frontiers | Frontiers in Physics

TYPE Hypothesis and Theory
PUBLISHED 19 February 2026
DOI 10.3389/fphy.2026.1737947

OPEN ACCESS

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RECEIVED 02 November 2025
REVISED 14 January 2026
ACCEPTED 19 January 2026
PUBLISHED 19 February 2026

CITATION
Machotka R (2026) Concept of quantum wave gravitation in the Euclidean model of space and time.
Front. Phys. 14:1737947.
doi: 10.3389/fphy.2026.1737947

Concept of quantum wave gravitation in the Euclidean model of space and time

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The Euclidean Model of Space and Time (EMST) was created as an alternative to the Special Theory of Relativity (STR) and the associated concept of spacetime. This model subsequently proved successful in describing elementary particles of matter and their wave properties in accordance with de Broglie's hypothesis. The model is based on a four-dimensional Euclidean space with one compactified dimension, thus differing fundamentally from Minkowski's (pseudo-Euclidean) space of STR. The fundamental contribution of the EMST lies in the integration of relativity and the wave properties of matter into a single theoretical framework. A logical step in the further development of the EMST as a unified physical concept is the formulation of a theory of gravitation. The article contains the foundations, justifications, and basic mathematical derivations of a scalar theory of gravitation, based exclusively on the wave nature of matter. It demonstrates the primary cause of gravitational action of one particle of matter on another, reveals the common origin of inertial and gravitational forces, and derives the Schwarzschild metric. It also shows small deviations from Newton's and Einstein's gravitation.

KEYWORDS

de Broglie waves, energy conservation, Euclidean metric, redshift, relativity, time dilation, variable speed of light, wave nature of matter

1 Introduction

Gravitation, as the most universal physical force, is currently explained by the General Theory of Relativity (GTR), i.e., as a consequence of the curvature of space-time by matter [1]. The GTR is based on the Special Theory of Relativity (STR) [2] and shares its basic concept. However, conceptual problems within the STR, (e.g., [3–6]) lead to its repeated questioning and attempts to find an alternative theory. One of these is the concept known as the Euclidean Model of Space and Time (EMST). The EMST, although created on different foundations than STR, leads to the same mathematical formulas and the same physical predictions. It is therefore potentially capable of replacing STR throughout its entire scope of validity [7]. At the same time, it is aimed to be compatible with the wave nature of matter and de Broglie's theorem of phase harmony [8]. It thus offers a connection between the so far incompatible understanding of relativity and the wave properties of matter. The EMST offers a unified explanation of relativistic and quantum phenomena at a fundamental level, which calls for increased attention to be paid to this different concept of space and time. The concept is still largely hypothetical, but the author has found no physical experiments that contradict it.

A logical and necessary step in the further development of the EMST as a fundamental physical concept describing the nature of space, time, and matter is the formulation of a theory of gravitation. This is the subject of this article. The EMST-based concept of the scalar theory of gravitation described hereafter has the potential to replace the GTR. Its aim is to demonstrate the potential of the EMST to provide a uniform explanation of quantum and relativistic phenomena and thus create a unified picture of the physical world. This is only a theoretical concept of theory of gravitation; a rigorous mathematical presentation of this theory in the form of tensor field equations will follow as the next step.

The basic considerations underlying theory of gravitation in the EMST concept are:

1. According to the EMST, elementary particles of matter (so-called particle-waves) move in four-dimensional space E_4-B at a uniform speed v_{4D}. If we were to assume that v_{4D} could be locally variable in space, the motion of particle-waves would not be uniform and straight, but uneven and curved. The particle-waves would behave as if they were affected by external "invisible" forces. Given the universal influence of the v_{4D} on all particle-waves in the space E_4-B, this would explain the effect of gravitation on all matter. The value of the v_{4D} would also influence the flow of time.
2. It can be shown that in an accelerated system S′, the v_{4D}' is locally variable and causes bending of particle-waves trajectories. The origin of gravitational and inertial forces is therefore in principle the same, as claimed by the "principle of equivalence" – the cornerstone of GTR. This means that the description of inertia and gravitation within the EMST is similar to their description in the GTR and will probably lead to identical mathematical formulas.
3. The local variability of v_{4D}' in an accelerating system explains the inertial properties of bodies, e.g., Newton's law of inertia. However, it does not explain the general gravitational interaction between bodies (e.g., the gravitational action of the Sun on the planets). It is therefore necessary to find the source of gravitation, i.e., the source of variability of v_{4D}, as a consequence of the presence of matter.

A detailed description of the EMST (without gravitation) is given in [7, 8]. For the purposes of this article, it will be necessary to recall the basic principles and differences from STR and the concept of spacetime (Minkowski space).

The original "nongravitational" version of the EMST is based on subsequent postulates:

1. Physical space E_4-B is four-dimensional Euclidean space with all dimensions being spacelike. The fourth space dimension is bounded (compactified).
2. The medium filling physical space (so called transmission medium) is non-dispersive, homogenous and isotropic. This medium does not move with respect to E_4-B.
3. All matter has wave nature and moves through transmission medium in the form of traveling waves. The 4D speed of particles of matter (particle-waves) is determined by the properties of the transmission medium filling physical space and is equal to the speed of light in a vacuum.
4. The total energy of particles of matter (particle-waves) is given by Planck's relation $E = h\,f$.

The meaning of specific terms used in the postulates will be clarified later in this chapter.

The postulates differ significantly from the postulates of GTR and cover both relativistic and, to some extent, also quantum physics. The justification for the postulates can be found in [7] (postulate 1) and in [8] (postulates 2, 3, Chap. 2). Postulate 4 is based on Planck's law and the photoelectric effect; the other postulates are not directly motivated by the interpretation of specific physical experiments. However, their interaction leads to the same results as the postulates of STR, i.e., they explain, for example, the zero result of the well-known Michelson–Morley experiment [7, Sect. 5.1]. Postulates 2 and 3 replaced the original "4D speed invariance postulate" introduced in [7, Sect. 3.2].

The foundations of classical (i.e., non-relativistic) physics and the above postulates are the starting points for deriving all the mathematical relations of the EMST presented in this article.

The EMST assumes the existence of partially bounded Euclidean space E_4-B. E_4-B is the usual Euclidean space E_3 (x, y, z) supplemented by a fourth bounded (compactified) dimension w. This dimension is miniature compared to the other three and therefore invisible on a macroscopic scale. Elementary particles of matter (particle-waves) are so small that they can move even in this dimension. Their movement in it is cyclical. One cycle corresponds to a trajectory 2.43×10^{-12} m [8], which is the wavelength of the lightest massive particle-wave, the electron. The topology of the fourth dimension and the shape of the path along which particle-waves move in this dimension are not important for the purposes of this article.

Macroscopically observable objects are composed of a large number of particle-waves. Their fourth dimension (w) is many orders of magnitude smaller (at the level of 10^{-12} m) than the other three and therefore imperceptible. As a result, the macroscopic objects have three dominant dimensions, and as a whole, can only move in three dimensions (x, y, z). All objects and the entire physical space therefore appear to be three-dimensional. To describe the behavior of macroscopic (i.e., composite) bodies, it suffices to consider velocities, accelerations, or potential fields only in three-dimensional space E_3.

The transmission medium is a hypothetical medium filling the E_4-B space. As a whole, the medium is at rest relative to the E_4-B space, but it allows energy to move in the form of waves. These are real waves of the transmission medium, i.e., small cyclic displacements of the medium relative to its equilibrium position. The speed of energy motion in the form of traveling waves is determined by physical properties of the medium – these are the same at all points of space E_4-B (the transmission medium is homogeneous, isotropic, and non-dispersive), so the speed of wave motion is always the same (without the presence of gravitation). The nature of the transmission medium is not known; from the EMST point of view, it is not matter, but an environment through which matter in the form of waves moves.

The coordinate system associated with the transmission medium is referred to as the "stationary coordinate system" and is the preferred frame of reference. However, its existence does not preclude the existence of other seemingly equivalent coordinate systems as well as "relativistic phenomena" in the form they are observed. The subject is discussed in detail in [7].

From the EMST point of view, all matter has a wave nature. Matter is a wave motion of transmission medium, motion of energy in space E_4-B in the form of localized wave packets (so-called particles-waves). The particle-waves are the fundamental building blocks of matter in all its forms (condensed matter, radiation, fields, etc.). It is irrelevant whether they are massive or massless, whether they are bosons or fermions; from the EMST perspective, they are all considered "particles of matter." The particle-waves include leptons, quarks, as well as gauge bosons. The "particle-waves" is just another name for objects that we commonly refer to as "particles." The altered name merely emphasizes their wave nature.

The speed of particle-waves in space E_4-B (speed v_{4D}) is determined by the properties of the transmission medium (see above). Experiments with photons show that the v_{4D} is equal to the speed of light (v_{4D} = c). The speed v_{4D} at which particle-waves move in the space E_4-B, is not generally identical to the commonly observed "three-dimensional speed" v_{3D} in the space E_3. The speed v_{3D} is the orthogonal projection of the v_{4D} from the space E_4-B into the space E_3. The following formula applies:

$$v_{4D} = \sqrt{v_x^2 + v_y^2 + v_z^2 + v_w^2} = \sqrt{v_{3D}^2 + v_w^2} \tag{1}$$

The quantities v_x, v_y, v_z, and v_w are velocities in the individual coordinate axes, where $v_x = \delta x/\delta t$, $v_y = \delta y/\delta t$, $v_z = \delta z/\delta t$ and $v_w = \delta w/\delta t$. Here δx, δy, δz and δw are infinitesimal differences in coordinates, and δt is an infinitesimal increment in the coordinate time t. The terms "4D speed" and "3D speed" will be used in the text to distinguish v_{4D} from ordinary speed v_{3D}.

From the perspective of E_4-B, the particle-waves are always in motion, but from the perspective of macroscopically perceived space E_3, this may not necessarily be so. The compactified dimension w allows motion of particle-waves without changing their x, y, z coordinates. Such particle-waves are at rest from the viewpoint of E_3. On the contrary, photons and other particle-waves with zero rest mass do not move in dimension w ($v_w = 0$). Their 3D speed is equal to their 4D speed ($v_{3D} = v_{4D}$).

Time in the EMST is measured by the number of particle-wave cycles in dimension w. Each particle-wave thus represents a kind of clock – it measures its own time. The speed at which these "clocks" run depends on their state of motion, as shown in [7]. Like STR, EMST distinguishes between two types of time – coordinate time t and proper time τ. Proper time is measured by the cycles of the relevant particle-wave, coordinate time by the cycles of a hypothetical particle-wave at the origin of the coordinate system. The relationship for kinematic time dilation is the same in EMST as in STR [7, Sect. 4.1].

Any particle-wave is a quantum of energy and is indivisible. Its dimensions are non-zero (it is a wave) and its total energy is given by the Planck relation,

$$E = h\,f \tag{2}$$

where f is its frequency and h is the Planck constant. Frequency is expressed as the number of cycles per unit of coordinate time. The same particle-wave can therefore have different frequencies depending on the rate of the reference clock. A change in the reference coordinate system (and thus the reference clock) causes a change in the energy of particle-waves. In physics, a change in the total energy of a particle-wave is interpreted as a change in its kinetic or potential energy (depending on the cause of the change).

It should be noted that the frequency of a particle-wave and the frequency of its cyclic motion in the fourth dimension are two different quantities. Their relationship is explained in [8, Sect. 4.3].

The relationship between energy E and 4D momentum p_{4D} of a particle-wave can be derived from the second law of motion. Let us consider the change in energy dE of a particle-wave due to a change in its momentum dp. The particle-wave moves at a speed $v_{4D} = ds/dt$, and therefore $(dp/dt)\,ds = F ds$. This relationship can be rewritten as $dp\,v_{4D} = dE$. Since v_{4D} is a constant in this case, the following formula holds:

$$p_{4D} = E/v_{4D} \tag{3}$$

Considering $\lambda_{4D} = v_{4D}/f$ and substituting (Equation 2) into (Equation 3), we obtain an alternative relationship

$$p_{4D} = h/\lambda_{4D} \tag{4}$$

where λ_{4D} is particle-wave wavelength in space E_4-B. Relation (Equation 4) is a four-dimensional variant of the well-known de Broglie relation for particle momentum. Manifestations of this relation in E_3 space are described in [8, Sect. 3.1].

For the momentum of any body, the general relation $p = m\ v$ applies. In the case of four-dimensional space, we can write $p_{4D} = m\,v_{4D}$. By combining this relation with (Equation 3), we obtain an analogue of Einstein's relation between mass m and energy E:

$$E = m\,{v_{4D}}^2 \tag{5}$$

The EMST is based on space and time, i.e., length and time quantities. From its perspective, mass is not an independent, fundamental quantity. It can be determined from the frequency and 4D velocity of a particle-wave, using relations (Equations 2, 5). As will be shown below, both the inertial and gravitational properties of particle-waves can be defined within EMST on the basis of the general properties of wave motion, i.e., without using the concept of mass.

Kinematic transformations of frequencies and wavelengths are discussed in detail in [8], so they are not included in this article. The formulas for energy and momentum transformation are based on them. It suffices to consider Equations 2, 3.

For transformations between the stationary coordinate system S and the moving coordinate system S′, the Lorentz transformation extended by a fifth equation applies [7]:

$$\delta x' = \frac{\delta x - u\,\delta t}{\sqrt{1-\frac{u^2}{v_{4D}^2}}}, \quad \delta y' = \delta y, \quad \delta z' = \delta z, \quad \delta w' = \delta w, \quad \delta t' = \frac{\delta t - \frac{u}{v_{4D}^2}\delta x}{\sqrt{1-\frac{u^2}{v_{4D}^2}}}$$

The quantity u is the speed of motion of S′ with respect to S. It is a 3D speed since coordinate systems rigidly coupled to macroscopic objects cannot move in the fourth dimension.

In the space E_4-B, the Euclidean metric is given by the following formula:

$$v_{4D}^2\,\delta t^2 = \delta x^2 + \delta y^2 + \delta z^2 + \delta w^2 \tag{6}$$

The quantity $\delta s = v_{4D}\,\delta t$ is a measure of the distance between two infinitesimally close points in the space E_4-B and, at the same time, a measure of the time necessary to travel it (δt). The increment of the coordinate w, which is connected to the flow of proper time τ, has a specific meaning. In the case of zero motion in E_3 ($\delta x = \delta y = \delta z = 0$), the following formula applies:

$$\delta t = \delta\tau = \delta w/v_{4D} \tag{7}$$

2 Theory of gravitation

2.1 Influence of variable v_{4D} on the flow of time

Previous articles concerning EMST [7, 8] were based on the assumption, that the value of v_{4D} is constant, or more precisely, that v_{4D} = c, where *c* is the speed of light in a vacuum. For the theory of gravitation, it is necessary to abandon this assumption. Let us now assume that the speed v_{4D} is locally and temporally variable in the stationary coordinate system S. Each point in space E_4-B (x, y, z, w) at coordinate time *t* can be assigned a value $v_{4D} = f(x, y, z, w, t)$, where *f* is a continuous differentiable function. The quantity v_{4D} is a scalar field in space E_4-B.

The rate of flow of coordinate time *t* is directly related to the value of v_{4D}. This clearly arises from the metric (Equation 6). The time δt required to move a particle-wave by given values δx, δy, δz, δw is the greater, the lower the value of v_{4D} is.

The same effect also affects the flow of proper time, and thus also the running of clocks. It follows from relation (Equation 7) that the value of $\delta\tau$ increases as v_{4D} decreases. Since we always measure proper time by the number of repetitions of a regularly recurring event (e.g., the oscillation of a quartz crystal, the frequency of radiation coming from the electron shell of cesium, etc.), there will be fewer repetitions when $\delta\tau$ is larger, and the clock will show a smaller increase in time. This phenomenon affects all clocks regardless of their design – the fact was first discussed by A. Einstein in [9]. In the terminology of Einstein's theory of relativity, this is a "universal effect" independent of the design of the clock.

Clocks affected only by universal effects, i.e., not affected by the specific design of the particular clock, will be referred to as "ideal". All further considerations will be based on the use of ideal clocks for time measurements.

As an example of the ideal clock, we can use the so-called particle clock. It is a particle-wave moving cyclically in dimension w. One cycle of the particle-wave is equal to one "tick" of the clock. The time between ticks is given by the length of the particle-wave's path and the speed of its motion. It is clear that the speed of the clock's "ticking" is directly proportional to the value of v_{4D} (for an invariant path), (Figure 1).

To consider the motion of clock in E_3, we must replace v_{4D} in relation (Equation 7) by v_w ($v_w = \sqrt{v_{4D}^2 - v_{3D}^2}$, see Equation 1). The relation then takes the form $\delta\tau = \delta w / v_w$. Alternatively, we can consider the prolongation of the particle-wave trajectory within a single cycle. In both cases, the result will be the same – prolongation of the duration of a single tick means slower "ticking" rate.

The slowing down of the motion of particle-waves in E_4-B and the slowing down of the clocks have the same origin and act against each other. If, in some part of space, the value of v_{4D} is lower than *c* by, say, 1%, the particle-wave will travel the given path in objectively longer time (an increase of 1%), but the lower rate of the clock (a decrease of 1%) will completely compensate the effect. Therefore, the change in v_{4D} speed will not be noticeable locally. The ratio of the path and the measured time will remain equal to c.

The change in speed v_{4D} cannot be detected locally by any known method. It is the speed at which the fundamental building blocks of matter (i.e., the particle-waves) move, and therefore it affects all physical processes. It affects the speed of quarks, photons, and leptons, it determines the speed of electrons in the electron shells of atoms and the frequencies of their emitted photons. Since the time component of all ongoing processes is affected, as well as all related physical quantities (frequency, speed, acceleration, force, etc.), it is not possible to detect the change in v_{4D} by their measurement and comparison.

However, the change in v_{4D} can be detected at greater distances by comparison of the clock rates of a pair of ideal clocks 1 and 2. If these are located in areas with different v_{4D}, one clock will run slower than the other. The mutual ratio is given by

$$\frac{ClockRate_1}{ClockRate_2} = \frac{v_{4D,1}}{v_{4D,2}} \tag{8}$$

where *ClockRate* is the number of "ticks" per selected time interval. By comparison of the mutual tick rates of remote clocks, regional variations in v_{4D} can be determined. If an extensive network of ideal, mutually non-moving clocks were available, deviations in *ClockRate* would indicate regional variations in the value of v_{4D}, (Figure 2).

2.2 The relationship between v_{4D} and particle-wave energy

In the following, we will assume that material bodies create a zone with a spatially variable value of v_{4D} around themselves – we will call this zone the gravitational field.

Let us consider a particle-wave, such as a photon, in the gravitational field. We will determine its frequency *f* using a clock (at rest) located in its immediate vicinity. If the photon moves freely downward in the gravitational field, its potential energy E_p will decrease, and its kinetic energy E_k will increase. According to the law of conservation of energy, its total energy *E* remains constant. The following generally applies to every particle-wave:

$$E = E_0 + E_p + E_k = const \tag{9}$$

The quantity E_0 is the rest energy of a particle-wave, which is zero (negligible) in the case of a photon. It should be noted that EMST does not distinguish between massive and massless particles and assigns potential energy to both. Its origin will be explained in Sect. 2.3.

Since the total energy $E = hf$ remains unchanged, *f* also remains unchanged. The frequency of a free-falling particle-wave does not change. However, its wavelength decreases together with decrease of v_{4D} ($\lambda_{4D} = v_{4D}/f$). The decrease in λ_{4D} is accompanied by an increase in momentum $p_{4D} = h/\lambda_{4D}$, see (Equation 4), and an increase in mass

$$m = p_{4D}/v_{4D} = hf/v_{4D}^2 \tag{10}$$

Although the frequency of a particle-wave does not change during free fall, the dependence of *ClockRate* on the local value of v_{4D} causes the frequency determined by different reference clocks is different. Phenomena such as gravitational redshift and blueshift do not reflect a change in the energy of the particle-wave, but rather a change in the rate (*ClockRate*) of the reference clocks. For instance, a clock in interstellar space runs faster than an imaginary clock on the surface of a massive star. In other words, time on the surface of the star flows more slowly, and all physical processes, including photon emission, are also slower.

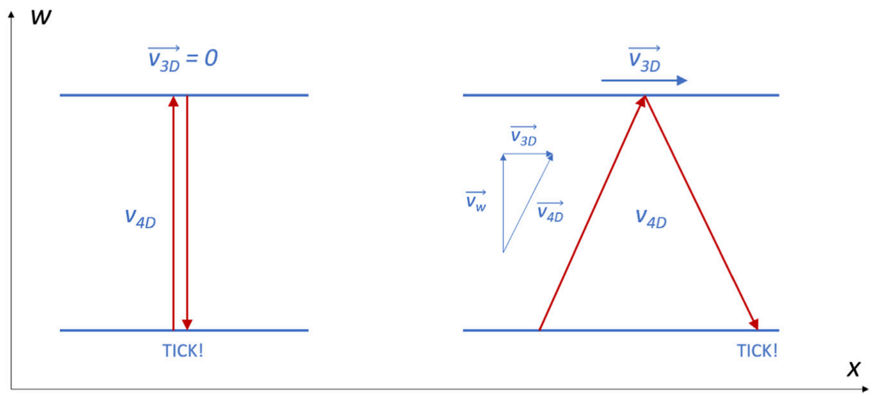

FIGURE 1
Simplified geometric model of the particle clock. The clock is based on the motion of the particle-wave in dimension *w*. On the left, the clock is at rest (v_{3D} = 0); on the right, the clock is moving in the direction of the *x*-axis. The time between ticks depends on the speed of the particle-wave (v_{4D}) and the 3D speed of the clock (v_{3D}).

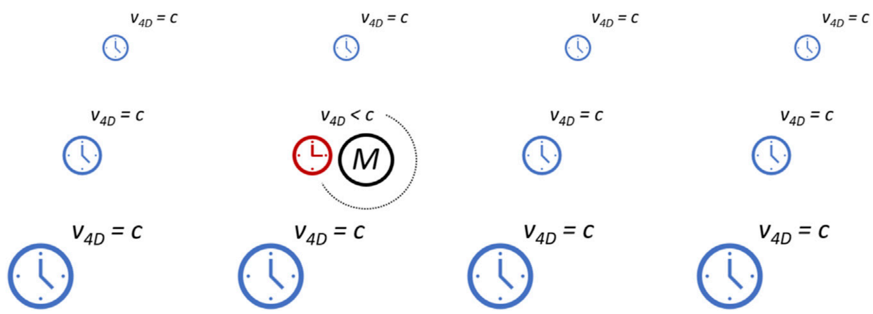

FIGURE 2
A stationary clock located in a region of lower v_{4D} runs provably slower than a stationary clock located in a region of higher v_{4D}. Variations may be caused, for example, by the presence of significant gravitational masses.

The dependence of the particle-wave frequency on the value of v_{4D} at the location of the reference clock is not surprising. It expresses the relative nature of potential energy. It is always related to a specific reference level. The EMST shows that the reference level is given by the local value of v_{4D}. A change in the reference level corresponds to the relocation of the reference clock to a location with a different v_{4D}. The result is a change in the frequency of the observed particle-wave, and thus its energy.

Let us consider a space and a pair of identical particle-waves A and B (e.g., electrons) arbitrarily distributed in it, as well as a pair of identical clocks 1 and 2. The particle-waves and clocks are at rest ($v_{3D} = 0$). The particle-waves would have the same energy if they were located in areas of the same v_{4D}, but the value of v_{4D} is different in the given locations. The following applies: $v_{4D,B} < v_{4D,A}$, $v_{4D,2} < v_{4D,1}$ (Figure 3).

Let us denote the frequency of particle-wave A relative to clock 1 as $f_{A,1}$, and relative to clock 2 as $f_{A,2}$. The following applies:

$$\frac{E_{A,2}}{E_{A,1}} = \frac{h\,f_{A,2}}{h\,f_{A,1}} = \frac{ClockRate_1}{ClockRate_2} = \frac{v_{4D,1}}{v_{4D,2}}$$

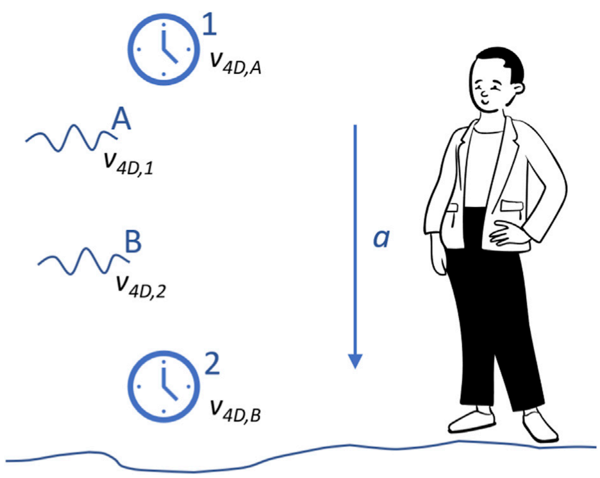

FIGURE 3
Example of the arrangement of a pair of identical clocks and a pair of identical particle-waves in a zone with variable v_{4D}.

It is clear from the formula that the frequency, and therefore also the energy of the particle-wave is greater relative to the slower clock 2.

A similar situation arises when comparing the frequencies of particle-waves A and B. If we relate them to clock 1, we get

$$\frac{f_{A,1}}{f_{B,1}} = \frac{v_{4D,A}}{v_{4D,B}} \tag{11}$$

i.e., the particle-wave in the region of greater v_{4D} has a higher frequency and thus also higher energy:

$$\frac{E_{A,1}}{E_{B,1}} = \frac{h f_{A,1}}{h f_{B,1}} = \frac{v_{4D,A}}{v_{4D,B}} \tag{12}$$

When using clock 2, we obtain different frequencies, but their ratio will be the same. This shows that identical particle-waves (e.g., free electrons at rest) have different energies depending on the local value of v_{4D}.

Particle-waves A and B have different frequencies, but their wavelength $\lambda_{4D} = v_{4D}/f$ is the same, see (Equation 11). This corresponds to the same value of the momentum p_{4D} and all of its components. It should be noted that p_{4D} is a vector in E_4 with components p_x, p_y, p_z, and p_w, which correspond to the projections of the wavelength λ_{4D} in the direction of the coordinate axes. For example, $p_x = h/\lambda_x$, see [8].

The wavelengths of identical particle-waves do not depend on the local value of v_{4D}. This fact can be used for distance measurement. The length of rigid measuring rods is determined by the distance between individual atoms in the crystal lattice. It can be reasonably assumed that these are fixed multiples of the wavelengths of electrons in the electron shells of atoms. That is, the dimensions of the rod do not depend on the local v_{4D}. The results of length measurements using rods will match the results of length measurements using light if local clocks are used for the transit time determination.

Using relations (Equation 10) and (Equation 12), we can write:

$$\frac{m_A}{m_B} = \frac{\frac{h f_A}{v_{4D,A}^2}}{\frac{h f_B}{v_{4D,B}^2}} = \frac{v_{4D,B}}{v_{4D,A}} \tag{13}$$

Particle-wave B has a higher mass than particle-wave A despite having lower energy.

2.3 Gravity potential

If the distribution of the v_{4D} is constant in time, it can be used to define a potential field in space – the gravity potential V. This term includes both gravitational potential (caused by the gravitational effects of matter) and inertial potential (caused by the acceleration of the reference frame); if both are present, it is their sum.

The gravity potential creates a scalar field in space E_3 (the compactified fourth dimension can be neglected when describing gravity). The function $V = V(x, y, z)$ is continuous and differentiable.

The gravity potential expresses the potential energy of a body of unit mass relative to a selected reference level ($V = E_p/m$). The potential decreases downward and increases upward. If the reference level of the potential is located outside the gravity field, the potential anywhere inside the field is negative.

Let us consider the potential of particle-wave A relative to clock 1 from the previous case. The energy of any particle-wave is given by $E = m v_{4D}^2 = p_{4D} v_{4D}$. The momentum p_{4D} is independent of the v_{4D}, so the infinitesimal change of E with v_{4D} can be written as $dE = p_{4D}\, dv_{4D} = m v_{4D}\, dv_{4D}$. The value dE represents the change in the potential energy of the particle-wave, i.e., $dE = dE_p$. Therefore the change in potential is given by $dV = dE_p/m = v_{4D}\, dv_{4D}$.

The potential of particle-wave A relative to clock 1 is

$$V_{A,1} = \int_1^A v_{4D}\, dv_{4D} = \left[\frac{v_{4D}^2}{2}\right]_1^A + C$$
$$= \left(\frac{v_{4D,A}^2}{2} - \frac{v_{4D,1}^2}{2}\right) + C = -\frac{1}{2} v_{4D,1}^2 \left(1 - \frac{v_{4D,A}^2}{v_{4D,1}^2}\right) + C$$

The integration constant C is determined by the choice of value of the potential at the location of the reference clock. The logical choice is $V_1 = 0$, which leads to $C = 0$.

The gravity potential (of particle-wave) at point A relative to reference clock 1 located outside the gravity field ($v_{4D,1} = c$) is

$$V_A = -\frac{1}{2} c^2 \left(1 - \frac{v_{4D,A}^2}{c^2}\right) \tag{14}$$

This defines the functional dependence of V on the v_{4D}.

The inverse relationship gives the ratio of v_{4D} to c,

$$\frac{\boldsymbol{v_{4D,A}}}{\boldsymbol{c}} = \sqrt{\mathbf{1} + \frac{\mathbf{2}\boldsymbol{V_A}}{\boldsymbol{c^2}}} \tag{15}$$

which can be modified for the mutual ratio of clock rates

$$\frac{\boldsymbol{ClockRate_A}}{\boldsymbol{ClockRate_1}} = \sqrt{\mathbf{1} + \frac{\mathbf{2}\boldsymbol{V_A}}{\boldsymbol{c^2}}} \tag{16}$$

It can also be written in the form known from the GTR

$$\boldsymbol{d\tau} = \boldsymbol{dt}\sqrt{\mathbf{1} + \frac{\mathbf{2}\boldsymbol{V_A}}{\boldsymbol{c^2}}} \tag{17}$$

which gives the increment of proper time τ at a point with gravity potential V_A relative to the independently flowing coordinate time t outside the gravity field. It can be seen that the EMST result is identical to the GTR result.

Regardless of the location of the reference clock, $v_{4D} = c$ always applies in its vicinity. Equations 14–17 are therefore valid not only for reference clocks located outside the field, but for any location of the clock.

2.4 Influence of the variable v_{4D} on particle-wave motion

In classical mechanics, the gradient of potential is acceleration

$$\boldsymbol{grad}(\boldsymbol{V}) = \left(\frac{\partial \boldsymbol{V}}{\partial \boldsymbol{x}}, \frac{\partial \boldsymbol{V}}{\partial \boldsymbol{y}}, \frac{\partial \boldsymbol{V}}{\partial \boldsymbol{z}}\right) = \left(-\boldsymbol{a_x}, -\boldsymbol{a_y}, -\boldsymbol{a_z}\right) = -\vec{\boldsymbol{a}} \tag{18}$$

In the EMST, any accelerated motion is a consequence of the variable value of v_{4D}. The above-mentioned relationship between acceleration and potential must, therefore, be verified and correctly interpreted. It will be shown that the vector $\vec{\boldsymbol{a}}$ does not represent

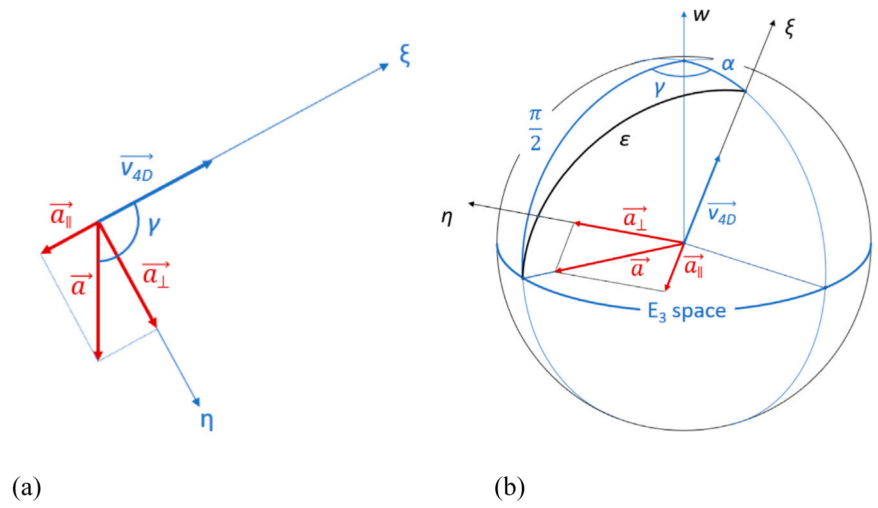

FIGURE 4
Decomposition of the acceleration vector into components related to the direction of motion of the particle-wave. **(a)** Plot in the ξ-η plane, **(b)** plot in 4D space (space E_3 represented as two-dimensional).

kinematic acceleration in some situations. I will refer to it as the "vector $\vec{a}$" (instead of acceleration $\vec{a}$) in cases where confusion might arise.

The relationship between the potential V and the velocity v_{4D} was derived above (Equation 15). It yields

$$\frac{dv_{4D}}{dV} = \frac{d\left(c\sqrt{1+\frac{2V}{c^2}}\right)}{dV} = \frac{c}{2}\frac{1}{\sqrt{1+\frac{2V}{c^2}}}\frac{2}{c^2} = \frac{1}{v_{4D}} \tag{19}$$

and so

$$grad(v_{4D}) = \left(\frac{\partial v_{4D}}{\partial x}, \frac{\partial v_{4D}}{\partial y}, \frac{\partial v_{4D}}{\partial z}\right) = \frac{\partial v_{4D}}{\partial V} grad(V) = \frac{1}{v_{4D}} grad(V) = -\frac{\vec{a}}{v_{4D}}$$

The dependence of vector $\vec{a}$ on the velocity v_{4D} is given by the formula

$$\vec{a} = -v_{4D}\, grad(v_{4D}) \tag{20}$$

For the analysis of particle-wave motion, it is convenient to decompose vector $\vec{a}$ into two components – a component parallel to the direction of particle-wave motion $\overrightarrow{a_\parallel}$ and a component perpendicular to it $\overrightarrow{a_\perp}$. At the same time, we introduce an auxiliary coordinate system with its origin at the center of the particle-wave and axes ξ and η (see Figure 4a).

In the coordinate system ξ, η, the vector $\vec{a}$ can be written as $\vec{a} = \boldsymbol{a}\left(\boldsymbol{a}_\parallel, \boldsymbol{a}_\perp\right)$, where

$$a_\parallel = -v_{4D}\frac{\partial v_{4D}}{\partial \xi},\ a_\perp = -v_{4D}\frac{\partial v_{4D}}{\partial \eta} \tag{21}$$

The relationship of these components to the vector $\vec{a}$ is given by formulas:

$$\mathbf{a}_\parallel = \|\vec{\mathbf{a}}\|\cos\boldsymbol{\varepsilon},\ \mathbf{a}_\perp = \|\vec{\mathbf{a}}\|\sin\boldsymbol{\varepsilon} \tag{22}$$

The angle ε between the 4D direction of particle-wave motion and the direction of vector $\vec{a}$ can be calculated using formula:

$$\cos\varepsilon = \sin\alpha\cos\gamma \tag{23}$$

Angle γ is the analogue to ε in ordinary space E_3, while angle α is the inclination of the 4D direction of particle-wave motion relative to axis w (Figure 4b). It holds that $\sin\alpha = v_{3D}/v_{4D}$.

It might seem that the value $\boldsymbol{a}_\parallel$ affects the speed of the particle-wave and the value $\boldsymbol{a}_\perp$ affects its direction, but only the second part is true. The component $\boldsymbol{a}_\parallel$ has no effect on the particle-wave speed. This is because the particle-wave is an undulation of the transmission medium and its speed is determined solely by the properties of this medium, specifically the value of v_{4D} – see (Equation 15). It is obvious that, with decreasing value of V (downward movement), the value of v_{4D} also decreases. The quantity v_{4D} is a 4D speed, which is not directly observable for most particle-waves, so we do not register the phenomenon. The v_{4D} is identical to the commonly observed 3D speed only for photons (and other particle-waves with zero rest mass). It can be claimed that a photon falling into a gravitational well slows down. However, this paradox is not new. The decrease in the speed of light in a gravitational field (relative to a reference clock located outside the field) is generally known and accepted within GTR.

Regardless of the decrease in speed, the 4D momentum and mass of the particle-wave increase as it falls into the gravitational well (see Sect. 2.2 above).

The transverse component $\overrightarrow{a_\perp}$ is a consequence of the change of v_{4D} in the transverse direction. The particle-wave has non-zero dimensions and its individual parts move at different speeds - depending on the local value of v_{4D} (Figure 5). One side of the wave moves faster than the other, causing wavefronts to twist. The direction of the wave bends towards the area of lower v_{4D}. The situation is analogous to atmospheric refraction of light, where different speeds of light (different refractive indices) cause its path to curve. This is a manifestation of Fermat's principle, which states that waves do not propagate along the shortest path, but along the path with the shortest time.

The radius of bending can be determined by the following consideration: The ratio of the path on the outer side of the arc to the path of the center of the particle-wave is equal to the ratio of local 4D speeds: $(l+dl)/l = (v_{4D}+dv_{4D})/v_{4D}$.

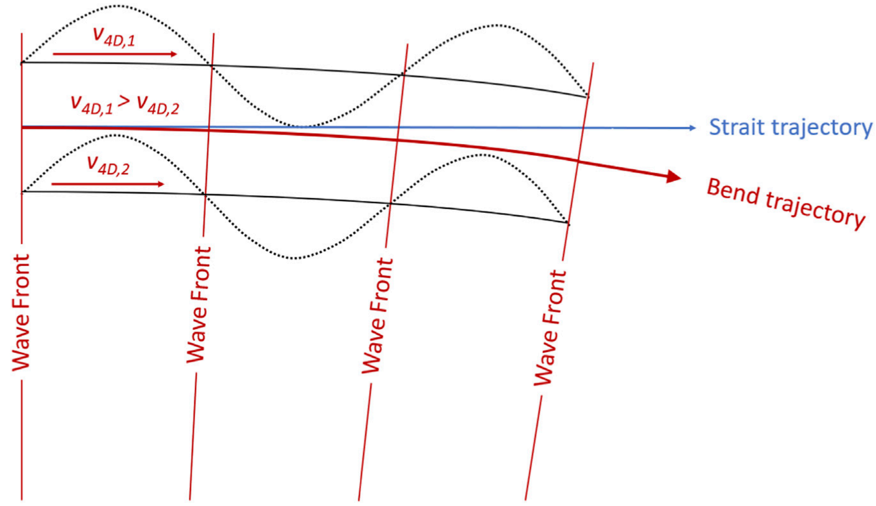

FIGURE 5
Bending of the particle-wave trajectory due to different values of v_{4D}.

The ratio of distances can be replaced by the ratio of radii $(r + dr)/r$, where the increment of radius dr is equal to the negative increment of $d\eta$: $(l + dl)/l = (r + dr)/r = (r - d\eta)/r$.

It can be written $-d\eta/r = dv_{4D}/v_{4D}$, hence

$$\frac{1}{r} = -\frac{dv_{4D}}{d\eta}\frac{1}{v_{4D}} \tag{24}$$

The radius depends on the rate of decrease in v_{4D} (i.e., on $dv_{4D}/d\eta$). By combining relations (Equation 24) and (Equation 21), it can be written

$$r = \frac{v_{4D}^2}{a_\perp} \Rightarrow a_\perp = \frac{v_{4D}^2}{r} \tag{25}$$

The relationship (Equation 25) shows that the transverse component of the vector $\vec{a}$ makes the particle-wave move in a circle with radius r. Centripetal acceleration of the same magnitude would have the same effect. The variable value of v_{4D} curves the trajectory of the particle-wave the same way as it would be curved by the acceleration $\boldsymbol{a}_\perp$ caused by some acting force (inertial, gravitational, etc.).

The deviation from the straight line is equal to $\eta = \xi^2/2r$, which, after substituting r from (Equation 25) and $\xi = v_{4D}\, t$, leads to $\boldsymbol{\eta} = \frac{v_{4D}^2 t^2 a_\perp}{2v_{4D}^2} = \frac{1}{2}\boldsymbol{a}_\perp \boldsymbol{t}^2$.

It can be seen that the quantity $\boldsymbol{a}_\perp$ is the actual kinematic acceleration with which the particle-wave moves in space E_3.

In non-relativistic cases, the difference between $\overrightarrow{a_\perp}$ and $\vec{a}$ can be neglected, since particle-waves moving at non-relativistic 3D speeds ($v_{3D} << v_{4D}$) perform their 4D motion primarily in the w dimension. The direction of their motion is therefore practically perpendicular to any acceleration vector $\vec{a} = (a_x, a_y, a_z)$. In these cases, the last formula can be rewritten into the familiar form

$$\eta = \frac{1}{2} a t^2 \tag{26}$$

It expresses the change in position of the particle-wave in E_3 under the influence of acceleration $\boldsymbol{a} = -\boldsymbol{grad}(V)$. The Equation 26 applies to all non-relativistically moving particles of matter, as well as composite bodies. The change in the state of motion of a body is independent of its mass, 3D velocity, direction of motion, or composition. And, as will be shown later, it does not depend on the way in which the gravity field was created.

In relativistic cases, the kinematic acceleration $\boldsymbol{a}_\perp$ is given by Equations 22, 23. The term *sin* α in Equation 23 acts equivalently as a relativistic mass increase in GTR.

The derivation of gravitational acceleration given above applies to any particle-wave (photon, neutrino, electron, muon, …) moving in any direction and at any (permissible) 3D velocity. It should be noted that the accelerated motion of particle-waves in the gravity field is not the result of acceleration or force acting at a distance, but rather the result of different values of v_{4D} in the immediate vicinity of the particle-wave. Acceleration or force is only a useful mathematical aid, not the real cause of the change in the particle's state of motion. Moreover, the usefulness of this aid is limited – see the component $\boldsymbol{a}_\parallel$ mentioned above.

2.5 Variable v_{4D} in non-inertial systems

Once it has been clarified that the cause of the curvature of particle-waves trajectories is the variable value of v_{4D}, the question inevitably arises: What is the cause of this variability? It is useful to follow Einstein's approach here and focus on the similarity between gravitational and inertial forces.

Let us consider space E_4-B filled with a homogeneous isotropic medium in which all particle-waves move at the same 4D speed, namely, speed c. In this space, there is a flat rotating disk that rotates at an angular velocity ω relative to the stationary coordinate system S (x, y, z). The coordinate system S′ (x', y', z') is rigidly connected to the disk. The axis of rotation is the common axis $z \equiv z'$.

Any point on the disk moves relative to S at a speed $\boldsymbol{v_s} = \boldsymbol{r_s}\boldsymbol{\omega}$, where r_s is the distance from the z-axis, $\boldsymbol{r_s} = \sqrt{\boldsymbol{x^2} + \boldsymbol{y^2}}$. The non-zero value of v_s causes the speed of particle-waves relative to the rotating system S′ to be lower than relative to the system S. This refers to the average two-way speed. The formula $\boldsymbol{v_{4D}}' = \sqrt{\boldsymbol{c^2 - v_s^2}}$ holds. It obviously holds for cases where $\boldsymbol{v_s} \perp \boldsymbol{v_{4D}}'$, i.e., in cases where the particle-wave motion is perpendicular to v_s. The validity for other directions of particle-wave motion is not obvious, but it also holds for them. A detailed justification can be found in [7].

The formula $v_{4D}' = \sqrt{c^2 - \omega^2 r_s^2}$ shows that in the rotating coordinate system, the velocity v_{4D}' is variable. It can be speculated that this variability causes the curvature of the trajectories of free particle-waves, and such curvature is identical to the effect of centrifugal acceleration $a_c = \omega^2 r_s$.

Derivation of the above formula for v_{4D}' with respect to radius r_s gives

$$\frac{dv_{4D}'}{dr_s} = \frac{-2\omega^2 r_s}{2\sqrt{(c^2 - \omega^2 r_s^2)}} = -\frac{\omega^2 r_s}{v_{4D}'}$$

By substituting into (Equation 21) and considering $\frac{dv_{4D}'}{dr_s} \equiv \frac{dv_{4D}}{d\eta}$ (these are identical variables with different notation), we obtain the formula

$$a_\perp' = v_{4D}' \frac{\omega^2 r_s}{v_{4D}'} = \omega^2 r_s$$

Clearly, $\boldsymbol{a_c} = \boldsymbol{a}_\perp'$ applies, i.e., the acceleration $\boldsymbol{a_c}$ caused by the rotation of the disk is equal to the acceleration $\boldsymbol{a}_\perp'$ of a particle-wave caused by the local change in v_{4D}'.

It is important to note that the change in v_{4D}' with the spatial position, and thus also the acceleration $\boldsymbol{a}_\perp'$, are phenomena tied to the rotating system S'. From the perspective of the stationary system S, the v_{4D} is the same everywhere ($v_{4D} = c$) and particle-waves move without acceleration (inertial motion). That is, the spatial variability of $\boldsymbol{v}_{4D}'$ is a consequence of the motion of the coordinate system S′ relative to S.

The acceleration $\boldsymbol{a}_\perp'$ can also be determined in another way, namely, by means of the function $V' = f(x', y', z')$ describing the distribution of potential in the system S' and subsequently by the relationship between acceleration and gradient of V'. For a rotating disk $\boldsymbol{V}' = -\frac{1}{2}\boldsymbol{\omega^2 r_s^2}$ applies. In the cylindrical coordinates (r, φ, z), the parameters of the acceleration vector can be determined from the potential V':

$$\vec{a}\left(a_r, a_\varphi, a_z\right) = -grad\left(V'\right) = -\left(\frac{\partial V'}{\partial r}, \frac{1}{r}\frac{\partial V'}{\partial \varphi}, \frac{\partial V'}{\partial z}\right) = \left(\omega^2 r_s, 0, 0\right)$$

i.e., the acceleration has a radial direction and is equal to $\boldsymbol{a_c}$. We have arrived at the same result as above, but the given procedure is usually easier.

The advantage of utilizing potential can be demonstrated in another typical situation – linear accelerated motion. Consider a system S′ moving with acceleration relative to the stationary system S. Assume constant acceleration a_S in the direction of the common axis $x \equiv x'$.

In this case, it is difficult to directly determine the change in v_{4D}' with position ($\boldsymbol{dv_{4D}'/dx'}$). This is because of v_{4D}'s dependence on time and the simultaneous impossibility of mutual synchronization of remote clocks. Their time shift changes over time. However, it is possible to determine the ratio of the v_{4D}' flow at different points of S′ by comparison of the clocks (*ClockRate*) located there (Equation 8) or to calculate it using the gravity potential – see (Equation 15). The potential in this case is given by $\boldsymbol{V'} = \boldsymbol{a_s x'}$, i.e., $\boldsymbol{\partial V'/\partial x'} = \boldsymbol{a_s}$. Using (Equation 19), we obtain $\boldsymbol{\partial v_{4D}'/\partial x'} = \boldsymbol{a_s / v_{4D}'}$. The known change in v_{4D}' with x' allows us to calculate the curvature of the path of a free particle-wave (Equation 24). Its acceleration relative to S′ can be determined using (Equation 20) or (Equation 18):

$$\vec{a}\left(a_x, a_y, a_z\right) = -grad\left(V'\right) = -\left(\frac{\partial V'}{\partial x}, \frac{\partial V'}{\partial y}, \frac{\partial V'}{\partial z}\right) = \left(-a_s, 0, 0\right)$$

The acceleration $\vec{\boldsymbol{a}}$ with which the free particle-wave moves relative to S′ is, except for the sign, the same as the acceleration of S′ relative to S.

It has been shown that, in non-inertial systems, the speed v_{4D} is a function of position. This applies to both linear accelerated as well as rotational motion. Since any motion of coordinate systems relative to each other can be understood as a combination of translations and rotations, it can be argued that v_{4D} is a function of position in all non-inertial systems. Its change with position subsequently affects the direction of motion of particle-waves.

It is important to note that the acceleration of particle-waves caused by the variable value of v_{4D} is exactly opposite to the acceleration of S′ relative to S. The inertia of matter is not a strange opposition of matter change its state of motion, but a natural property of waves (i.e., particle-waves) to move along the trajectory with the shortest time (Fermat's principle).

2.6 Undulation of the transmission medium as the source of gravitation

Since it has been shown that the spatially variable v_{4D} is the cause of inertial acceleration, it can be expected to be the cause of gravitational acceleration as well. Logically, the question arises: What is the cause of the variability of v_{4D} in the case of gravitation?

Based on the analogy between inertia and gravitation, one possibility is that the cause of the variable v_{4D} is some motion of the reference frame relative to the stationary frame. However, the specific character of gravitation (e.g., the existence of a central gravitational field) does not allow us to find an adequate type of motion within the E_3 or E_4-B space (for global Euclidean systems). Considering a hypothetical fifth spatial dimension, a suitable type of motion can be found – it is the rotation of E_4-B relative to the stationary space E_5, where areas of lower potential are further from the axis of rotation (larger radius r_V) than areas of higher potential. For the speed v_v in the additional 5th dimension, $\boldsymbol{v_V} = \boldsymbol{r_V \Omega}$ applies. As a result, the speed v_{4D} is lower in areas of lower potential, since $\boldsymbol{v_{4D}}' = \sqrt{\boldsymbol{c^2 - v_v^2}}$ applies. This model can be optimized to correspond to actual gravity, but the question is whether it corresponds to reality in general. It adds another large, yet undetected spatial dimension and, at the same time, assumes the existence of a yet undetected angular velocity $\boldsymbol{\Omega}$, at which the entire universe (space E_4-B) rotates. However, the main disadvantage of this model is that it ignores the fundamental importance of mass as a source of gravitation.

Since Newton's time, it has been known that matter is the source of gravitation. The cause of local variability of v_{4D} should therefore be the presence of matter, i.e., of particle-waves. These are packets of energy moving through space in the form of waves. Each particle-wave is, by its very nature, a source of motion of the transmission medium. The motion of the medium is cyclic – after short time, the transmission medium returns to its initial position – it does not shift anywhere. However, its average speed is non-zero.

The average speed of the transmission medium through which an undulation passes depends on the amplitude, frequency, waves shape, and type of undulation (sinusoidal, helical, etc.). Of these quantities, only the frequency is known with certainty ($E = h\,f$). Therefore, a direct calculation of the average speed is not possible without further assumptions.

However, a different approach can be used: It is known that the energy of any wave motion consists of the elastic energy of the transmission medium and its kinetic energy. For example, in the case of waves on a string, the ratio of these energies is 1:1, i.e., half of the energy is kinetic and half is elastic [10, page 34]. For other types of wave motion, this ratio may be different. For our purposes, it suffices to assume that the wave motion of all particle-waves has the same character, and so the ratio of elastic and kinetic energy is the same. In that case, the ratio of the kinetic energies of particle-waves A and B will be equal to the ratio of their total energies. Since kinetic energy is proportional to the square of the velocity of the transmission medium, $\boldsymbol{E_k = 1/2mv_m^2}$, the ratio of the mean square velocities v_m of the transmission medium as a result of the wave motion of particle-waves with energies E_A and E_B will be

$$\frac{v_{m,A}}{v_{m,B}} = \sqrt{\frac{E_A}{E_B}}$$

Based on $\boldsymbol{v_{4D}} = \sqrt{\boldsymbol{c^2 - v_m^2}}$ and (Equation 14) it holds

$$V_A = -\frac{1}{2}v_{m,A}^2 \tag{27}$$

i.e., the ratio of the potentials is proportional to the ratio of the energies of the particle-waves

$$\frac{V_A}{V_B} = \frac{E_A}{E_B}$$

The formula shows that particle-waves with n times greater energy create a gravitational field with n times greater potential.

From the known property of gravitational potential (Newton's relation $V = -GM/r$) and relation (Equation 27), it follows that

$$v_m = \sqrt{\frac{2GM}{r}} \tag{28}$$

i.e., v_m decreases with the growing distance r from the center of the particle-wave. It is a natural property of waves that they are not sharply outlined. Instead, they oscillate the surrounding medium, propagating not only forward, but also, to a certain extent, sideways. This also applies to particle-waves.

The motion of the transmission medium caused by a particle-wave is its motion relative to the stationary coordinate system S. This motion affects the local value of v_{4D} ($\boldsymbol{v_{4D}} = \sqrt{\boldsymbol{c^2 - v_m^2}}$), slows down other particle-waves, bends their trajectories, and simultaneously slows down the running of clocks.

The wave motion of the transmission medium caused by a single isolated particle-wave is understandably very small. The corresponding value of the mean square velocity can be determined using Equation 28. An electron at a distance of 1 m with a mass of $m_e = 9.1 \times 10^{-31}$ kg causes the transmission medium to move at a mean velocity of $v_m = 1.1 \times 10^{-20}$ m/s. This corresponds to a wave amplitude not exceeding 10^{-40} m for a frequency of $f = m_e\frac{c^2}{h} = 1.2 \times 10^{20}$ Hz. For more massive particles, the mean square velocity is higher, while the amplitude of the carrier medium is lower. For a proton with a mass of $m_p = 1.67 \times 10^{-27}$ kg, the values are as follows: $v_m = 4.7 \times 10^{-19}$ m/s, $f = 2.3 \times 10^{23}$ Hz, and the amplitude does not exceed 10^{-42} m. However, there is a large number of particle-waves in space, and all the waves combine with each other. A superposition of waves occurs. This results in wave superposition, in which the velocities, as well as the actual displacements, add together.

The maximum displacement that the transmission medium can achieve as a result of Earth's gravitation can be determined by the following simplified reasoning:

The mean square velocity v_m for the Earth's mass of 6×10^{24} kg is equal to 2.8×10^7 m/s. The frequencies of individual particle-waves range from 10^{20} Hz (electron) to 10^{23} Hz (proton and other baryons). Using the lowest of the frequencies mentioned, 10^{20} Hz, the displacement is approximately 10^{-13} m. This is an upper (maximum) estimate. The displacements are, therefore, very small, which explains the inability to detect the wave motion (i.e., deformations) of the transmission medium in our surroundings.

The question arises: In which dimension the transmission medium oscillates? Based on the existence of polarization phenomena (polarization of photons, electrons, or neutrons), it can be assumed that particle-waves have the nature of transverse waves. However, this in itself does not fully answer the question of the direction of the transmission medium's displacements. It could be a wave motion in some fifth dimension, i.e., in such a way that E_4-B is a hyperplane (membrane) in space E_5. However, there are no indications for such an arrangement. It is more likely that the displacements of the transmission medium lie within E_4-B, i.e., they have a very general direction in four-dimensional space. The existence of the intrinsic (spin) angular momentum of particles supports this arrangement. The wave motion of the transmission medium thus remotely resembles the propagation of the transverse waves through rigid bodies, such as S-waves through the Earth.

In wave superposition, the instantaneous displacements of the transmission medium are added together at each point in space. The same applies to the addition of velocities. The resulting velocity of the transmission medium depends on the magnitude and direction of the individual velocities. Let us now try to find a general relationship for calculating the mean square velocity v_m of the transmission medium caused by the wave motion of a large number of particle-waves. All these particle-waves act simultaneously at the same point in space.

The composition of the mean square velocities of the transmission medium requires, among other things, consideration of the nature of its oscillation. This may be oscillation in a straight line, in a plane, or in 3D space, in all cases perpendicular to the direction of motion of the particle-wave in E_4-B. The specific variant depends on the polarization of the particle-wave. In any case, the mean square velocity can be decomposed into components in the direction of the coordinate axes. The components represent the mean square velocities in the individual dimensions – x, y, z, w:

$$v_m^2 = v_{mx}^2 + v_{my}^2 + v_{mz}^2 + v_{mw}^2$$

In this way, we can decompose the mean square velocities of all acting particle-waves, and then sum their effects by components. In the summation, the contributions of individual particle-waves can be considered statistically uncorrelated (the mean square velocities corresponding to individual particle-waves are independent of each other, and the same applies to their components in the direction of the coordinate axes). This means that the mean square velocities can be added in the same way as other statistically independent quantities expressed by their mean square value. This is analogous to the propagation of standard deviations in statistical analysis. The x-components $\boldsymbol{v_{mx,1}}, \boldsymbol{v_{mx,2}}, \ldots, \boldsymbol{v_{mx,n}}$ corresponding to individual particle-waves 1 to n are added according to the formula $\boldsymbol{v_{mx}^2} = \sum_{i=1}^{n} \boldsymbol{v_{mx,i}^2}$. The same applies for components in other axes. The formula for the resulting mean square velocity can be derived as follows:

$$v_m^2 = \sum_{i=1}^{n} v_{mx,i}^2 + \sum_{i=1}^{n} v_{my,i}^2 + \sum_{i=1}^{n} v_{mz,i}^2 + \sum_{i=1}^{n} v_{mw,i}^2$$
$$= \sum_{i=1}^{n} \left(v_{mx,i}^2 + v_{my,i}^2 + v_{mz,i}^2 + v_{mw,n}^2 \right) = \sum_{i=1}^{n} v_{m,i}^2$$

It is, therefore, a simple sum of the squares of the mean square velocities. The direction of oscillations has no effect on the result.

The resulting mean square velocity does not depend on the direction of motion, the polarization of individual particles-waves, or the number of dimensions in which the transmission medium oscillates. The formula also applies to the case of space E_4-B as a membrane (hyperplane) in multidimensional space. The only limitations are given by the statistical nature of the formula, which assumes a large number of simultaneously acting particle-waves and their mutual uncorrelatedness (independence).

Using (Equation 27), the formula can be rewritten as

$$V = \sum_{i=1}^{n} V_i \tag{29}$$

The Equation 29 expresses the composition of the gravitational potentials of individual particle-waves. It is their simple sum at any point in space. This formula is identical to the formula valid in Newtonian gravitation, and simultaneously in the Newtonian limit of GTR.

Waves propagate in the transmission medium at speed v_{4D}, which determines the speed of gravitation. When calculating the potential, it is therefore necessary to take into account the time delay – the time it takes for the waves to reach the given point in space.

2.7 Influence of variable v_{4D} on space metric

The standard metric of space E_4 has the form

$$\delta s^2 = \delta x^2 + \delta y^2 + \delta z^2 + \delta w^2 \tag{30}$$

where δs is the measure of the separation (distance) between two adjacent points in space. The separation is given in a measure of length (e.g., meters). However, the metric of space E_4-B is given by a slightly different relation (Equation 6), where the spatial separation δs is replaced by the time separation δt. It applies

$$\delta s = v_{4D}\, \delta t \tag{31}$$

The relationship (Equation 31) reflects the fact that length measurements are always related to the flow of time. In a situation where all matter takes the form of waves, it is not possible to define a unit of length that is independent of time. This is also reflected in the modern definition of the meter in the SI system. It includes not only time but also the speed of light, [11].

If the value of the speed of light was the same throughout the universe, there would be no fundamental difference between metrics (Equation 6) and (Equation 30). Both would be Euclidean. In the EMST, however, the speed of light (more precisely, the speed of particle-wave motion v_{4D}) is variable. Due to the presence of matter, the ratio between δs and δt changes and the Euclidean metric (Equation 6) ceases to be Euclidean. A logical contradiction arises – if the metric (Equation 30) is used, space E_4-B is Euclidean, but if (Equation 6) is used, it is not Euclidean. From a geometric point of view, the correct metric is (Equation 30), as it works with units of length and ignores the speed v_{4D}. From a physical point of view, however, we prefer the metric (Equation 6), because there is no such thing as a universal unit of length independent of the v_{4D}. This applies primarily to the measurement of lengths using the transit time of light. However, it also applies partially to "rigid measuring rods." Our beliefs about them are misleading. These measuring rods are made up of waves, and their dimensions are derived from the wavelengths of the particle-waves that make them up. And as we know, wavelength depends on the v_{4D} and the frequency – that is, on the flow of time. So, we cannot *a priori* assume that they're independent of the v_{4D}.

The fact that the presence of matter affects the motion of particle-waves (changing both their speed and trajectory) gives the impression that space is curved by the influence of matter. The shortest line connecting two points (realized, for example, by the path of photons) is not identical to the shortest line according to Euclidean metrics (Equation 30), see Figure 6. Gravitational effect influences transit times, wavelengths, and directions. It creates a perfect illusion of a curved space. However, if we consider the local values of v_{4D} and rectify distances, wavelengths, and directions for their influence, i.e., if we switch to purely geometric units free from the influence of the variable v_{4D}, we find that space is still Euclidean and the metric (Equation 30) applies without any exception.

In the following text, three types of lengths will be distinguished:

Euclidean lengths s_E are purely geometric lengths independent of the v_{4D} value. They are expressed in a standard length unit, which is the "meter" as defined by the SI, realized in an area outside the influence of the gravitational field. Here, I refer to the dependence of v_{4D} and the flow of time on the gravitational potential, see (Equations 15–17). The formula $\delta s_E = \mathbf{c}\, \delta t$ applies, where t represents coordinate time unaffected (not slowed) by the effect of gravitation.

Local lengths s_L: The Euclidean meter, according to the SI definition, is, coincidentally, identical to the meter realized locally within a gravitational field. The requirement is that the gravitational potential of the reference clock and along the measured length are the same. As mentioned above, the rate of the clock depends on v_{4D} – see (Equation 8). For the same number of clock ticks (for the same amount of time), light travels the same distance. The wavelengths of particle-waves (electrons, locally emitted photons, etc.) will also be the same, i.e., length measuring tools will also have the same dimensions. Local lengths are therefore identical to Euclidean lengths, but unlike them, they are physically realizable in a gravitational field. However, their definition does not allow the measurement of lengths between points with different gravitational potential.

Corrected lengths s_C: To determine lengths passing through areas with different v_{4D}, the SI meter definition can be applied, except that the reference clock is not located at the same potential level as the measured length. It can be located outside the gravitational field ($V = 0$, $v_{4D} = c$) or anywhere within it ($V < 0$, $v_{4D} < c$). A different potential level at the location of the reference clock will affect the resulting lengths – these will be different from Euclidean ones. A variable value of v_{4D} in the area of the measured length, combined with a constant value of v_{4D} at the location of the reference clock, will cause the length of the meter to be also variable. Corrected lengths in the area of variable V (i.e., variable v_{4D}) do not create a Euclidean system.

The increment of the corrected length $\boldsymbol{\delta s_C}$ is given by $\delta s_C = v_{4D}\delta t = \sqrt{1+\frac{2V}{c^2}}\,c\,\delta t = k\,\delta s_E$, where

$$k = \sqrt{1+\frac{2V}{c^2}} \tag{32}$$

The values of v_{4D} and V are related to the potential level of the reference clock. If this clock is located outside the gravitational field, then $\boldsymbol{V \le 0}$, $\boldsymbol{v_{4D} \le c}$ applies throughout the entire space. Length increments $\boldsymbol{\delta s_C}$ inside the gravitational field (where $\boldsymbol{v_{4D} < c}$) are smaller than $\boldsymbol{\delta s_E}$. Any distance measured using increments $\boldsymbol{\delta s_C}$ will therefore be greater than the same distance measured using $\boldsymbol{\delta s_E}$ (i.e., by SI meter). The formula $\boldsymbol{s_C = \frac{1}{k} s_E}$ applies.

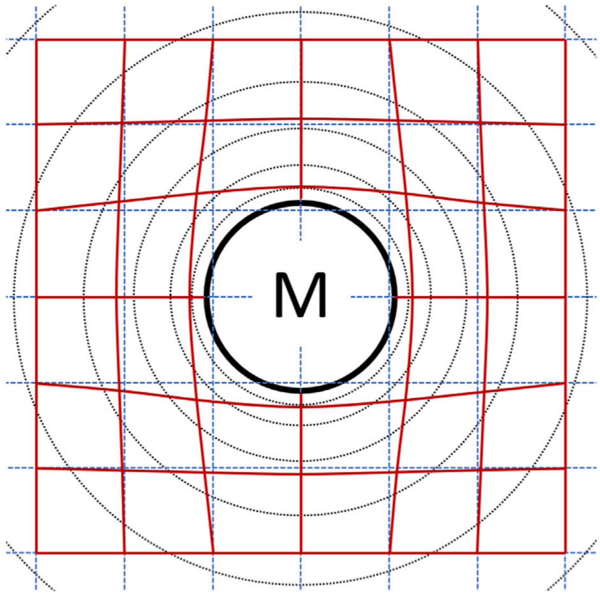

FIGURE 6
The apparent curvature of space due to the influence of matter. The case of a central spherical body with mass M is shown. The lines of shortest time (red) are not the shortest lines according to the Euclidean metric (blue). Near the body, the speed v_{4D} is lower, so the lines of shortest time take a slight detour. Areas of equal gravitational potential V (equal v_{4D}) are marked in black.

2.8 Gravitational field of a central body

The finding that space is Euclidean, even in areas affected by gravitation, is useful in deriving the metric of the central gravitational field. This term refers to the gravitational field generated by a point object or a body with a spherically symmetric distribution of mass. Central gravitational fields are of great importance in physics, because they describe the gravitational influence of planets and stars on bodies in their vicinity.

For the derivation of the metric of the central gravitational field, we start with the Euclidean metric of four-dimensional space. Subsequently, we implement the influence of the variable v_{4D} into it – i.e., we move from a purely geometric model to a physical model.

The E_4 metric (as well as E_4-B metric) in spherical coordinates (supplemented by the fourth coordinate w) is given by the relation

$$\delta s_E^2 = \delta r_E^2 + r_E^2\left(\delta\theta^2 + \sin^2\theta\,\delta\phi^2\right) + \delta w_E^2$$

Here, $\boldsymbol{r_E}$, $\boldsymbol{\theta}$ and $\boldsymbol{\phi}$ are polar coordinates in E_3, $\boldsymbol{\delta r_E}$, $\boldsymbol{\delta\theta}$ and $\boldsymbol{\delta\phi}$ are their increments, and $\boldsymbol{\delta w_E}$ is the increment in the fourth coordinate. All length quantities are Euclidean.

For the transition to the physical model, it is necessary to include the influence of the variable v_{4D} – move to Corrected lengths. For the derivation, a mathematical model involving a pair of concentric circles C and $C+$ will be used. The centers of the circles are located in the central body and their radii are r_E and $r_{E+} = r_E + \delta r_E, \delta r_E \to 0$. The reference level of gravitational potential for corrected lengths is the potential on circle C ($V_R = -GM/r_E$), i.e., the length of this circle expressed in Corrected lengths will be the same as in Euclidean lengths. The potential on circle $C+$ is $V = -GM/(r_E + \delta r_E)$. The circumferences of the circles in Corrected lengths relative to the reference potential V_R are

$O_C = O_E = 2\pi r_E$ and $O_{C+} = k_R/k\,2\pi(r_E + \delta r_E)$, where k is given by (Equation 32) and

$$k_R = \sqrt{1+\frac{2V_R}{c^2}} = \sqrt{1-\frac{2GM}{r_E c^2}} = \sqrt{1-\frac{R}{r_E}} \tag{33}$$

Since $k \neq k_R$, the circumference of circle O_{C+} differs from the Euclidean $O_{E+} = 2\pi(r_E + \delta r_E)$.

The value of k can be expressed as a multiple of k_R, assuming $\delta r_E \ll r_E$.

$$\begin{aligned}
k &= \sqrt{1-\frac{R}{r_E+\delta r_E}} \approx \sqrt{1-\frac{R}{r_E}\left(1-\frac{\delta r_E}{r_E}\right)} = \sqrt{1-\frac{R}{r_E}+\frac{R}{r_E^2}\delta r_E} \\
&= \sqrt{k_R^2+\frac{R}{r_E^2}\delta r_E} = k_R\sqrt{1+\frac{R}{k_R^2 r_E^2}\delta r_E} \approx k_R\left(1+\frac{R}{2k_R^2 r_E^2}\delta r_E\right) \\
&\approx k_R\frac{1}{\left(1-\frac{R}{2k_R^2 r_E^2}\delta r_E\right)}
\end{aligned}$$

Subsequently, the increase in the radius in Corrected lengths can be compared with the same increase in Euclidean lengths:

$$\begin{aligned}
\delta r_C &= r_{C+} - r_C = \frac{O_{C+}-O_C}{2\pi} = \frac{k_R}{k}(r_E+\delta r_E) - r_E \\
&= \left(1-\frac{R}{2k_R^2 r_E^2}\delta r_E\right)(r_E+\delta r_E) - r_E = r_E + \delta r_E \\
&\quad - \frac{R}{2k_R^2 r_E}\delta r_E - \frac{R}{2k_R^2 r_E^2}\delta r_E^2 - r_E \approx \delta r_E\left(1-\frac{R}{2k_R^2 r_E}\right) \\
&= \delta r_E\left(1-\frac{R}{2(r_E-R)}\right) = k_{mod}\,\delta r_E
\end{aligned}$$

where

$$k_{mod} = \left(1 - \frac{R}{2\,(r_E - R)}\right) \tag{34}$$

In the transition from Euclidean lengths to Corrected lengths, only the increment of the radius changes ($\delta r_C = k_{mod}\,\delta r_E$). The circumference of the circle O_C and thus also the derived radius $r_C = O_C/2\pi$ remain unchanged ($r_C = r_E$). The same applies to the increment in dimension w, which lies in the same potential as circle C ($\delta w_C = \delta w_E$) We can write

$$\delta s_E^2 = \frac{\delta r_C^2}{k_{mod}^2} + r_C^2\left(\delta\theta^2 + sin^2\,\theta\,\delta\phi^2\right) + \delta w_C^2.$$

The value δw_C is, from a physical point of view, the increment of proper time determined by local clock $\delta w_C = c\,\delta\tau$.

The increment δs_E represents the distance between points in space E_4-B. Its expression using the time of stationary reference clocks located outside the gravitational field leads to the formula $\delta s_E = v_{4D}\,\delta t$ – see (Equation 31). Considering the ratio between v_{4D} and c (Equation 15) and the relationships (Equation 33), we obtain the metric of space in the area of the central gravitational field

$$c^2\delta t^2 k_R^2 = \frac{\delta r_C^2}{k_{mod}^2} + r_C^2\left(\delta\theta^2 + sin^2\,\theta\,\delta\phi^2\right) + c^2\delta\tau^2 \tag{35}$$

Coordinates and their increments are always real numbers in the EMST and can be both positive and negative. On the other hand, time increments δt and $\delta\tau$ are always non-negative (they are related to the increments of the path or the number of clock ticks – see [7]). The coefficients k_R and k_{mod} are given by Equations 33, 34), where $r_C = r_E$. The quantity $R = 2GM/c^2$ is known from the GTR as the Schwarzschild radius.

For $R \ll r_C$, the difference between k_R and k_{mod} is negligible. We can write

$$k_{mod} = \left(1 - \frac{R}{2\,(r_C - R)}\right) \approx \sqrt{1 - \frac{R}{r_C}} = k_R \tag{36}$$

The metric (Equation 35) can be rewritten for $R \ll r_C$ in the form known from GTR

$$\left(1 - \frac{R}{r_C}\right)c^2\delta t^2 = \frac{\delta r_c^2}{1 - \frac{R}{r_C}} + r_C^2\left(\delta\theta^2 + sin^2\,\theta\,\delta\phi^2\right) + c^2\delta\tau^2$$

i.e., in the form of the Schwarzschild metric. The meaning of the individual quantities is the same as in GTR. This also applies to the radius r_C, which is the radial coordinate calculated from the circumference of a circle. The corrected lengths form the same set of coordinates that was used by Schwarzschild in his solution.

2.9 Energy as a source of gravitation

As mentioned above, in the presented theory of gravitation, the principle source of gravitational attraction is the energy of matter, not its mass. The energy-mass ratio (which is constant in the GTR) is variable in the EMST – it depends on the variable value of v_{4D}, $E = m\,v_{4D}^2$, see (Equation 5). Therefore, it is not possible to interchange mass and energy in the formulas for gravitational potential or acceleration. As the potential decreases (moving down into the gravitational well), the energy of the particle-waves decreases, but their mass increases.

It is necessary to keep in mind the following when assessing the influence of gravitational potential on physical quantities:

- The dimensions of objects are independent of potential (Local lengths are equal to Euclidean lengths,
- Time flows more slowly in areas of lower potential (Equation 16),
- The mass of bodies is higher in areas of lower potential (Equation 13).

The above is reflected in the implementation of the fundamental units of these quantities (meter, second, kilogram).

In general, physical quantities containing only length quantities (distance, area, volume, etc.) and quantities containing mass and time in the opposite power (momentum [$kg\ m\,s^{-1}$], angular momentum [$kg\ m^2\ s^{-1}$], etc.) are not dependent on gravitational potential. For example, the value of Planck's constant h [$kg\ m^2\ s^{-1}$] is also independent of V.

The formulas describing the effects of gravitation are similar to Newton's, but they are based on particle-wave energy as the principal source of gravitation. Energy refers to the total energy of a particle-wave ($E = h\,f = E_0 + E_p + E_k$), see Equations 2, 9. The two most fundamental gravitation formulas take the form

$$V = -\overline{\varkappa}\frac{E}{r_C} \tag{37}$$

$$a = -\overline{\varkappa}\frac{E}{r_C^2} \tag{38}$$

i.e., the product GM is substituted by the product of $\overline{\varkappa}E$.

It can be seen that the mass of the central body M is replaced by its energy E, and Newton's gravitational constant G is replaced by a new constant $\overline{\varkappa}$. For weak gravitational fields, the value of $\overline{\varkappa}$ can be derived from G [$kg^{-1}\ m^3\ s^{-2}$], $\overline{\varkappa} = G/c^2 = 7{,}425 \times 10^{-28}$ [$kg^{-1}\ m$]. It is important to note that neither G nor $\overline{\varkappa}$ are constants in the true sense of the word. Both are functions of the gravitational potential V, and therefore also of v_{4D}. For reference clocks "1" and "2" in regions with different potentials (see example above), $\overline{\varkappa}_2/\overline{\varkappa}_1 = v_{4D,2}/v_{4D,1}$ and $G_2/G_1 = v_{4D,2}^3/v_{4D,1}^3$. The constant $\overline{\varkappa}$ is less dependent on the value of the gravitational potential than G.

The gravitational potential of composite bodies is the sum of the gravitational potentials of individual particle-waves. The total value can be determined by simple addition – see relation (Equation 29). At this stage, the different energies of identical particle-waves (e.g., free electrons at rest) in places with different potentials become significant. Particle-waves deeper in the gravitational well have lower energy than identical particle-waves higher up – see Sect. 2.6.

3 Discussion

The concept of gravitation theory based on the EMST (GT-EMST) differs fundamentally from the one based on GTR. In particular, the foundations and mathematical notation of the two theories are completely different. The GT-EMST can be classified as a scalar theory of gravitation, i.e., a theory in which the source of gravitation is described by a scalar field. In this case by the v_{4D}

speed field. As a consequence, mathematical notation is considerably simpler in the GT-EMST. However, the resulting mathematical formulas of both theories are very similar or identical.

The GT-EMST explains the origin of gravitational time dilation and gives the functional dependence of this dilation on gravitational potential. It also explains the common origin of gravitational and inertial forces from the general properties of waves (Fermat's principle). It shows that gravitational and inertial forces have a common origin in the spatially variable value of v_{4D}, but the very reason is different. For (apparent) inertial forces, it is apparent differences in the speed v_{4D}; for (real) gravitation, it is a real decrease in v_{4D} due to real waves in the transmission medium.

Eliminating the principle of relativity as a fundamental law of the universe removes the latent contradiction between the non-existence of a privileged reference frame for linear motion and the existence of such a frame for rotational motion. This contradiction, which originates in STR, does not exist in the EMST. The EMST assumes the existence of a privileged reference frame for all types of motion. It also explains why it is not possible to experimentally distinguish this frame from others for linear motion [7].

The GT-EMST is not just a theory of gravitation. The dependence of the trajectory of matter (particles-waves) on the variable v_{4D} is simultaneously a theory of inertia. It explains the curvature of the trajectories of physical objects and the change in their energy due to the existence of apparent (inertial) forces. It shows that the acceleration of a body does not depend on its mass – it explains the universal influence of inertial and gravitational forces on all matter.

The GT-EMST shows that the curvature of space due to gravitation is only apparent. It is a consequence of the interaction between Fermat's principle and the variable value of v_{4D} in space. Matter consisting of waves (particles-waves) moves along paths with the shortest time, not along geometrical straight lines. Although space appears curved in physical experiments, it is possible to consider the causes of this curvature, introduce numerical corrections, and show that space is Euclidean even in the presence of the gravitational influence of matter. This is analogous to the refraction of light in the Earth's atmosphere. Although light travels along curved paths and the measured directions and distances do not form a Euclidean system, no one doubts that the space in which light travels is Euclidean. It suffices to consider the local refractive indices (local speeds of light), correct the measured directions and distances for their influence, and the corrected quantities will form a Euclidean system. This is a common procedure used, for example, in geodetic measurements.

Numerical corrections can be also applied to clock rates of local clocks. The corrections are both gravitational (correction of clock rate depending on the local potential) and kinematic (correction based on the clock's speed of motion). It is therefore possible to numerically correct the clock's operation and recalculate it to the selected potential level and selected state of motion. This already happens, for example, when correcting the operation of atomic clocks on GNSS satellites, [12, 13], and is also part of the definition of so-called coordinate times [14]. The corrections are identical in the EMST and the GTR.

The dependence of particle-wave frequency on local gravitational potential (see Equations 11, 15) is the cause of the gravitational Aharonov–Bohm effect [15].

Unlike the STR, the EMST assumes the existence of a preferred, so-called "stationary coordinate system". It would therefore be possible, at least theoretically, to convert the time of an arbitrary clock to the time in the stationary gravitation-free system. This would give us a single time for the entire universe, time that is independent of the motion and location of clocks. This time can be considered as "cosmological time" – an independent time parameter of the evolution of the universe. This possibility represents a fundamental departure from the theory of relativity, which considers all coordinate systems to be equivalent and therefore does not permit the definition of a single cosmological time.

Under usual physical conditions, the metric of the central gravitational field derived within the GT-EMST is identical to the Schwarzschild metric. This means that, in the case of a central field, the physical predictions of the EMST are the same as those of the GTR. The only difference is in the replacement of the coefficient k_R with the coefficient k_{mod} (Equation 36) in the radial term of the metric (Equation 35). The values of these coefficients are practically identical for usual situations where $R \ll r_C$. The biggest difference within the solar system occurs on the surface of the Sun, where $k_R = 0,997855$ while $k_{mod} = 0,997848$ for the Sun's values $R = 3 \times 10^6\ m$ and $r_C = 7 \times 10^8\ m$. Their ratio $k_R/\ k_{mod} = 1 + 7.10^{-6}$. This value is so close to 1 that detecting the deviation will be very difficult or even impossible with any existing technology. For the solar system, the GT-EMST and the GTR predictions can therefore be considered identical. However, differences occur in massive astronomical objects outside the solar system.

The GT-EMST concept is unique in that any particle-wave influences the motion of all surrounding particle-waves, reducing their speed v_{4D}, but does not affect its own speed. The particle-wave does not affect itself in any way. This eliminates the theoretical problem of Newton's classical solution, which has difficulty describing the gravitational effect of a point mass on itself.

The assumption that gravitation is caused by particle-waves, and thus by wave motion of the transmission medium, offers an answer to the question of how fast gravitation propagates. All waves move through the transmission medium at speed v_{4D}, and gravity propagates at the same speed. Changes in the distribution of gravitational masses manifest themselves at distant locations with a delay proportional to the distance. In the cases of dynamic sources of gravitation (e.g., close binary stars), areas of greater and lesser undulation of the transmission medium (areas of greater and lesser v_{4D}) arise, spreading through space from such sources. Such areas influence the actual gravitational effect – they create so-called gravitational waves. These waves move at speed v_{4D}.

The fact that gravitation may not be caused by mass, but by the total energy of matter, see (Equations 37, 38), can influence our understanding of the gravitation of very massive objects. Galaxies may be an example. The central part of a galaxy is located deeper in the gravitational well – the mass here has less energy than similar mass at the periphery of the galaxy. This effect weakens the gravitational influence of the central regions of the galaxy, and at the same time, relatively strengthens the influence of the peripheral parts. This finding is important for modeling the rotation of galaxies and the effect of so-called dark matter on them.

The idea that gravitation is caused by a locally variable speed of light is not new. Albert Einstein considered it as the cause of the gravitational bending of light in his 1911 paper "On the Influence of Gravitation on the Propagation of Light" [16]. However, within the framework of classical or relativistic physics, the variable speed of light could not be a general cause of gravity, as it had no relation to the motion of ordinary (baryonic) matter. It could only affect particles moving at the speed of light, especially photons. For this reason, none of the theories of gravitation based on a variable speed of light [17, 18] received much attention. An attempt was made to overcome this limitation by introducing a dual space metric, but this is an *ad hoc* solution without sufficient justification. It introduces free parameters whose physical interpretation is unclear [19, 20]. A less radical approach separates the speed of light from the constant c as a parameter of the space-time metric [21]. However, even in this case, additional parameters without clear physical meaning have been introduced. It was the EMST and its prediction that all particles of matter move at the same 4D speed that permitted a fundamental shift in the understanding of gravity and the role of locally variable speed of light in it. It has made it possible to create a comprehensive theory of gravitation based on the natural properties of space, time, and matter.

A notable exception among works in this field is "Flat Space Gravitation" (FSG) by J.M.C. Montanus [22], which is based on relativity in uncurved Euclidean space. The so-called "absolute Euclidean space-time" used here is very similar to the EMST [23, 24]. Montanus, just like the author of this article, concludes that the gravitational curvature of space is only apparent:

"The idea of a curved space–time is based on the tacit assumption that the free space relation $ds^2 = c^2 d\tau^2$ *also holds in the situation with gravitation. Without the latter assumption the concept of curvature becomes redundant."* [22, p. 1561].

FSG has other similarities with the GT-EMST (e.g., a similar metric for the central gravitational field), but it completely omits the causes and mechanism of gravitational interaction. The derivation of FSG is purely mathematical and not entirely consistent (it does not consider the influence of the variable c on the ratio of mass and energy - $E = m\, c^2$). Although very inspiring and pioneering, FSG lacks an explanation of the principles of gravitation offered by the GT-EMST. It also lacks clear justification for choosing the tensor field as the source of gravitation.

The GT-EMST is formulated to be relativistically invariant. It is based on the EMST, which is equivalent to the STR, it takes into account the finite speed of gravity propagation, the state of motion of the source of gravitation (its energy, including kinetic energy) and the state of motion of the object on which gravitation acts (the term $\sin\alpha$ in (Equation 23) is equivalent to the relativistic increase in the mass of the object). In summary, it can be said that GT-EMST covers all areas of validity of GTR, leading to very similar, but not identical, physical predictions.

GT-EMST was derived using Newton's formula for potential (Sect. 2.6). This was modified in Sect. 2.9 by replacing the mass of the source by its total energy. For weak gravitational sources, the difference is negligible. Newtonian gravitation can be considered an approximation of the GT-EMST for weak stationary fields.

For many years, scalar theories of gravitation were not very popular, as there was no strictly scalar theory that would fit the experimental data [25]. However, this has changed recently, and there are at least two other scalar theories of gravitation claiming to fit all types of tests in the Solar System. These are the Geometric scalar theory of gravity [26] and A viable relativistic scalar theory of gravitation [27]. Both are based on flat Minkowski space and the assumption of a constant speed of light, i.e., on different foundations than GT-EMST. Nevertheless, both prove that scalar theories are not *a priori* excluded from the description of gravitation.

It must be admitted that there is currently no evidence that waves created by particles of matter are the cause of gravitation, nor is there any evidence that such waves exist at all. However, the author is not aware of any evidence indicating that such waves do not exist.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RM: Writing – original draft, Writing – review and editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. The author would like to thank Brno University of Technology for supporting this research under project No. FAST-S-25-8850.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. This was limited to the use of DeepL translator as a help for manuscript translation.

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Publisher's note

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