weber's theory in the alternative paradigm, the paradox of a variable mass disappears by itself. Now we have the reason for excluding the mass-velocity dependence from the Gerber theory as opposed to Roseveare's statement (see Introduction).

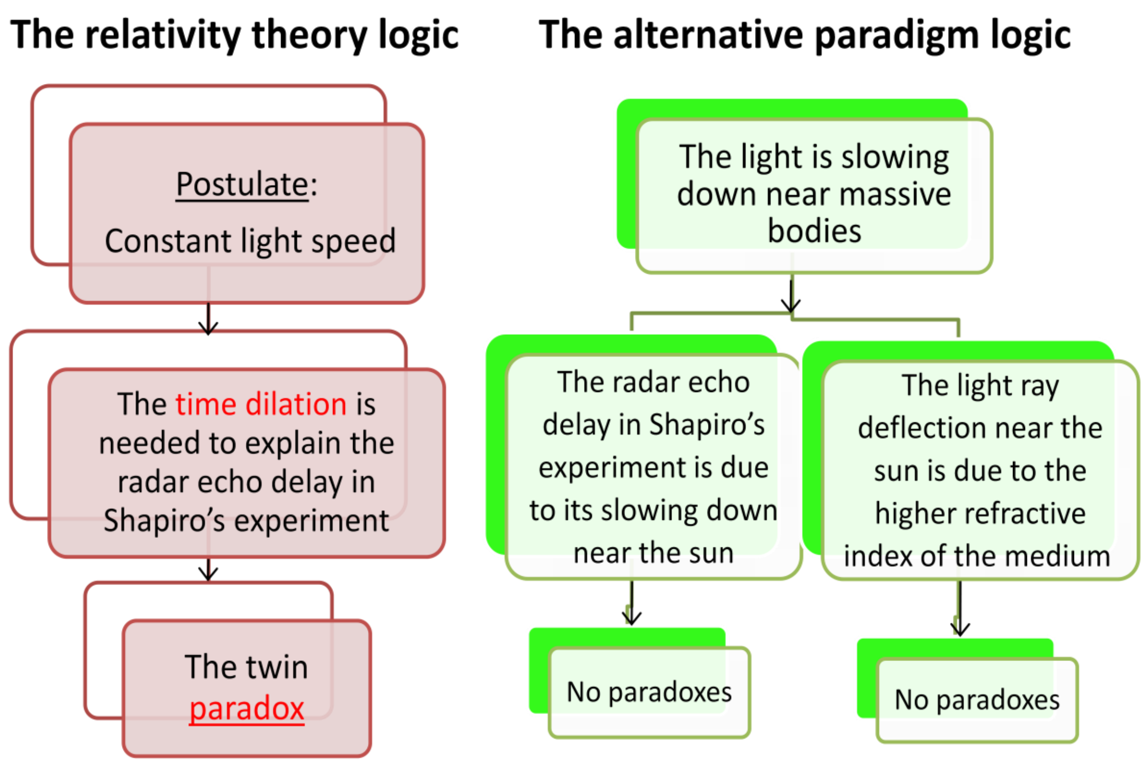

Fig.2.The postulate of the constant light speed requires the time dilation and eventually results in the twin paradox.

It should be also noted that with the help of Weber's force the Faraday paradox and other paradoxes of electrodynamics are resolved [4]. Our analysis of Gerber's approach to the derivation of the generalized potential sheds light on the nature of gravitation.

Summary

Weber's force law has many remarkable properties. In particular, intractable (insoluble) paradoxes of electrodynamics can be solved using it as a basis. Nevertheless, Weber's famous contemporaries Helmholtz and Maxwell demanded an expression for the electric potential which would guarantee energy conservation for the charges. Weber presented such a potential, but it did not satisfy Maxwell, and eventually Weber's theory was superseded by others. In this article we have made a correction to the Weber potential; the correction is based on Gerber's physical model for the gravitational interaction of moving bodies. As a result, all doubts about the validity of Weber's theory are dispelled so that the undermined reputation of his theory is restored.

Gerber's gravitational law also belongs to the same paradigm. Our analysis of Gerber's approach to the derivation of the generalized potential sheds light on the nature of gravitation. The phenomenon is based on two interrelated processes, whereas previously proposed theories of gravitation were based on one process. General theory of relativity and its modifications stand alone; they are based not on a process, but on the curvature of spacetime without specifying the physical cause of this curvature.

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