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Article

There Is a Master Reality beyond Each Observer's Reality

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Abstract: In special (SR) and general relativity (GR), coordinate space x_1, x_2, x_3 and coordinate time t span "coordinate spacetime". Here I disclose two issues in SR/GR: (1) No device measures x_i or t. Rulers and clocks measure proper distance d_i and proper time τ. Rather than being physical quantities, x_i and t are mathematical constructs. One observer sets his d_i and τ equal to x_i and t. (2) As in the geocentric model, there is no holistic view. Reality is always described from just one perspective. The analogy holds despite the covariance of SR/GR. In any transformed coordinates, there is again just one perspective. In Euclidean relativity (ER), d_1, d_2, d_3, d_4 span "proper spacetime" ($d_4 = c\tau$). All energy is moving through a 4D Euclidean space (ES) at the speed c. Each observer's reality is created by projecting ES orthogonally to his proper space d_1, d_2, d_3 and to his proper time $\tau = d_4/c$. These four axes are set equal to x_1, x_2, x_3, t in SR/GR and reassembled to a non-Euclidean spacetime. Thus, the symmetry of spacetime in SR/GR does not match the group SO(4) of ES. This mismatch is not an issue if we apply SR/GR to an observer's reality (coordinate spacetime) and ER to what I call "master reality" (proper spacetime). Different realities do require different theories! What matters is that each observer's reality can be retrieved from the master reality. ER boosts physics by solving the mysteries of time, the c^2 in mc^2, the Hubble tension, dark energy, the wave–particle duality, and entanglement. I conclude: Only in proper coordinates does nature disclose her secrets.

Keywords: spacetime; cosmology; Hubble constant; Hubble diagram; quantum mechanics

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Important Remarks

There are two different ways of how to read nature: in an observer's coordinates (coordinate space and coordinate time) or else in each object's coordinates (proper space and proper time). In special relativity (SR) [1] and general relativity (GR) [2], Albert Einstein followed the first way. Today, most physicists take SR/GR as the ultimate truth since they have been confirmed many times over. Here I show: They are not the ultimate truth. There is a master reality beyond each observer's reality. However, I will not (!) disprove SR/GR. Both theories work very well in each observer's reality. I only question the "generality" of GR. There is another theory that is even more general than GR: Euclidean relativity (ER). The present paper stands out because of three reasons: (1) I disclose two issues in SR/GR. (2) I explain why SR/GR make correct predictions despite these two issues. (3) By solving 15 mysteries, I demonstrate that ER is a very powerful theory.

Five pieces of advice: (1) *Do not take SR/GR as the ultimate truth.* Previous reviewers made a systematic error by doing so. ER is different. In ER, all energy is moving through a 4D space at the speed of light c. (2) *Be patient and fair.* All of physics cannot be addressed in one paper. SR/GR have been tested for 100+ years. ER also needs time to make its way. (3) *Do not be prejudiced against a theory that solves many mysteries.* New concepts often do so. (4) *Appreciate illustrations.* Geometric derivations are equivalent to equations and assist us in imagining four dimensions. (5) *Consider that you might be biased.* In ER, several concepts of today's physics are obsolete. Experts in these concepts might feel offended.

To sum it all up: Predictions made by SR/GR are correct, but ER penetrates to a deeper level. I apologize for having prepared several preprint versions. It was tricky to figure out why SR/GR make correct predictions despite two issues. Sect. 2 is about these two issues. In Sect. 3, I formulate the basic physics of ER. In Sect. 4, I recover the Lorentz factor and gravitational time dilation. In Sect. 5, ER solves 15 mysteries at once.

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1. Introduction

Today's concepts of space and time were coined by Albert Einstein. His SR [1] claims a flat spacetime with an indefinite distance function. SR is often interpreted in Minkowski spacetime, which visualizes relativistic effects very well [2]. Predicting the lifetime of particles [4] is one example that supports SR. GR [2] claims a curved spacetime with a pseudo-Riemannian metric. The deflection of starlight during a solar eclipse [4] and the very high accuracy of GPS [6] are two examples that support GR. Quantum field theory [6] unifies classical field theory, SR, and quantum mechanics (QM), but not GR.

The three postulates of ER: (1) All energy is moving through a 4D Euclidean space (ES) at the speed c. (2) The laws of physics have the same form in each observer's reality, which is created by projecting ES orthogonally to his proper space and to his proper time. (3) All energy is "wavematter" (electromagnetic wave packet and matter in one). My first postulate is stronger than the second SR postulate: c is absolute and universal. My second postulate is limited to each observer's reality rather than to inertial frames. My third postulate is a generalized concept of energy that makes ER compatible with QM.

I am not the first physicist to investigate ER. Montanus described ER and formulated relativistic dynamics in proper time [8,9], but he ignored that the symmetry group SO(3,1) of spacetime in SR does not match the group SO(4) of ES. Thus, electrodynamics does not work in ES. I will explain why this mismatch is not an issue (see Sect. 3). Almeida studied trajectories in ES [9]. Gersten showed that the Lorentz transformation is equivalent to an SO(4) rotation in a "mixed space" [11] (see Sect. 3). van Linden provides a good overview of various ER models that have been proposed [11]. However, no conclusive theory of ER has yet been published. Physicists are refusing ER because of two reasons: (1) Customized concepts, such as dark energy, make GR work in cosmology. (2) ER faces some geometric paradoxes if not applied properly. *This paper marks a turning point:* I disclose two issues in SR/GR (see Sect. 2), and I avoid paradoxes in ER (see Sect. 4).

It is instructive to contrast Newton's physics, Einstein's physics, and ER. In Newton's physics, all energy is moving through a 3D Euclidean space as a function of independent time. The speed of matter is $v_{3D} \ll c$. In Einstein's physics, all energy is moving through a 4D non-Euclidean spacetime. The speed of matter is $v_{3D} < c$. In ER, all energy is moving through a 4D Euclidean space. The 4D speed of everything is $u_{4D} = c$. Newton's physics [13] once inspired Kant [14]. Will ER revolutionize both physics and philosophy?

2. Two Issues in Special and General Relativity

There are two concepts of time in SR and GR: observer-related coordinate time t and proper time τ of each observer/object. The fourth coordinate in SR/GR is t. In § 1 of SR, Einstein gives an instruction of how to synchronize two clocks at P and Q. At "P time" t_P, a light pulse is sent from P towards Q. At "Q time" t_Q, the pulse is reflected at Q towards P. At "P time" t_P^*, it is back at P. The clock at Q synchronizes to the clock at P if

$$t_Q - t_P = t_P^* - t_Q \tag{1}$$

In § 3 of SR, Einstein derives the Lorentz transformation. The coordinates x_1, x_2, x_3, t of an event in a system K are transformed to the coordinates x'_1, x'_2, x'_3, t' in K′ by

$$x'_1 = \gamma\,(x_1 - v_{3D}\,t)\ , \tag{2a}$$

$$x'_2 = x_2\ , \tag{2b}$$

$$x'_3 = x_3\ , \tag{2c}$$

$$t' = \gamma\,(t - v_{3D}\,x_1/c^2)\ , \tag{2d}$$

where K′ moves relative to K in x_1 at a constant speed v_{3D} and $\gamma = (1 - v_{3D}^2/c^2)^{-0.5}$ is the Lorentz factor. Mathematically, Eqs. (1) and (2a–d) are correct for an observer R in K describing his reality. Because of the relativity postulate, there are similar equations for an observer B in K′ describing his reality. Physically, there is an issue: No device measures x_i or t. Rulers and clocks measure proper distance d_i and proper time τ. Rather than being physical quantities, x_i and t are mathematical

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constructs. One observer sets his d_i and τ equal to x_i and t. If R sets his τ equal to t, the clock of B won't be aware of it. Thus, it cannot display the value t' that R calculates in Eq. (2d)! The same issue applies to GR as it also makes use of a coordinate space and a coordinate time.

To understand why d_i and τ describe relativistic effects just as well as x_i and t, we consider time dilation. In § 4 of SR, Einstein derives that there is a dilation in coordinate time: A clock "b" of B is slow with respect to a clock "r" of R by the factor γ. Because time dilation was experimentally confirmed, any other concept of time must recover it. Here is a preview of how it works (see Sect. 3 for more details): There are two variables in which a time dilation can show up. In SR, "b" is slow with respect to "r" in t', which belongs to B. In ER, "b" is slow with respect to "r" in $d_4 = c\tau$, which belongs to R.

There is also a second issue in SR/GR: As in the geocentric model, there is no holistic view. Reality is always described from just one perspective. In medieval times, it was natural to believe that all celestial bodies revolve around Earth. Only astronomers wondered about the retrograde loops of planets and claimed: No, they cannot revolve around Earth. In modern times, engineers have improved the precision of rulers and clocks. Eventually, it was natural to believe that all rulers and clocks are aware of an observer's construed x_i and t. How could they be aware? Aren't dark energy and non-locality just as strange as retrograde loops? The analogy holds despite the covariance of SR/GR. In any transformed coordinates, there is again just one perspective. Certainly, the analogy is not perfect: The geocentric model is wrong, whereas the scope of SR/GR is limited (see Sect. 3).

3. The Basic Physics of Euclidean Relativity

The indefinite distance function in SR [1] is usually written as

$$c^2\,\mathrm{d}\tau^2 \;=\; c^2\,\mathrm{d}t^2 - \mathrm{d}x_1^2 - \mathrm{d}x_2^2 - \mathrm{d}x_3^2 \;, \tag{3}$$

where $\mathrm{d}\tau$ is a distance in τ and $\mathrm{d}t$ is the related distance in t. Coordinate space x_1, x_2, x_3 and coordinate time t span "coordinate spacetime". It is a *construed* spacetime because all four coordinates are mathematical constructs. We may rearrange Eq. (3) if it makes sense—I will demonstrate that it does—and get

$$c^2\,\mathrm{d}t^2 \;=\; \mathrm{d}d_1^2 + \mathrm{d}d_2^2 + \mathrm{d}d_3^2 + \mathrm{d}d_4^2 \;, \tag{4}$$

where $\mathrm{d}d_i = \mathrm{d}x_i$ $(i = 1, 2, 3)$ and $\mathrm{d}d_4 = c\,\mathrm{d}\tau$ are distances in ES. In Eq. (4), the roles of t and τ have switched: The fourth coordinate in ER is an object's proper time τ (what any clock displays). The variable t becomes the new invariant "cosmic time". I keep the same symbol "t" to emphasize the equivalence of Eqs. (3) and (4). The coordinates d_1, d_2, d_3, d_4 span "proper spacetime". It is a *natural* spacetime because all four coordinates are physical quantities. Proper spacetime is a synonym for ES. The switch must not be confused with the Wick rotation [15], which replaces t with it, but keeps τ as the invariant.

The metric in Eq. (4) is Euclidean. Because of the symmetry, we are free to label the four axes of an object's reference frame. We always take d_4 as that axis in which it is moving at the speed c. The axes d_1, d_2, d_3 span its proper space. Thus, we define

$$\tau \;=\; d_4/c \;, \tag{5}$$

$$\boldsymbol{\tau} \;=\; d_4\,\boldsymbol{u}/c^2 \;, \tag{6}$$

where $\boldsymbol{\tau}$ is the 4D vector "proper flow of time" of an object and $\boldsymbol{u}$ is its 4D velocity. The four components of $\boldsymbol{u}$ are $u_i = \mathrm{d}d_i/\mathrm{d}t$. Thus, Eq. (4) matches my first postulate

$$u_1^2 + u_2^2 + u_3^2 + u_4^2 \;=\; c^2 \;. \tag{7}$$

It is instructive to contrast coordinate time t, proper time τ, and cosmic time t. Coordinate time t is equal to $\tau = |\boldsymbol{\tau}|$ for the observer only. Thus, it is an extrinsic measure of time for the observer only. Proper time τ is an intrinsic measure of time: It is independent of any observer. Cosmic time t is the total distance covered in ES (integral over the path length) divided by c. Cosmic time is invariant and thus absolute. Proper time and cosmic time are subordinate quantities derived from distance and c. *Only by covering distance is time passing by for each object.* Thus, I suggest to measure

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distance in "light seconds", c in its own new unit to be given, and time in "light seconds per this new unit".

All four coordinates d_i are dimensions of space. Each observer's reality is created by projecting ES orthogonally to his proper space d_1, d_2, d_3 and to his proper time $\tau = d_4/c$. These four axes are set equal to x_1, x_2, x_3, t in SR/GR and reassembled to a non-Euclidean spacetime. At first glance, this relation between ER and SR/GR seems to be tricky. But it just reflects that the perspective of mankind is often egocentric. The human brain tends to believe that it is center and measure of everything else. It is natural for mankind to believe that Earth would be the center of the universe and that its own concepts of space and time would be general concepts. Egocentrism is persistent. It took centuries to learn that there is a reality beyond the geocentric model. Has mankind learned from history?

The biggest challenge is that the symmetry of spacetime in SR/GR does not match the group SO(4) of ES. Here is how to meet the challenge: This mismatch is not an issue if we apply SR/GR to an observer's reality (coordinate spacetime) and ER to what I call "master reality" (proper spacetime). Different realities do require different theories! What matters is that each observer's reality can be retrieved from the master reality. Depending on the respective axes of projection, different observers may experience a different proper space d_1, d_2, d_3 and a different 4D vector $\boldsymbol{\tau}$. I use Cartesian coordinates in all ES diagrams. Below some diagrams, I project ES to an observer's 3D space. We are free to label the axis of relative motion in 3D space. We often take d_1 as this axis. The corresponding ES diagrams display d_1 and d_4. In SR/GR, there is no master reality.

Let us now compare SR with ER. We consider two identical clocks "r" (red clock) and "b" (blue clock). In SR, clock "r" is at rest: It moves only in the axis ct at $x_1 = 0$. Clock "b" starts at $x_1 = 0$, but moves in the axis x_1 at a constant speed of $v_{3D} = 0.6\,c$. Figure 1 left shows that very instant when both clocks moved 1.0 s in the coordinate time of "r". Clock "b" moved 0.6 Ls (light seconds) in x_1 and 0.8 Ls in ct' (time dilation). Thus, "b" displays "0.8". ER is different: Figure 1 right shows that very instant when both clocks moved 1.0 s in the proper time of each clock. Clock "b" moved 0.6 Ls in d_1. According to Eq. (7), it also moved 0.8 Ls in d_4. In total, "b" moved 1.0 Ls. Thus, both clocks display "1.0".

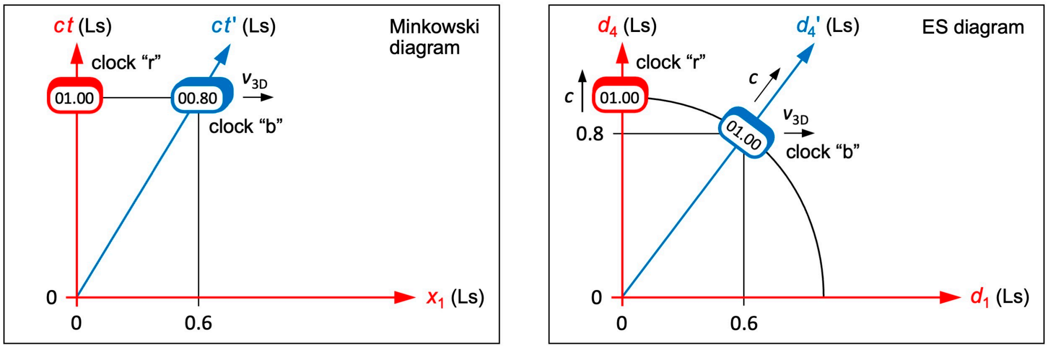

Figure 1. Minkowski diagram and ES diagram for two identical clocks "r" (red) and "b" (blue). **Left:** That very instant is shown when both clocks moved 1.0 s in the coordinate time of clock "r". **Right:** That very instant is shown when both clocks moved 1.0 s in the proper time of each clock.

Now watch out as this paragraph demystifies time dilation: Let observer R be with clock "r". Let observer B be with clock "b". In SR, t belongs to R and t' belongs to B. Observer R *calculates* (Lorentz transformation) that clock "b" displays $t' = 0.8$ s. Thus, "b" is slow with respect to "r" in t'. Time dilation in SR thus occurs in t', which belongs to B. In ER, d_4 belongs to R and d_4' belongs to B. Observer R *measures* (in his unprimed coordinate d_4) that clock "b" is at the position of $d_4 = 0.8$ Ls. Thus, "b" is slow with respect to "r" in d_4. Time dilation in ER thus occurs in d_4, which belongs to R. *In both SR and ER, "b" is slow with respect to "r".* However, coordinate time t and t' are mathematical constructs, whereas proper time τ and d_4 are physical quantities.

Gersten showed that the Lorentz transformation is equivalent to an SO(4) rotation in x_1, x_2, x_3, ct' [11]. He calls these coordinates "mixed space" because ct' is the only primed coordinate. Such a "mixed space" does not make sense physically, but we can take it as a hint that coordinate spacetime is not a natural concept. In SR, the Lorentz transformation rotates the mixed

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coordinates x_1, x_2, x_3, ct' to x'_1, x'_2, x'_3, ct. In ER, the unmixed coordinates d'_1, d'_2, d'_3, d'_4 appear rotated with respect to d_1, d_2, d_3, d_4 (see Sect. 4).

There is also a huge difference in the synchronization of clocks: In SR, each observer is able to synchronize a moving clock to his clock (same value of t in Figure 1 left). But if he does, the two clocks aren't synchronized from the perspective of the moving clock. In GR, the same applies to a clock in a gravitational field. In ER, clocks with the same 4D vector $\boldsymbol{\tau}$ are always synchronized, whereas clocks with different 4D vectors $\boldsymbol{\tau}$ and $\boldsymbol{\tau}'$ are never synchronized (different values of d_4 in Figure 1 right).

4. Geometric Effects in 4D Euclidean Space

We consider two identical rockets "r" (red rocket) and "b" (blue rocket) and assume: There is an observer R (or B) in the rear end of rocket "r" (or else rocket "b") who uses d_1, d_2, d_3, d_4 (or else d'_1, d'_2, d'_3, d'_4) as his coordinates. d_1, d_2, d_3 (or d'_1, d'_2, d'_3) span the 3D space of R (or else B). d_4 (or d'_4) relates to the proper time of R (or else B). The rockets started at the same point P and are moving relative to each other at a constant speed $v_{3\mathrm{D}}$. All 3D motion is in d_1 (or else d'_1). The ES diagrams (Figure 2 top) must fulfill my first two postulates and the requirement that both rockets started at the same point P. This can be achieved only by rotating the two reference frames with respect to each other. The projections to the 3D spaces of R and of B are shown in Figure 2 bottom. For a better visualization, the rockets are drawn in 2D although their width is in the axes x_2, x_3 and x'_2, x'_3.

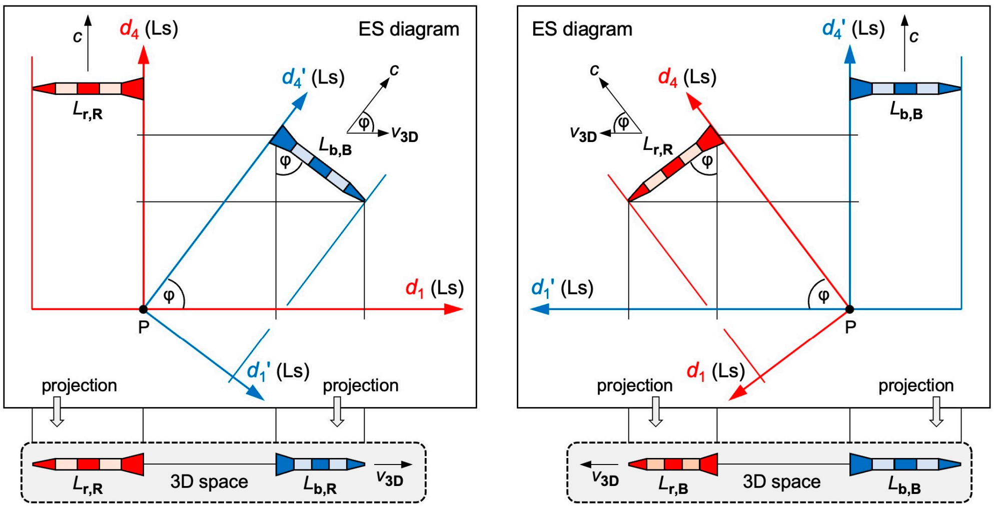

Figure 2. ES diagrams and 3D projections for two identical rockets "r" (red) and "b" (blue). All axes are in Ls (light seconds). **Top left and right:** In ES, both rockets are moving at the speed c, but in different directions. **Bottom left:** Projection to the 3D space of observer R. Rocket "b" recedes from "r" at a constant speed $v_{3\mathrm{D}}$. Rocket "b" contracts to $L_{\mathrm{b,R}}$. **Bottom right:** Projection to the 3D space of observer B. Rocket "r" recedes from "b" at a constant speed $v_{3\mathrm{D}}$. Rocket "r" contracts to $L_{\mathrm{r,B}}$.

Up next, we confirm: (1) The reference frames of R and B are rotated with respect to each other *causing length contraction.* (2) The time of R and the time of B flow in different 4D directions *causing time dilation.* Let $L_{i,\mathrm{R}}$ (or $L_{i,\mathrm{B}}$) be the length of rocket i as measured by R (or else B). In a first step, we project the blue rocket in Figure 2 top left to the axis d_1.

$$\sin^2\varphi + \cos^2\varphi = (L_{\mathrm{b,R}}/L_{\mathrm{b,B}})^2 + (v_{3\mathrm{D}}/c)^2 = 1 , \qquad (8)$$

$$L_{\mathrm{b,R}} = \gamma^{-1} L_{\mathrm{b,B}} \qquad \text{(length contraction)}, \qquad (9)$$

where $\gamma = (1 - v_{3\mathrm{D}}^2/c^2)^{-0.5}$ is the same Lorentz factor as in SR. Rocket "b" appears contracted to R by the factor γ^{-1}. But which distances will R observe in his axis d_4? For the answer, we mentally continue the rotation of rocket "b" in Figure 2 top left until it is pointing vertically down ($\varphi = 0°$) and serves as R's ruler in the axis d_4. In the projection to the 3D space of R, this ruler contracts to zero: The axis d_4 disappears for R.

In a second step, we project the blue rocket in Figure 2 top left to the axis d_4.

$$\sin^2\varphi + \cos^2\varphi = (d_{4,\mathrm{B}}/d'_{4,\mathrm{B}})^2 + (v_{3\mathrm{D}}/c)^2 = 1 , \quad (10)$$

$$d_{4,\mathrm{B}} = \gamma^{-1}\, d'_{4,\mathrm{B}} , \quad (11)$$

where $d_{4,\mathrm{B}}$ (or $d'_{4,\mathrm{B}}$) is the distance that B moved in d_4 (or else d'_4). With $d'_{4,\mathrm{B}} = d_{4,\mathrm{R}}$ (R and B cover the same distance in ES, but in different directions), we calculate

$$d_{4,\mathrm{R}} = \gamma\, d_{4,\mathrm{B}} \qquad \text{(time dilation)}, \quad (12)$$

where $d_{4,\mathrm{R}}$ is the distance that R moved in d_4. Eqs. (9) and (12) tell us: *Predictions made by SR are correct because the Lorentz factor* γ *is recovered in the projections to* d_1 *and* d_4.

To understand how an acceleration in 3D space manifests itself in ES, we now assume that clock "b" accelerates in the axis d_1 of clock "r" towards Earth (Figure 3). Clock "r" and Earth move only in the axis d_4. Because of Eq. (7), the speed of clock "b" in d_1 increases at the expense of its speed in d_4.

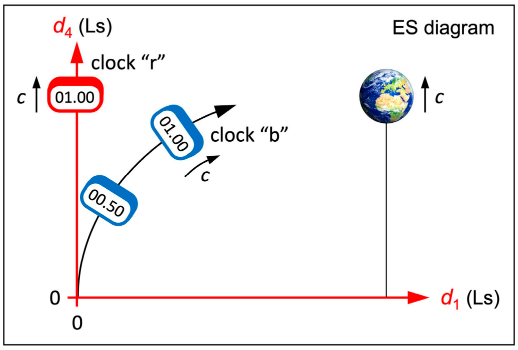

Figure 3. ES diagram for two identical clocks "r" (red) and "b" (blue). Clock "b" accelerates in the axis d_1 towards Earth. Clock "r" and Earth move only in the axis d_4.

Gravitational waves [15] support the idea of GR that gravitation would be a property of spacetime. However, particle physics is still considering gravitation a force, which has not yet been unified with the other forces of physics. I claim that curved trajectories in ES replace curved spacetime in GR. To support my claim, I now use ES coordinates to calculate gravitational time dilation. Let "r" and "b" be two identical clocks, which are far away from Earth. Initially, they are next to each other and move in the same axis d_4 at the speed c. At some time, clock "b" is sent in free fall towards Earth in the axis d_1 of clock "r". The kinetic energy of "b" (mass m) is

$$\tfrac{1}{2} m u_{1,\mathrm{b}}^2 = GMm/r , \quad (13)$$

where G is the gravitational constant, M is the mass of Earth, $u_{i,\mathrm{b}}$ is the speed of clock "b" in the axis d_i, and r is its distance to Earth's center. By applying Eq. (7), we get

$$u_{4,\mathrm{b}}^2 = c^2 - u_{1,\mathrm{b}}^2 = c^2 - 2GM/r . \quad (14)$$

With $u_{4,\mathrm{b}} = \mathrm{d}d_{4,\mathrm{b}}/\mathrm{d}t$ ("b" moves in the axis d_4 at the speed $u_{4,\mathrm{b}}$) and $c = \mathrm{d}d_{4,\mathrm{r}}/\mathrm{d}t$ ("r" moves in the axis d_4 at the speed c), we calculate

$$\mathrm{d}d_{4,\mathrm{b}}^2 = (c^2 - 2GM/r)\,(\mathrm{d}d_{4,\mathrm{r}}/c)^2 , \quad (15)$$

$$\mathrm{d}d_{4,\mathrm{r}} = \gamma_{\mathrm{gr}}\, \mathrm{d}d_{4,\mathrm{b}} \qquad \text{(gravitational time dilation)}, \quad (16)$$

where $\gamma_{\mathrm{gr}} = (1 - 2GM/(rc^2))^{-0.5}$ is the same dilation factor as in GR. Eq. (16) tells us: *Predictions made by GR are correct because the dilation factor* γ_{gr} *is recovered in the projection to* d_4. Thus, GPS satellites do their job in ER as well as in GR! If clock "b" returns to clock "r", the time displayed by "b" will be behind the time displayed by "r". This dilation is due to projecting a curved trajectory. In GR, it is due to a curved spacetime.

I finish this section with three instructive examples (Figure 4). They demonstrate how to project from ES to 3D space and disclose the benefit of the four symmetric distances d_i. Problem 1: A rocket moves along a guide wire. In ES, rocket and wire move at the speed c. We assume that the wire

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moves in its axis d_4. As the rocket moves along the wire, its speed in d_4 must be slower than c. Wouldn't the wire eventually be outside the rocket? Problem 2: A mirror passes a rocket. An observer in the rocket's tip sends a light pulse to the mirror and tries to detect the reflection. In ES, all objects move at the speed c, but in different directions. We assume that the observer moves in his axis d_4. How can he ever detect the reflection? Problem 3: Earth revolves around the sun. We assume that the sun moves in its axis d_4. As Earth covers distance in d_1, d_2, d_4, its speed in d_4 must be slower than c. Wouldn't the sun escape from the orbital plane of Earth?

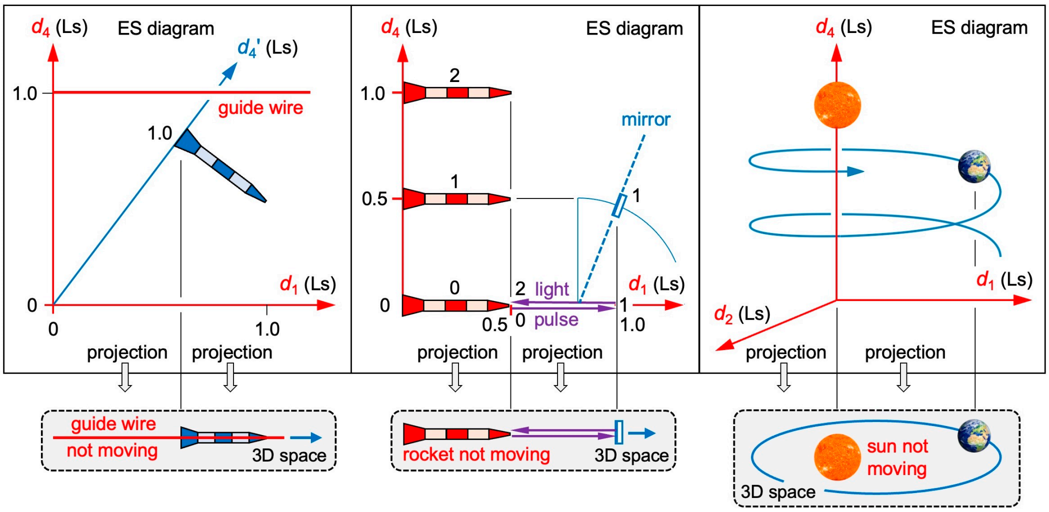

Figure 4. Graphical solutions to three geometric paradoxes. **Left:** A rocket moves along a guide wire. In 3D space, the guide wire remains within the rocket. **Center:** An observer in a rocket's tip tries to detect the reflection of a light pulse. Between two snapshots (0–1 or 1–2), rocket, mirror, and light pulse move 0.5 Ls in ES. In 3D space, the light pulse is reflected back to the observer. **Right:** Earth revolves around the sun. In 3D space, the sun remains in the orbital plane of Earth.

The questions in the last paragraph seem to imply that there are geometric paradoxes in ER, but there aren't. The fallacy in all problems lies in the assumption that there would be four observable (spatial) dimensions. But just three distances of ES are observable! All problems are solved by projecting 4D ES orthogonally to 3D space (Figure 4). *These projections tell us what an observer's reality is like because "suppressing the axis d_4" is equivalent to "length contraction makes d_4 disappear".* The suppressed axis d_4 is experienced as time. We easily verify in an observer's 3D space: The guide wire remains within the rocket; the light pulse is reflected back to the observer; the sun remains in the orbital plane of Earth. Other ER models [8–11] face paradoxes because they do not project ES to an observer's reality.

5. Solving 15 Fundamental Mysteries of Physics

We recall: (1) An observer's reality is created by projecting ES. (2) In SR/GR, the four axes of such a reality are reassembled to a non-Euclidean spacetime. *Because information is lost in all projections, the performance of SR/GR must be limited.* In this section, I show that ER solves 15 mysteries and that five concepts of today's physics are obsolete in ER.

5.1. Solving the Mystery of Time

Cosmic time is the total distance covered in ES divided by c. Proper time is what any clock displays (distance d_4 divided by c). By contrast, there is no definition of coordinate time other than "what I read on my clock" (attributed to Einstein himself).

5.2. Solving the Mystery of Time's Arrow

The arrow of time is a synonym for "time moving only forward". It emerges from the fact that the distance covered in ES is steadily increasing.

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5.3. Solving the Mystery of the c^2 in mc^2

In SR, where forces are absent, the total energy E of an object is given by

$$E = \gamma mc^2 = E_{\text{kin,3D}} + mc^2 , \quad (17)$$

where $E_{\text{kin,3D}}$ is the object's kinetic energy in 3D space and mc^2 is its "energy at rest". SR does not tell us why there is a factor c^2 in the energy of objects that in SR never move at the speed c. ER provides this missing clue and is thus superior to SR: $E_{\text{kin,3D}}$ is an object's kinetic energy in the axes d_1, d_2, d_3 of the observer, mc^2 is its kinetic energy in his axis d_4, and γmc^2 is the sum of both energies. In Eq. (17), ER is shining through! The c^2 tells us: All energy is moving through ES at the speed c. ER also makes us understand

$$E^2 = p^2c^2 = p_{3\text{D}}^2c^2 + m^2c^4 , \quad (18)$$

where p is the total momentum of an object and $p_{3\text{D}}$ is its momentum in 3D space. After dividing Eq. (18) by c^2, we recognize the vector addition of an object's momentum $p_{3\text{D}}$ in the axes d_1, d_2, d_3 of the observer and its momentum mc in his axis d_4.

5.4. Solving the Mystery of Relativistic Effects in Special Relativity

In SR, length contraction and time dilation can be derived from the Lorentz transformation, but their physical cause remains in the dark. ER discloses that length contraction and time dilation stem from projecting ES to an observer's reality.

5.5. Solving the Mystery of Relativistic Effects in General Relativity

In GR, a curved spacetime causes gravitational time dilation. ER discloses that gravitational time dilation stems from projecting curved trajectories in ES to the axis d_4 of an observer, which relates to his proper time τ. If an object accelerates in his proper space, it automatically decelerates in his proper time! Curved spacetime is a GR-specific concept, which has its roots in coordinate space and coordinate time. Of course, further considerations will be necessary that describe gravitation and gravitational effects in ER.

5.6. Solving the Mystery of the Cosmic Microwave Background

In this section, I outline an ER-based model of cosmology. There is no need to create ES. Euclidean space exists just like all numbers. For some reason, there was a Big Bang. In the GR-based Lambda-CDM model, the Big Bang occurred "everywhere" because space inflated from a singularity. In ER, the Big Bang can be localized: It injected a huge amount of energy into a non-inflating ES at once at what I call "origin O", the only natural reference point in ES. The Big Bang was a singularity in provided energy! Initially, all energy was receding from O at the speed c. The Big Bang provided radial momentum! Today, all energy is confined to a 4D hypersphere with the radius r. A lot of energy is confined to its 3D hypersurface expanding at the speed c. Because of interactions, some energy departed from its radial motion while keeping the speed c.

Shortly after the Big Bang, energy was highly concentrated in ES. In the projection to any reality, a very hot and dense plasma was created. While this plasma was expanding, it cooled down. During plasma recombination, radiation was emitted, which we observe as cosmic microwave background (CMB) today [16]. At temperatures of roughly 3,000 K, hydrogen atoms formed. The universe became more and more transparent for the CMB. In the Lambda-CDM model, this stage was reached 380,000 years "after" the Big Bang. In ER, these are 380,000 light years "away from" the Big Bang. If there was no cosmic inflation (see Sect. 5.9), the value "380,000" still needs to be recalculated in ER.

Figure 5 left shows the ES diagram for observers on Earth (here Earth is moving in d_4). A lot of energy moves radially: It keeps the radial momentum provided by the Big Bang. The CMB is moving transversally to the axis d_4. It cannot move in d_4 as it already moves in d_1 at the speed c. I now interpret three remarkable observations: (1) The CMB is nearly isotropic just because it was created equally in d_1, d_2, d_3. (2) The temperature of the CMB is very low because of a very high recession speed $v'_{3\text{D}}$ (see Sect. 5.10) of all the involved plasma particles and thus a very high Doppler redshift. (3) The CMB can still be observed today because it started moving at a speed $c' \ll c$ in a very dense medium.

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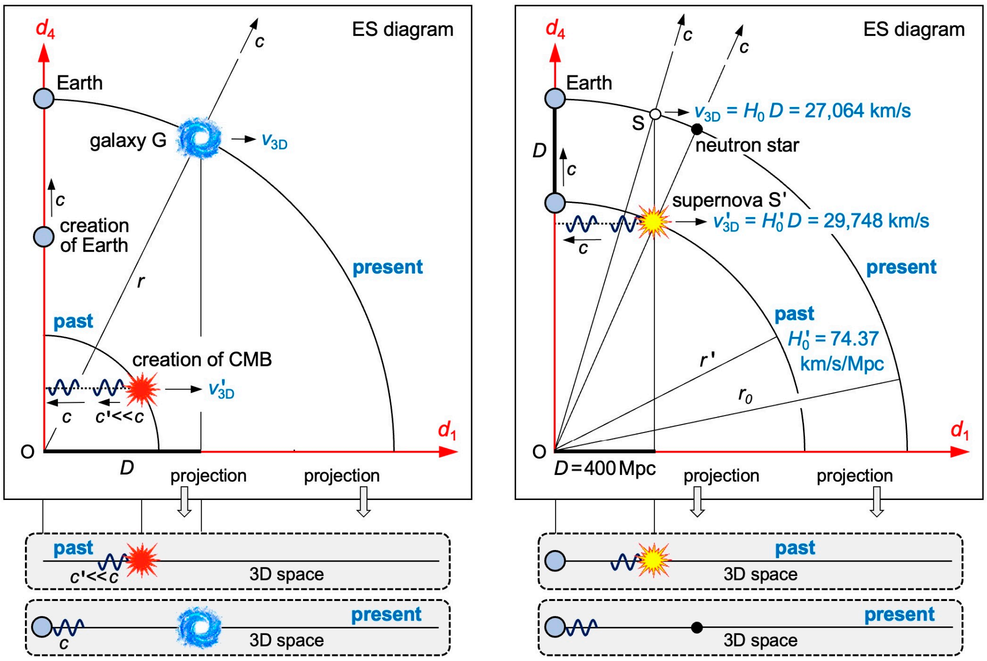

Figure 5. ES diagrams and 3D projections for solving the mysteries 5.6, 5.7, and 5.10. The displayed circular arcs are part of a 3D hypersurface, which is expanding in ES at the speed c. **Left:** The CMB was created in the past and started moving at a speed $c' \ll c$. The galaxy G is receding from Earth today at the speed $v_{3\mathrm{D}}$. **Right:** A supernova S′ occurred in the past when the radius r' of the hypersurface was smaller than today's radius r_0. It occurred at a distance $D = 400$ Mpc from Earth. If a supernova S occurs today at the same distance D, it recedes slower than S′.

5.7. Solving the Mystery of the Hubble–Lemaître law

The speed $v_{3\mathrm{D}}$ at which a galaxy G recedes from Earth in 3D space (Figure 5 left) relates to their 3D distance D as c relates to the radius r of the 4D hypersphere.

$$v_{3\mathrm{D}} = Dc/r = H_t\, D\ , \tag{19}$$

where $H_t = c/r = 1/t$ is the Hubble parameter and t is the cosmic time elapsed since the Big Bang. Eq. (19) is the Hubble–Lemaître law [17,18]: The farther a galaxy, the faster it is receding from Earth. Cosmologists are already aware that H_t is a parameter rather than a constant. They are not yet aware of the 4D Euclidean geometry.

5.8. Solving the Mystery of the Flat Universe

ES is projected orthogonally to an observer's proper space and his proper time. Thus, each observer experiences two seemingly discrete structures: a flat 3D space and time.

5.9. Solving the Mystery of Cosmic Inflation

It is assumed that a cosmic inflation of space in the early universe [20,21] caused the isotropic CMB, the flatness of the universe, and large-scale structures (inflated from quantum fluctuations). I just demonstrated that ER explains the first two observations. ER also explains the third observation if we assume that the impacts of quantum fluctuations have been expanding in ES at the speed c. ***In ER, cosmic inflation is an obsolete concept.***

5.10. Solving the Mystery of the Hubble Tension

There are several methods for calculating the Hubble constant $H_0 = c/r_0$, where r_0 is today's radius of the 4D hypersphere. Up next, I explain why the calculated values do not match. I consider measurements of the CMB made with the *Planck space telescope* and compare them with calibrated distance ladder techniques using the *Hubble space telescope.* According to team A [22], there is $H_0 = 67.66 \pm 0.42$ km/s/Mpc. According to team B [23], there is $H_0 = 73.52 \pm 1.62$ km/s/Mpc.

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Team B made great efforts to minimize the error margin by optimizing the distance measurements. I will show that misinterpreting the redshift data causes a systematic error in team B's calculation of H_0. Let us assume that the value of team A is correct. We now simulate a supernova S′ at a 3D distance of $D = 400$ Mpc. If this supernova occurred today (S in Figure 5 right), we would calculate

$$v_{3D} = H_0\, D = 27{,}064 \text{ km/s} , \qquad (20)$$

$$z = \Delta\lambda/\lambda_0 \approx v_{3D}/c = 0.0903 , \qquad (21)$$

where the redshift parameter z tells us how any wavelength λ_0 of the supernova's light is either *passively stretched* by an expanding space (team B), or how each λ_0 is redshifted by the Doppler effect of objects that are *actively receding* in ES (ER-based model). In Figure 5 right, there is an arc "past" when the supernova S′ occurred and an arc "present" when its light arrives on Earth. Because all energy is moving through ES at the speed c, Earth moved the same distance D, but in the axis d_4, when the light of S′ arrives. Thus, team B is receiving data from a time $t' = 1/H_{t'}$ when there was $r' < r_0$ and $H_{t'} > H_0$.

$$1/H_{t'} = r'/c = (r_0 - D)/c = 1/H_0 - D/c , \qquad (22)$$

$$H_{t'} = 74.37 \text{ km/s/Mpc} . \qquad (23)$$

Thus, team B is calculating $H_{t'}$ rather than H_0 because it does not take Eq. (22) into account. For a short distance of $D = 400$ kpc, Eq. (22) tells us that $H_{t'}$ deviates from H_0 by only 0.009 percent. When plotting v'_{3D} versus D for long distances (50 Mpc, 100 Mpc, ..., 450 Mpc), the slope $H_{t'}$ is indeed 8 to 9 percent higher than H_0. I kindly ask team B to adjust the calculated speed v'_{3D} to today's speed v_{3D} by converting Eq. (22) to

$$H_{t'} = H_0\, c \,/\, (c - H_0\, D) = H_0 \,/\, (1 - v_{3D}/c) , \qquad (24)$$

$$v_{3D} = v'_{3D} \,/\, (1 + v'_{3D}/c) . \qquad (25)$$

Of course, team B is well aware of the fact that the supernova's light was emitted in the past. But in the Lambda-CDM model, all that counts is the timespan during which the light is traveling from the supernova to Earth. Along the way, its wavelength is passively stretched by expanding space. The moment when the supernova occurred is irrelevant. In the ER-based model, that moment is relevant, but the timespan is irrelevant. The wavelength of the light is initially redshifted by the Doppler effect. During the journey to Earth, the parameter z' remains constant. It is tied up in some "package" when the supernova occurs and then sent to Earth, where it is measured. A 3D hypersurface (made of energy!) is expanding rather than space. ***In ER, expansion of space is an obsolete concept.***

5.11. Solving the Mystery of Dark Energy

The systematic error made by team B can be fixed within the Lambda-CDM model by adjusting v'_{3D} to today's speed v_{3D} according to Eq. (25). Up next, I reveal a systematic error that is inherent in the Lambda-CDM model itself. It has to do with assuming an accelerating expansion of space, and it can only be fixed by replacing this model with the ER-based model of cosmology. Today's cosmologists are favoring an accelerating expansion of space because the calculated recession speeds deviate from those values predicted by Eq. (19). These deviations increase with distance and are explained by an accelerating expansion of space, which would stretch the wavelength even more.

The ER-based model gives a simpler explanation for the deviations from the Hubble–Lemaître law: $H_{t'} = 1/t'$ from any past is higher than H_0. The older the redshift data, the more does $H_{t'}$ deviate from H_0, and the more does v'_{3D} deviate from v_{3D}. If a supernova S (small white circle in Figure 5 right) occurred today at the same distance of 400 Mpc as S′, the supernova S would recede slower (27,064 km/s) than S′ (29,748 km/s) just because $H_{t'}$ deviates from H_0. As long as we are not familiar with the 4D Euclidean geometry, higher redshifts are attributed to an accelerating expansion of space. Now that we know the 4D geometry, we can attribute higher redshifts to data from deeper pasts.

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Perlmutter et al. [23] and Riess et al. [25] interpret data from high-redshift supernovae as an accelerating expansion of space. In ER, all redshifts stem from the Doppler effect of receding galaxies. Because the Lorentz factor is recovered in the projections from ES, the equations of SR remain valid in an observer's reality. Thus, there is

$$\frac{v_{3D}}{c} = \frac{(1+z)^2-1}{(1+z)^2+1} , \tag{26}$$

where z is the observed redshift. While the supernova's light moved D in the axis d_1, Earth moved the same D in the axis d_4 (Figure 5 right). Let r' be the radius when the light was created. From Eq. (19) and $r' = r_0 - D$, we calculate v'_{3D} at the time t'.

$$v'_{3D} = v_{3D}\, r_0/r' = v_{3D} \,/\, (1 - D/r_0) \; . \tag{27}$$

Figure 6 shows the distance modulus μ of 16 low-redshift and 24 high-redshift supernovae versus v'_{3D}/c. Low-redshift data were published by Hamuy et al. [25], high-redshift data by Perlmutter et al. [23]. I considered those supernovae that had been studied by both [23] and [26]. For all 40 supernovae, I calculated v_{3D} from Eq. (26). Then I used Eq. (27), $D = 10^{0.2\mu+1}$, and $r_0 =$ 14.25 Gpc to calculate v'_{3D}.

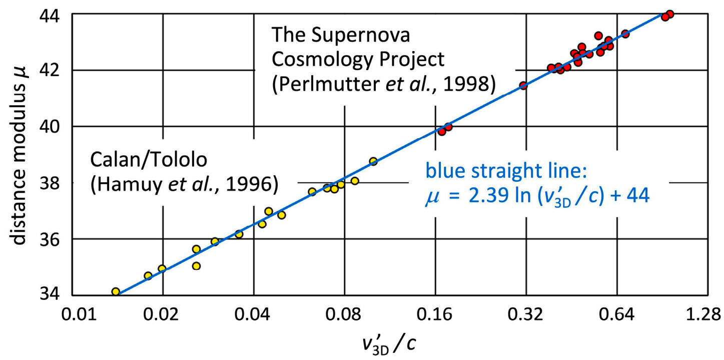

Figure 6. Hubble diagram for 40 Type Ia supernovae. The horizontal axis displays adjusted speeds. All data including their uncertainties are listed in the Appendix A.

Linear regression yields the blue straight line in Figure 6. The equation is given by

$$v'_{3D} = H_0^* \, D \; , \tag{28}$$

where H_0^* is a true constant. The offset "44" in Figure 6 relates to $H_0^* \approx 48$ km/s/Mpc (see Appendix B). H_0^* is lower than H_0 in the Lambda-CDM model, but it is not the task of ER to recover a value that stems from a different reality (coordinate spacetime). Only in ER do all 40 supernovae fit well to a straight line. Eq. (28) is the correct Hubble–Lemaître law. In ER, space is not expanding. Energy is receding! The term "dark energy" [28] was coined to explain an accelerating expansion of space. In ER, there is no expansion of space. ***In ER, dark energy is an obsolete concept.*** It has never been observed anyway.

Thus, any expansion of space (uniform as well as accelerating) is only virtual. There is no accelerating expansion of the Universe even if the Nobel Prize in Physics 2011 was given "for the discovery of the accelerating expansion of the Universe through observations of distant supernovae". This praise contains two misconceptions: (1) In the Lambda-CDM model, "Universe" also implies space, but space is *not expanding* at all. (2) There is receding energy, but it is moving *uniformly* in ES at the speed c. In an observer's reality, there only seems to be an accelerating expansion of space.

Radial momentum provided by the Big Bang drives all galaxies away from the origin O. They are driven by themselves rather than by dark energy! If the 3D hypersurface has always been expanding at the speed c, the time elapsed since the Big Bang is $1/H_0^*$, which is 20.4 billion years rather than 13.8 billion years [28]. The new estimate would explain the existence of stars as old as 14.5 billion years [29]. Table 1 compares two models of cosmology. Be aware that "Universe" (capitalized) in the Lambda-CDM model is not the same as "universe" in the ER-based model. In the next two sections, I will demonstrate that ER is compatible with QM. Since "quantum gravity" is meant to make GR compatible with QM, I conclude: ***In ER, quantum gravity is an obsolete concept.***

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Table 1. Comparing the Lambda-CDM model with the ER-based model of cosmology.

Lambda-CDM model based on GR	Model of cosmology based on ER
Big Bang was the beginning of the Universe.	Big Bang was the injection of energy into ES.
Big Bang occurred "everywhere".	Big Bang can be localized at an origin O of ES.
Big Bang occurred about 13.8 billion years ago.	Big Bang occurred about 20.4 billion years ago.
There are two competing values of H_0.	H_0^* is approximately 48 km/s/Mpc.
The Universe: all space, all time, and all energy.	The universe: proper 3D space of one observer.
Space is inflating and expanding.	Galaxies are receding radially in ES.
Space is driven by dark energy.	Galaxies are driven by radial momentum.
Spacetime is curved.	Trajectories of objects are curved in ES.
"Time is what I read on my clock." (A. Einstein)	Time is distance covered in ES divided by c.
GR isn't compatible with quantum mechanics.	ER is compatible with quantum mechanics.

5.12. Solving the Mystery of the Wave–Particle Duality

The wave–particle duality was first discussed by Niels Bohr and Werner Heisenberg [30] and has bothered physicists ever since. Electromagnetic waves are oscillations of an electromagnetic field, which propagate through an observer's 3D space at the speed c. In some experiments, objects behave like waves. In other experiments, the same objects behave like matter (particles). Up next, I explain how one and the same object can be deemed both wave and matter. From an observer's perspective, each object is wave or matter depending on its 3D speed. From its own perspective, it is always matter.

According to my third postulate, all energy is "wavematter" (electromagnetic wave packet and matter in one), a concept of energy shown in Figure 7. If I observe a wavematter WM in my reality (external view, coordinate spacetime!), I deem it wave (if its speed is $v_{3D} = c$), or matter ($v_{3D} \ll c$), or either one ($v_{3D} < c$). If I deem WM wave, it propagates in my axis x_1 and oscillates in my axes x_2 and x_3 (electromagnetic field). Propagating and oscillating occur in coordinate time t. However, WM does have features of a particle, too: From its own perspective (internal view, not available in SR/GR), the axis of its 4D motion disappears because of length contraction at the speed c. Thus, WM deems itself matter at rest. Be aware that "wavematter" is not just a new word for the duality, but a generalized concept of energy that discloses *why* there is a duality.

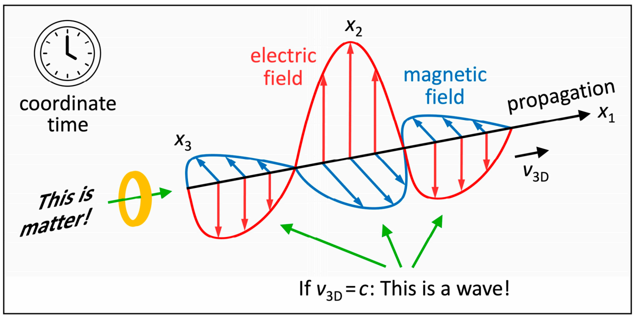

Figure 7. Concept of wavematter. Artwork illustrating how one and the same object can be deemed both wave and matter. If I observe a wavematter (external view), it comes in four orthogonal dimensions: propagation, electric field, magnetic field, and coordinate time. I deem it wave or matter depending on its 3D speed. Each wavematter deems itself matter at rest (internal view).

What I deem wave, deems itself matter. Each wavematter is wave and matter in one, but waves appear in an observer's reality only. Waves cannot appear in ES because of its SO(4) symmetry. Einstein demonstrated that energy is equivalent to mass [32]. This equivalence manifests itself in the wave–particle duality. Since each wavematter is moving through ES at the speed c, length contraction suppresses its 4D motion. From its own perspective (in its reality), all of its energy "condenses" to mass in matter at rest.

In a double-slit experiment, an observer detects coherent waves that pass through a double-slit and produce some pattern of interference on a screen. He deems all of these wavematters waves because he is not tracking through which slit each wavematter passes. Thus, he is an *external* observer. The photoelectric effect is quite different. Of course, one can externally witness how one photon

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releases one electron from a metal surface. But the physical effect ("Do I have enough energy to release one electron?") is up to the photon's view. Only if the photon's energy exceeds the binding energy of an electron is this electron released. Thus, the photoelectric effect must be interpreted from the *internal* view of the photon. Here its view is crucial! It behaves like a particle.

The wave–particle duality is also observed in matter, such as electrons [33]. According to my third postulate, electrons are wavematter, too. From the internal view (if I track them), electrons are particles: "Which slit will I pass through?" From the external view (if I do not track them), electrons behave more like waves. Because I automatically track slow objects (slow in my 3D space), I deem all macroscopic wavematters matter. This argument justifies drawing solid rockets and celestial bodies in my diagrams.

5.13. Solving the Mystery of Quantum Entanglement

The term "entanglement" [33] was coined by Erwin Schrödinger in his comment on the Einstein–Podolsky–Rosen paradox [35]. These three physicists argued that QM would not provide a complete description of reality. Schrödinger's word creation did not solve the paradox, but it demonstrates our difficulties in comprehending QM. John Bell proved that QM is not compatible with local hidden-variable theories [36]. Several experiments have confirmed that quantum entanglement violates the concept of locality [37–38]. Ever since has it been considered a non-local effect.

We will now "untangle" quantum entanglement *without* the concept of non-locality. All we need to do is discuss it in ES. Figure 8 displays two wavematters that were created at once at a point P and are now moving away from each other in opposite directions $\pm d_4'$ at the speed c. I claim that these two wavematters are entangled. If they are observed by a third wavematter moving in a direction other than $\pm d_4'$, they appear as two objects. This third wavematter cannot understand how the entangled wavematters communicate with each other in no time. This is the external view.

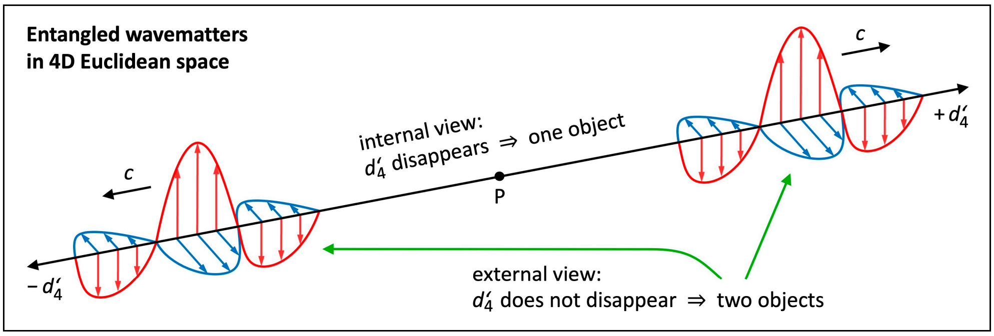

Figure 8. Entanglement in 4D ES. For each displayed wavematter, the axis $\pm d_4'$ disappears because of length contraction. It deems its twin and itself one object (internal view). For a third wavematter moving in a direction other than $\pm d_4'$, these wavematters appear as two objects (external view).

And here is the internal view: For each entangled wavematter in Figure 8, the axis $\pm d_4'$ disappears because of length contraction at the speed c. In their common (!) proper space spanned by d_1', d_2', d_3', either one of them deems itself at the very same position as its twin. From either perspective, they are one object, which has never been separated. This is how they communicate with each other in no time! The different positions in d_4' are irrelevant: *The twins stay together in their proper space even if their proper time flows in opposite directions.* Entanglement occurs because an observer and his observed objects may experience a different proper space and a different 4D vector $\boldsymbol{\tau}$. ER explains entanglement of electrons or atoms, too. They move at a speed $v_{3D} < c$ in my proper space, but in their axis $\pm d_4'$ they move at the speed c. Any measurement will tilt the axis of 4D motion of one wavematter and thus destroy the entanglement. ***In ER, non-locality is an obsolete concept.***

5.14. Solving the Mystery of Spontaneous Effects

In *spontaneous emission,* a photon is emitted by an excited atom. Prior to the emission, the photon's energy was moving with the atom. After the emission, this energy is moving by itself. Today's physics cannot explain how this energy is boosted to the speed c in no time. In ES, both atom and photon are moving at the speed c. So, there is no need to boost any energy to the speed c.

All it takes is energy from ES whose 4D motion "swings completely" (rotates by an angle of 90°) into an observer's 3D space—and this energy speeds off at once. In *absorption,* a photon is spontaneously absorbed by an atom. Today's physics cannot explain how the photon's energy is slowed down to the atom's speed in no time. In ES, both photon and atom are moving at the speed c. So, there is no need to slow down any energy. Similar arguments apply to pair production and to annihilation. Spontaneous effects are another clue that energy is always moving through ES at the speed c.

5.15. Solving the Mystery of the Baryon Asymmetry

According to the Lambda-CDM model, almost all matter in the Universe was created shortly after the Big Bang. Only then was the temperature high enough to enable the pair production of baryons and antibaryons. But the density was also very high so that baryons and antibaryons should have annihilated each other again. Since we do observe a lot more baryons than antibaryons today (known as the "baryon asymmetry"), it is assumed that an excess of baryons must have been produced in the early Universe [39]. However, such an asymmetry in pair production has never been observed.

ER offers a unique solution to the baryon asymmetry: Since each wavematter deems itself matter, there was matter in ES immediately after the Big Bang. *Today, there is much less antimatter than matter because antimatter is created in pair production only*. One may ask: Why does wavematter not deem itself antimatter? Energy has two faces: wave and matter. "Antimatter" is not the opposite of matter, but it has the opposite electric charge. It also seems to flow backward in time because proper time flows in opposite directions for any two wavematters created in pair production. These two wavematters are entangled: They are moving away from each other in opposite directions at the speed c.

6. Conclusions

ER solves mysteries that have not been solved in 100+ years or that have been solved, but with several customized concepts: cosmic inflation, expansion of space, dark energy, quantum gravity, and non-locality. These concepts are obsolete in ER, but they are needed in today's physics to make cosmology and QM work. On the other hand, electromagnetic and gravitational waves are facts in today's physics, but they cannot appear in ES because of its SO(4) symmetry. This is not an issue because SR/GR and ER describe different realities. In SR/GR, the four axes of ES are reassembled to a non-Euclidean spacetime. It is this reassembly that enables the formation of waves! Physicists feel comfortable with SR/GR, but if we think of an observer's reality as an oversize stage, the key to cosmology and QM is beyond the curtain. *Only in proper coordinates does nature disclose her secrets.*

SR/GR have been confirmed many times over. Thus, they are considered two of the greatest achievements of physics. I showed that their performance is limited, and I suspect that this limitation causes the current stagnation in physics. It was a very wise decision to award Albert Einstein the Nobel Prize for his theory of the photoelectric effect [40] rather than for SR/GR. ER penetrates to a deeper level. Einstein, one of the most brilliant physicists ever, did not realize that the fundamental metric in nature is Euclidean. For the first time, mankind understands the nature of time: Time is distance covered in ES divided by c. The human brain is able to imagine that we are moving through 4D space at the speed of light! *With that said, conflicts of mankind become all so small.*

Final remarks: (1) Chances are that ER will be considered a quantum leap in physics. I ask you once more to be patient and fair. All of physics cannot be addressed in one paper, but 15 solved mysteries should be sufficient to get this paper published. (2) The charm of ER is its symmetry. However, you will cherish ER only if you give yourself a little push—by accepting that an observer's reality is merely a projection. We must not ask in physics: Why is his reality a projection? Nor must we ask: Why is his reality a probability function? (3) It looks like Plato was right with his famous *Allegory of the Cave* [41]: Mankind experiences a projection that is blurred because of QM. This paper lays the groundwork for ER. Everyone is welcome to join in. May ER get the broad acceptance that it deserves.

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Data Availability Statement: All data displayed in Figure 6 are listed in the Appendix A.

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Conflicts of Interest: The author has no competing interests to declare.

Appendix A

All data displayed in Figure 6 including their uncertainties.
Col. 1: IAU name assigned to the supernova.
Col. 2: Redshift z according to [23].
Col. 3: Uncertainty in z according to [23].
Col. 4: Distance modulus μ according to [26].
Col. 5: Uncertainty in μ according to [26].
Col. 6: Distance D in parsec calculated from $D = 10^{0.2\mu+1}$.
Col. 7: v_{3D}/c calculated from Eq. (26).
Col. 8: v'_{3D}/c calculated from Eq. (27).

SN	z	σ_z	μ	σ_μ	D (pc)	v_{3D}/c	v'_{3D}/c
1990O	0.030	0.002	35.90	0.20	1.514E8	0.0296	0.0299
1990af	0.050	0.002	36.84	0.21	2.333E8	0.0488	0.0496
1992P	0.026	0.002	35.64	0.20	1.343E8	0.0257	0.0259
1992ae	0.075	0.002	37.77	0.19	3.581E8	0.0722	0.0741
1992ag	0.026	0.002	35.06	0.24	1.028E8	0.0257	0.0259
1992al	0.014	0.002	34.12	0.25	6.668E7	0.0139	0.0140
1992aq	0.101	0.002	38.73	0.20	5.572E8	0.0959	0.0998
1992bc	0.020	0.002	34.96	0.22	9.817E7	0.0198	0.0199
1992bg	0.036	0.002	36.17	0.19	1.714E8	0.0354	0.0358
1992bh	0.045	0.002	36.97	0.18	2.477E8	0.0440	0.0448
1992bl	0.043	0.002	36.53	0.19	2.023E8	0.0421	0.0427
1992bo	0.018	0.002	34.70	0.23	8.710E7	0.0178	0.0179
1992bp	0.079	0.002	37.94	0.18	3.873E8	0.0759	0.0780
1992br	0.088	0.002	38.07	0.28	4.111E8	0.0841	0.0866
1992bs	0.063	0.002	37.67	0.19	3.420E8	0.0610	0.0625
1993B	0.071	0.002	37.78	0.19	3.597E8	0.0685	0.0703
1995ar	0.465	0.005	42.81	0.22	3.648E9	0.3643	0.4896
1995as	0.498	0.001	43.21	0.24	4.385E9	0.3835	0.5540
1995aw	0.400	0.030	42.04	0.19	2.559E9	0.3243	0.3953
1995ax	0.615	0.001	42.85	0.23	3.715E9	0.4457	0.6029
1995ay	0.480	0.001	42.37	0.20	2.979E9	0.3731	0.4717
1995ba	0.388	0.001	42.07	0.19	2.594E9	0.3166	0.3871
1996cf	0.570	0.010	42.77	0.19	3.581E9	0.4228	0.5647
1996cg	0.490	0.010	42.58	0.19	3.281E9	0.3789	0.4922
1996ci	0.495	0.001	42.25	0.19	2.818E9	0.3818	0.4759
1996cl	0.828	0.001	43.96	0.46	6.194E9	0.5393	0.9540
1996cm	0.450	0.010	42.58	0.19	3.281E9	0.3554	0.4617
1997F	0.580	0.001	43.04	0.21	4.055E9	0.4280	0.5982
1997H	0.526	0.001	42.56	0.18	3.251E9	0.3992	0.5172
1997I	0.172	0.001	39.79	0.18	9.078E8	0.1574	0.1681
1997N	0.180	0.001	39.98	0.18	9.908E8	0.1640	0.1763
1997P	0.472	0.001	42.46	0.19	3.105E9	0.3684	0.4710
1997Q	0.430	0.010	41.99	0.18	2.500E9	0.3432	0.4162
1997R	0.657	0.001	43.27	0.20	4.508E9	0.4660	0.6816

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1997ac	0.320	0.010	41.45	0.18	1.950E9	0.2707	0.3136
1997af	0.579	0.001	42.86	0.19	3.733E9	0.4275	0.5792
1997ai	0.450	0.010	42.10	0.23	2.630E9	0.3554	0.4358
1997aj	0.581	0.001	42.63	0.19	3.357E9	0.4285	0.5606
1997am	0.416	0.001	42.10	0.19	2.630E9	0.3345	0.4102
1997ap	0.830	0.010	43.85	0.19	5.888E9	0.5401	0.9205

Appendix B

Estimation of H_0^*.

$$\mu = 2.39 \ln(v'_{3D}/c) + 44$$
$$5 \log D - 5 = 2.39 \ln(v'_{3D}/c) + 44$$
$$\ln D / \ln 10 = 0.478 \ln(v'_{3D}/c) + 9.8$$
$$\ln D = 1.1 \ \ln(v'_{3D}/c) + 22.6$$
$$D \approx (v'_{3D}/c) \times 6.31\text{E}9$$
$$v'_{3D} \approx D \times 0.048 \text{ m/s/pc}$$
$$H_0^* \approx 48 \text{ km/s/Mpc}$$

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