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RESEARCH ARTICLE

What is Hidden in the Gerber's Gravitational Potential?

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Abstract

Paul Gerber proposed in 1898 a velocity-dependent gravitational potential intended to represent the rate of propagation of gravitation and to account for the anomalous perihelion advance of Mercury. The potential has the form of a Newtonian term multiplied by a retardation factor depending on the radial velocity divided by a propagation speed. Its historical importance is that, at leading order, it yields the same perihelion-advance formula later obtained in general relativity. This contribution analyzes the formula, decomposes its mathematical parts, identifies the physical information inserted into it. This paper tries to reveal what information is inserted into this formula: that gravity is not treated as an instantaneous action at a distance, the term dr/dt tells the potential whether the test body is moving inward or outward. This term contains information about motion, not only about static distance. The formula naturally introduces small corrections of order v/c (it eliminates the gravitation aberration), and v^2/c^2 with acceleration corrections. The cooperation of these corrections results in the correct value for the anomalous perihelion advance of Mercury. This inspiration was employed for the evaluation of the anomalous acceleration of Pioneer 10 and Pioneer 11 – the Pioneer anomaly. There were derived formulae for the outward and inward acceleration corrections of objects moving in the Solar system away from the Sun and towards to the Sun. Finally, we have proposed a general formula of the Gerber´s gravitational potential based on the probable behavior of blue- and redshifted gravitons leading to the correction known as the "dark matter" and "dark energy". The lead angle of the graviton helix generates axial forces – attractive and repulsive forces.

Keywords: Blue- and Redshifted Gravitons, "Dark Energy", "Dark Matter", Gerber´s Gravitational Potential, Pioneer Anomaly, the Lead Angle of Helix Generates Axial Forces.

1. Introduction: why Gerber Deserves a Careful Reading[1]

In the history of gravitation, Paul Gerber occupies an uncomfortable position. He is remembered because his retarded-potential calculation led to the correct leading formula for Mercury´s anomalous perihelion advance, e.g. [1]-[14]. He is also criticized because the route by which he reached that formula was not accepted as a satisfactory theory of gravitation. A fair analysis should avoid two opposite errors, The first error is to dismiss Gerber as worthless simply because general theory became the successful theory. The second error is to claim that Geber had already discovered the full content of Einstein´s theory. Gerber inserted into a Newtonian-looking potential an important intuition: gravity may not be a timeless action-at-a-distance, but delayed, motion-sensitive interaction.

This paper therefore treats Gerber´s potential as a historical and mathematical object. The question is not whether it can replace general relativity, e.g. [15]-[28]. The question is what information was inserted into the formula, what mathematical properties it has, why it gives Mercury´s perihelion shift, and where it fails as a physical theory.

2. The Formula: Newton Plus a Retardation Factor

The Newtonian potential energy of two masses M and m separated by a distance r is:

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$$V\_N(r) = -\frac{GMm}{r} \tag{1}$$

Gerber´s velocity dependent gravitational potential may be written in modern notation as:

$$V\_G(r,\dot{r}) = -\frac{GMm}{r}\frac{1}{\left(1-\frac{\dot{r}}{c_g}\right)^2} \tag{2}$$

Here dr/dt means the radial rate of change of the separation, and c_g is the propagation speed that Gerber associated with gravity. In many historical presentations c_g is simply written as c, because Gerber inferred a value close to the speed of light from Mercury´s perihelion data.

Gerber´s potential can be divided into three conceptual layers as it is shown in Table 1.

Table 1. *The anatomy of the Gerber´s gravitational potential*

Part	Mathematical form	Inserted information
Newtonian core	$-\frac{GMm}{r}$	The ordinary inverse-distance gravitational potential
Motion variable	$\dot{r} = \frac{dr}{dt}$	The potential depends on the radial motion, not only on position
Retardation scale	c_g	A finite speed is inserted into the interaction through the ration (dr/dt)/c_g
Amplification factor	$\frac{1}{\left(1-\frac{\dot{r}}{c_g}\right)^2}$	The Newtonian potential is modified by a velocity-dependent delay factor
New: Transverse graviton speed	$c_g = c\sqrt{1+\frac{2GM}{r\,c^2}}$	The conical Pappus spiral with a graviton has a longitudinal speed c and transverse speed c_g
c_g for the Schwarzschild radius R_S	$c_g = \sqrt{2}c$	Elimination of the singularity at the Schwarzschild radius

The Gerber´s potential for c_g = constant can be expanded as:

$$V\_G = -\frac{GMm}{r}\left[1+\frac{2\dot{r}}{c_g}+\frac{3\dot{r}^2}{c_g^2}+\ldots\right] \tag{3}$$

This expansion shows clearly what was inserted into Newtonian potential: a hierarchy of velocity-dependent corrections. The small parameter is (dr/dt)/c_g. In a planetary orbit this number is tiny, but over many revolutions the resulting small correction accumulates into a measurable precession of perihelion. There is a possible innovation to insert into the Gerber´s potential the transverse speed of graviton c_g instead of the longitudinal speed of graviton c to avoid the singularity at the Schwarzschild radius.

3. What Information is Inserted in the Formula?

The first piece of information is that gravity is not treated as an instantaneous action at a distance. The potential contains a propagation speed c_g. Historically, this was a natural question at the end of nineteenth century, when electrodynamics had already made finite field propagation central to physics.

The formula asks whether the separation is changing. The term dr/dt tells the potential whether the test body is moving inward or outward. This is why the phrase "the field carries memory" is a useful metaphor: the gravitational effect contains information about motion, not only about the static distance.

The formula 2(dr/dt)/c_g is a hidden part in the mathematical structure of the Gerber´s potential and via this mathematical trick the physics of the orbit behaves as gravity acts with infinite speed, preserving the perfect stability of Mercury´s path. The physical reality is that gravity propagates at a finite speed, but the mathematical structure of the Gerber´s potential features a built-in cancellation mechanism to overcome the gravitational aberration [11].

The Gerber´s formula naturally introduces another small correction: 3(dr/dt)^2/c_g^2 that describes the correction for the radial acceleration of the test mass during its path around the central mass.

4. Mathematical Properties of Gerber´s Potential

When the radial velocity is very small compared with the propagation speed, (dr/dt)/c_g is near zero, and Gerber´s formula reduces to Newton´s potential:

$$if\ |\dot{r}| < c_g\ then\ V\_G \to V\_N = -\frac{GMm}{r} \tag{4}$$

The potential is a generalized potential: it depends on both r and dr/dt. A generalized radial force is therefore obtained not only by differentiating with respect to r, but also by accounting for the dr/dt dependence:

$$F(r) = d/dt(\partial V\_G/\partial \dot{r}) - \partial V\_G/\partial r \tag{5}$$

To leading non-Newtonian order, the associated radial force contains terms of the schematic form:

$$F(r) \approx -(GMm/r^2)\left[1 - 3(\dot{r}^2/c_g^2) + 6(r\ddot{r}/c_g^2) + \ldots\right] \tag{6}$$

The exact signs depend on the adopted sign convention for the radial direction and potential. The important point is that force law contains acceleration-like and velocity-like corrections, not only inverse-square term.

The denominator in Gerber´s factor vanishes when dr/dt=c_g:

$$1 - \frac{\dot{r}}{c_g} = 0 \tag{7}$$

This singular behavior is not a practical problem for ordinary planetary motion, where the radial speeds are much smaller than c_g, but it shows that the formula should not be treated as a universal relativistic law. However, we can eliminate this singularity at the Schwarzschild radius with c_g interpreted as the transverse graviton speed:

$$1 - \frac{\dot{r}}{c_g} = 1 - \frac{\dot{r}}{c\sqrt{1 + \frac{2GM}{rc^2}}} = 1 - \frac{1}{\sqrt{2}} = \frac{2-\sqrt{2}}{2} \tag{8}$$

With this new model of blue- and redshifted gravitons we might further develop the inner mathematical structure of the Gerber´ potential. The energy lost by redshifted photons in the gravitational field is transferred to the blueshifted gravitons and vice versa – the conservation of the total energy in the gravitational field.

The celebrated result is that Gerber´s potential leads to the leading perihelion advance per orbit:

$$\Delta\varpi = \frac{6\pi GM}{a(1-\varepsilon^2)c^2} \tag{9}$$

where a is the semi-major axis and ε is the eccentricity. If c_g is set equal to the speed of light c, this is the same expression obtained from the Schwarzschild solution of general relativity. For Mercury, this gives approximately 43 arcseconds per century for the anomalous part after Newtonian perturbations and other effects are removed. Gerber used the observed anomaly in the reverse direction: he inferred a propagation speed to the speed of light.

5. How Gerber´s Potential was Received

Gerber´s 1898 paper was part of a broader late nineteenth-century effort to modify Newtonian gravitation by analogy with electrodynamics. Many proposals inserted finite propagation speeds, velocity-dependent forces, or Weber-Riemann- type terms into gravity [9]. Most of these attempts were eventually abandoned because they lacked a consistent relativistic field structure and because Maxwellian electrodynamics changed the standards for acceptable theories.

Gerber´s potential became controversial after Einstein´s 1915 calculation of the perihelion advance. The mathematical identity of the leading Mercury formula attracted attention, especially among critics of relativity. In 1917 Gerber´s expanded work was republished in Annalen der Physik. This historical episode led to questions of priority and to sharp criticism of Gerber´s derivation.

The mainstream scientific judgement was that Gerber´s theory did not provide a valid alternative to general relativity. The deeper reason was that general relativity supplied a whole architecture: field equations, covariance, the equivalence principle, light bending, gravitational redshift, and later a coherent post-Newtonian and gravitational-wave framework. Gerber supplied one successful leading formula but not the full building. Gerber should be credited for touching an important idea: finite propagation and velocity-dependent gravity. But reproducing one numerical coefficient is not enough to establish a fundamental theory.

6. What May Still be Valuable in Gerber´s Formula?

The valuable part of Gerber´s formula is not the claim that it replaces general relativity. Its value is heuristic.

It preserves a simple inscription: the gravitational interaction may contain delayed information about motion. This inscription may be expressed in four ideas summarized in Table II.

Table 2. *The four ideas how to further develop the Gerber´s formula*

Idea	Modern interpretation
Causality	The gravitational effect should not be purely instantaneous
Retardation	The present field may encode information from earlier source configuration
Velocity dependence	Motion of source and test body matters in any finite-propagation theory
Field memory	The field is not only a static pull, it carries information about history and motion

Gerber´s retarded gravitational potential is neither a worthless curiosity nor a complete theory. It is an important velocity-dependent potential that gives the correct formula for the perihelion advance of Mercury. It may still carry some "hidden" physical meaning in this simple mathematical formula.

Table III summarizes some "hidden" physical meaning extracted from the Gerber´s gravitational potential.

Table 3. *The "hidden" physical meaning deposited in the Gerber´s gravitational potential*

Correction	Formula	Physical meaning
The first order correction	$\frac{2\dot{r}}{c_g}$	Removes the gravitational aberration
The second order correction	$\frac{3\dot{r}^2}{c_g^2}$	Correction of the radial acceleration
Longitudinal graviton speed	$c_{g\rightarrow} = c$	The rate of propagation of the gravitational field
Transverse graviton speed	$c_{g\updownarrow} = c\sqrt{1+\frac{2GM}{rc^2}}$	Absorbs the energy from redshifted photons in the gravitational field
Energy to graviton	$E_g = mc_g^2 = m\left(1+\frac{2GM}{rc^2}\right)$	Absorbs the energy from redshifted photon
Energy from redshifted photon	$E_p = mc_p^2 = m\left(1-\frac{2GM}{rc^2}\right)$	Redshifted photon in the gravitational field
Graviton speed at the Schwarzschild radius	$c_g = c\sqrt{1+\frac{r_S}{r}} = \sqrt{2}\,c$	Elimination of the singularity at the Schwarzschild radius
The lead angle of the graviton helix generates axial forces – attractive and repulsive forces.		

7. The Pioneer Anomaly

The Pioneer anomaly was an unexpected, subtle deceleration detected in the flight paths of NASA´s Pioneer 10 and Pioneer 11 spacecraft as they traveled into deep space, e.g. [29]-[33]. For decades, navigators noticed the probes were slowing more than expected under the Sun´s gravity, sparking theories about new physics. When the spacecraft passed about 20 astronomical units (AU) from the Sun, telemetry data revealed an unmodelled acceleration directed toward the Sun. The deceleration was extremely small:

$$a_P = (8.74 \pm 1.33) \times 10^{-10}\ ms^{-2} \tag{10}$$

Over a 10-year period, this reduced the outbound velocity by about 1 km/h. Because no obvious mechanical or gravitational factors explained the discrepancy, scientists hypothesized that the effect might be a manifestation of dark matter, the Kuiper belt, or even breakdown in Einstein´s theory of relativity.

After intensive recovery and analysis of archival spacecraft data by scientists, the mystery was largely resolved in 2012 as the anisotropic heat loss [33]. This thermal radiation explanation was proven, and many exotic hypotheses to explain the Pioneer anomaly were stopped in further development.

There was developed a modified gravity model (MOND - Modified Newtonian Dynamics) proposed by Mordehai Milgrom [34], that suggests that

Newton´s second law (F = ma) breaks down when the acceleration of an object drops below a fundamental threshold $a_0 \approx 1.2 \times 10^{-10}$ m/s^2, and it was applied to the Pioneer anomaly due to its striking numerical similarity to the probes´ unexplained deceleration.

Gerber derived his correction of the Newtonian potential for the circular path. For the linear outward direction from the Sun, we propose a correction in the form:

$$\frac{1}{\sqrt{1-\frac{\dot{r}^2}{c_g^2}}} \approx 1+\frac{1}{2}\frac{\dot{r}^2}{c_g^2}+\frac{3}{8}\frac{\dot{r}^4}{c_g^4}+\ldots \tag{11}$$

The second order correction should describe the corrected acceleration directed toward the Sun. Table IV compares this formula with the experimental value of the Pioneer anomaly.

Table 4. *The experimental deceleration data for spacecrafts Pioneer 10 and Pioneer 11 and the second order correction calculation*

The Pioneer anomaly	$a_p = 8.74 \pm 1.33 \times 10^{-10}$ **m/s^2**
Speed of Pioneer 10 from the Sun	$v_{10} = 11.9$ km/s
Speed of Pioneer 11 from the Sun	$v_{11} = 11.2$ km/s
The second order correction	$\frac{1}{2}\frac{\dot{r}^2}{c_g^2}$
Calculated deceleration of Pioneer 10	$a_{10} = 7.867 \times 10^{-10}$ m/s^2
Calculated deceleration of Pioneer 11	$a_{11} = 6.969 \times 10^{-10}$ m/s^2

The second order correction describes the interaction of gravitons with both spacecrafts Pioneer 10 and Pioneer 11 very well. The experimental data for these spacecrafts [33] are shown in Fig. 1. The second order acceleration correction is very sensitive to the spacecraft speeds directing from the Sun. This effect reveals that an interaction between Solar gravitons and spacecraft atoms occur directly on those spacecrafts. During this interaction of gravitons and spacecraft atoms, the joint interaction forms an axial force towards to the Sun.

We can model this situation between gravitons and spacecraft mass as an apparent mass increase (= APPARENT DARK MATTER) that increases the gravitational force:

$$m_{APP} = \frac{m_{TRUE}}{\sqrt{1-\frac{\dot{r}^2}{c_g^2}}} \approx m_{TRUE}\left(1+\frac{1}{2}\frac{\dot{r}^2}{c_g^2}+\frac{3}{8}\frac{\dot{r}^4}{c_g^4}+\ldots\right) \tag{12}$$

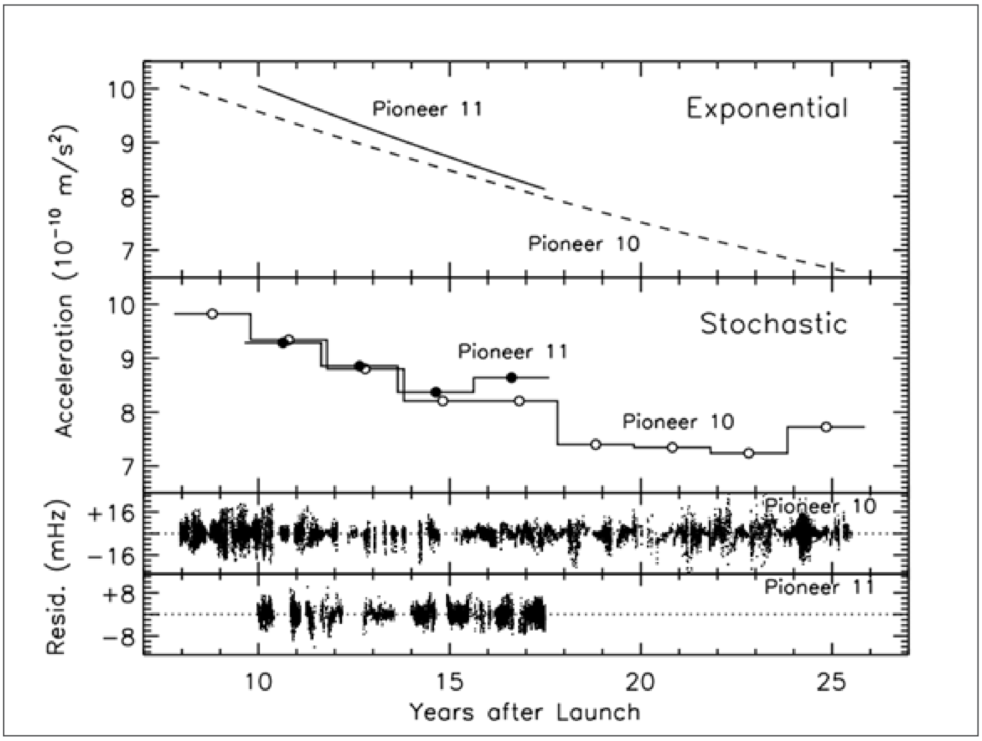

Figure 1. *The experimental data of deceleration for spacecrafts Pioneer 10 and Pioneer 11 (Figure from [33])*

On the other hand, when spacecrafts travel towards to the Sun, we predict the apparent mass decrease (= APPARENTLY MISSING DARK MATTER = DARK ENERGY) that decreases the gravitational force:

$$m_{APP} = m_{TRUE}\sqrt{1-\frac{\dot{r}^2}{c_g^2}} \approx m_{TRUE}\left(1-\frac{1}{2}\frac{\dot{r}^2}{c_g^2}-\frac{1}{8}\frac{\dot{r}^4}{c_g^4}-...\right) \quad (13)$$

We propose to continue with these gravitational experiments in the Solar system because such sensitive experiments might reveal additional information about the gravitational field.

8. The Blueshifted and Redshifted Gravitons

The Gerber gravitational potential might open a door to the microworld of properties of gravitons [35]. Let us model a graviton as the helix as it is shown in Fig. 2. In the standard situation the lead angle of the helix equals $\psi = 45°$, $\sin^4 \psi$ stands for the Rutherford scattering of inactive gravitons, $\cos^4 \psi$ describes the active gravitons. The effective gravitational activity of gravitons depends on the relative speed of gravitons and the test mass. The higher cross section of gravitons results in a higher scattering of "inactive" gravitons. The lower cross section increases the "activity" of gravitons. This effect can be seen as the APPARENT DARK MATTER for the redshifted gravitons or the MISSING APPARENT DARK MATTER = DARK ENERGY for the blueshifted gravitons.

We can rewrite the Gerber´s correction formula as:

$$\frac{1}{\left(1-\frac{\dot{r}}{c_g}\right)^2} = \frac{1}{(1-\cos 2\psi)^2} = \frac{1}{4\sin^4\psi} = \frac{\cos^4 45°}{\sin^4 45°} = \cot^4 45° \quad (14)$$

$$V = \frac{GMm}{r}\cot^4\psi = \frac{GMm}{r}\frac{\cos^4\psi}{\sin^4\psi} \quad (15)$$

The "redshifted" graviton is more active – lower graviton scattering and higher graviton activity – and there we observe the APPARENT DARK MATTER. The blueshifted gravitons is more often scattered (the higher graviton cross section) and lesser graviton activity – results in the MISSING DARK MATTER = DARK ENERGY.

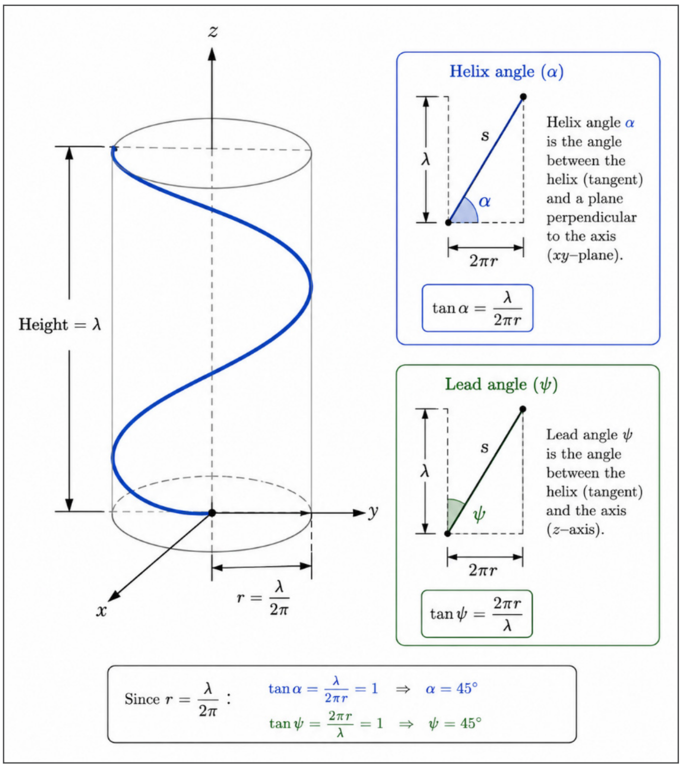

Figure 2. *The model of a graviton as the helix with the helix angle $\alpha = 45°$ and the lead angle $\psi = 45°$*

The lead angle of the graviton helix generates AXIAL FORCES! These axial forces must be considered in the design of gravitational experiments.

9. Conclusion

Mercury´s extreme orbital profile acts as a gateway to understanding advanced gravitational physics. While classical Newtonian mechanics provides an adequate approximation for radial and tangential speeds, it fails fundamentally to account for the minute anomalies in radial acceleration and falls into mathematical ruin regarding gravitational aberration.

General relativity proves that instantaneous behavior of gravity is an elegant illusion. The finite propagation lag of spacetime curvature is continuously corrected by velocity-dependent gravitomagnetic forces, ensuring the preservation and long-term equilibrium of Mercury´s journey around the Sun.

The return to the Gerber´s gravitational potential with a more detailed inspection of this mathematical formula reveals some mathematical tricks how to solve the gravitational aberration, the radial acceleration correction, and an inspiration toward the microworld of gravitons. The Pioneer anomaly can be interpreted as the interaction of "redshifted" gravitons with Pioneer 10 and Pioneer 11 that could be described as the "APPARENT DARK MATTER". The prediction of the existence of "blueshifted" gravitons leads to the "MISSING APPARENT DARK MATTER" = "DARK ENERGY".

Paul Gerber laid the first stone on our journey towards the microworld of mysterious gravitons: the lead angle of the graviton helix generates AXIAL FORCES! These axial forces (both attractive and repulsive forces) must be considered in the design of gravitational experiments. Paul Gerber´s quote: „…in contrast to the foregoing state, could be called a state of tension (Zwangszustand) giving rise, as soon as it reaches the other mass, to a movement of that mass."

Nature may have given us *correct formulae* before giving us their *deep physical interpretation.* This has happened many times in physics.

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Conflict of Interest

The author declares that there is no conflict of interest.

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