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[Markolf H. Niemz](#) *

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Natural Spacetime: Describing Nature in Natural Concepts

Markolf H. Niemz 

Heidelberg University, Theodor-Kutzer-Ufer 1–3, 68167 Mannheim, Germany
Correspondence: markolf.niemz@medma.uni-heidelberg.de

Today's physics describes nature in "empirical concepts" (based on observation), such as coordinate space/time in special relativity (SR), curved spacetime in general relativity (GR), and wave/particle. There are coordinate-free formulations of SR/GR, but there is no absolute time in SR/GR and thus no "holistic view" (universal for all objects at the *same* instant in time). **I show:** Euclidean relativity (ER) provides a holistic view by describing nature in "natural concepts" (immanent in all objects). Proper space/time (pure distance) replace coordinate space/time. Curved worldlines in flat Euclidean spacetime (ES) replace curved spacetime. "Wavematters" (pure energy) replace wave/particle. Any object's proper space d_1, d_2, d_3 and its proper time τ span d_1, d_2, d_3, d_4 (ES), where $d_4 = c\tau$. The invariant is absolute, cosmic time θ . All energy moves through ES at the speed c . An observer's view is created by orthogonally projecting ES to his proper space and to his proper time. For each object, there is a 4D vector "flow of proper time" τ . Information is lost if the 4D vector τ is ignored, as in SR/GR. ER solves the Hubble tension. Also, ER declares dark energy and non-locality obsolete. **I conclude:** (1) Acceleration rotates an object's τ and curves its worldline in flat ES. (2) Information hidden in τ solves 15 mysteries. (3) Different concepts disable a unification of SR/GR and ER. Either scope is limited. We must not apply SR/GR but ER whenever τ is crucial (high-redshift supernovae, entanglement). We must not apply ER but SR/GR whenever we use empirical concepts.

Keywords: spacetime; cosmology; Hubble tension; dark energy; quantum mechanics; non-locality

There are two legitimate approaches to describing nature: either in "empirical concepts" (based on observation) or else in "natural concepts" (immanent in all objects). Observation implies that the description may not be complete or that it may require concepts that are obsolete in the second approach. Special and general relativity (SR/GR) take the first approach [1, 2], but there is no absolute time in SR/GR and thus no "holistic view" (universal for all objects at the *same* instant in time). Euclidean relativity (ER) takes the second approach and provides a holistic view. The editors of several top journals informed me that SR and GR must not be put into question. They are mistaken because in this paper I show that the empirical concepts of SR/GR fail to solve fundamental mysteries.

A new theory poses questions: (1) *Does ER predict the same relativistic effects as SR/GR?* Yes, I show that the Lorentz factor and gravitational time dilation are recovered in ER, but empirical concepts (such as waves) are handled by SR/GR only. (2) *What are the benefits of ER?* ER solves 15 mysteries, including the Hubble tension, dark energy, and non-locality. ER tells us that we must not apply SR/GR to objects that are very far away (high-redshift supernovae) or that move in opposite 4D directions at the speed of light (entanglement). In such extreme situations, the 4D vector "flow of proper time" of ER (see Sect. 3) is crucial. (3) *Does ER make quantitative predictions?* ER explains the 10 percent deviation in the published values of H_0 . The other 14 mysteries are solved qualitatively.

Seven pieces of advice: (1) *Do not reject ER unless you can disprove it.* No one has disproven ER yet. (2) *Read carefully.* I do not disprove SR/GR. I show that the scope of SR/GR is limited. (3) *Be receptive to a different spacetime.* In ER, spacetime is flat and the worldlines are curved. (4) *Do not apply the concepts of SR/GR to ER.* A reviewer argued that spacetime cannot be Euclidean because in SR/GR spacetime is non-Euclidean. This is as if he argued that Earth cannot orbit the sun because in geocentrism the sun orbits Earth. (5) *Be fair.* One paper cannot cover all of physics. SR/GR have been tested for 100+ years. ER deserves the same chance. (6) *Appreciate illustrations.* As a geometric theory, ER complies with the stringency of math. (7) *Be objective.* Experts may feel offended. The 4D vector "flow of proper time" is the key to ER. I apologize for my many preprint versions. I received little support. The preprints document my path. The final version is all that is needed.

1. Introduction

Today’s concepts of space and time were coined by Albert Einstein. In SR, space and time are merged into a flat spacetime described by the Minkowski metric. SR is often presented in Minkowski spacetime [3]. Predicting the lifetime of muons [4] is one example that supports SR. In GR, a curved spacetime is described by the Einstein tensor. The deflection of starlight [5] and the high accuracy of GPS [6] are two examples that support GR. Quantum field theory [7] unifies classical field theory, SR, and QM but not GR.

The two postulates of ER: (1) All energy moves through Euclidean spacetime (ES) at the speed of light c . Mathematically, ES is 4D Euclidean space. Physically, only three axes are spatial. (2) The laws of physics have the same form in each observer’s view. His view is created by orthogonally projecting ES to his proper space and to his proper time. In SR, these two projections are called an observer’s “coordinate space” and “coordinate time”, but they are assembled to a non-Euclidean spacetime. In ER, these two projections span a Euclidean spacetime. My **first postulate** is stronger than the second SR postulate: c is both absolute and universal. My **second postulate** refers to each observer’s view rather than to inertial frames. On top, I use natural concepts: Proper space/time (pure distance) replace coordinate space/time. Curved worldlines in flat ES replace curved spacetime. “Wavematters” (pure energy, see Sect. 5.13) replace wave/particle. To improve readability, all of my observers are male. To make up for it, Mother Nature is female.

Fig. 1 left illustrates that an observer’s view is created by orthogonally projecting ES (see Sect. 4 for orthogonal projections). Fig. 1 right illustrates that there are two approaches to describing nature. ER describes her in natural concepts and tells us how an observer’s view is created. SR/GR describe nature in empirical concepts and tell us how the view of an observer R relates to the view of an observer B. There is absolute time in ER only. Because of different concepts, we must not play SR/GR off against ER. ER does not compete with SR/GR. So, what is ER good for? *ER solves mysteries that are rooted in ES.*

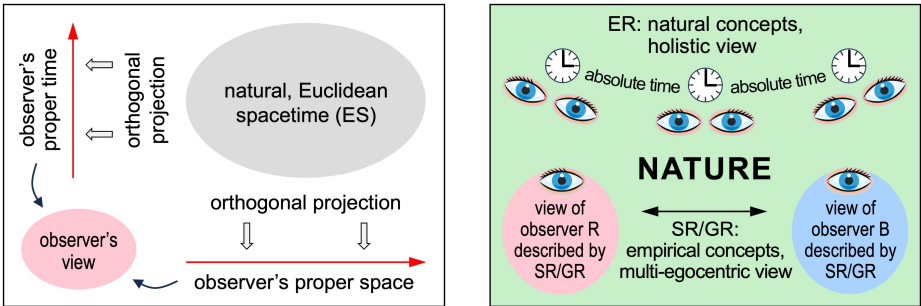


Fig. 1 Euclidean spacetime and observer’s view. **Left:** How to create an observer’s view. **Right:** ER and SR/GR describe nature in different concepts.

In 1969, Newburgh and Phipps [8] pioneered ER. Montanus [9] added a constraint: A pure time interval must be a pure time interval for all observers. According to Montanus [10], this constraint is required to avoid the twin paradox and a “character paradox” (confusion of photons, particles, antiparticles). I show that the constraint is obsolete. *Whatever is proper time for me, it may be one axis of proper space for you.* There is no twin paradox if we choose cosmic time as the parameter. There is no “character paradox” if we consider pure energy and the 4D vector “flow of proper time”. Montanus confirmed that ER predicts the precession of Mercury’s perihelion [10] and other relativistic effects [11], but he failed to formulate Maxwell’s equations in ER because of a missing minus sign [10]. He overlooked that the SO(4) symmetry of ES is incompatible with waves. ER does not dispute waves. In an observer’s view, “wavematters” (see Sect. 5.13) reduce to waves or else particles. However, as empirical concepts, waves and particles are handled by SR/GR.

Almeida [12] studied geodesics in ES. Gersten [13] showed that the Lorentz transformation can be considered an SO(4) rotation (see Sect. 3). van Linden maintains a website about ER (<https://euclideanrelativity.com/>). Most physicists reject ER because dark energy

and non-locality make cosmology and QM work, ES excludes waves, and paradoxes turn up if ES is misinterpreted. This paper marks a turning point. I disclose an issue in SR/GR. I justify the exclusion of waves in ES. I avoid paradoxes by projecting ES.

It is instructive to contrast Newton’s physics, Einstein’s physics, and ER. In Newton’s physics, all energy moves through 3D Euclidean space as a function of independent time. There is no speed limit for matter. In Einstein’s physics, all energy moves through a non-Euclidean spacetime. The 3D speed of matter is $v_{3D} < c$. In ER, all energy moves through ES. The 4D speed of all energy is c . Newton’s physics [14] shaped Kant’s philosophy [15]. I am convinced that ER will trigger a reformation of physics and philosophy.

2. Disclosing an Issue in Special and General Relativity

The fourth coordinate in SR is an observer’s coordinate time t . In § 1 of SR, Einstein gives an instruction for synchronizing clocks at the points P and Q. At t_P , a light pulse is sent from P to Q. At t_Q , it is reflected at Q. At t_P^* , it is back at P. The clocks synchronize 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

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

$$x'_2 = x_2 , \quad x'_3 = x_3 , \tag{2b}$$

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

where K' moves relative to K in x_1 at the constant speed v_{3D} and $\gamma = (1 - v_{3D}^2/c^2)^{-0.5}$ is the Lorentz factor. Mathematically, Eqs. (2a–c) are correct: They transform the coordinates from K to K'. There are covariant equations that transform the coordinates from K' to K. Physically, there is an issue in SR and also in GR: *The empirical concepts of SR/GR fail to solve fundamental mysteries*. There are coordinate-free formulations of both SR [16] and GR [17], but there is no absolute time in SR/GR and thus no “holistic view” (I repeat the definition: universal for all objects at the *same* instant in time). The view in SR/GR is multi-egocentric: SR/GR work for all observers, but each observer’s view is egocentric. All observers’ views taken together do not make a holistic view because they still do not provide absolute time. Without absolute time, observers do not always agree on what is past and what is future. Physics paid a high price for dismissing absolute time: ER restores absolute time (see Sect. 3) and solves 15 fundamental mysteries (see Sect. 5). Thus, the issue is real.

The issue in SR/GR is not about making wrong predictions. It has much in common with the issue in the geocentric model: In either case, there is no holistic view. Geocentrism is the egocentric view of mankind. In the old days, it was natural to believe that all celestial bodies would orbit Earth. Only astronomers wondered about the retrograde loops of some planets and claimed that Earth orbits the sun. In modern times, engineers have improved rulers and clocks. Today, it is natural to believe that it would be fine to describe nature as accurately as possible but in the empirical concepts of one or more observers. The human brain is smart, but it often takes itself as the center/measure of everything.

The analogy of SR/GR to the geocentric model is not perfect: Heliocentrism and geocentrism exclude each other, whereas ER and SR/GR complement each other. Even so, the analogy is close: (1) After a transformation in SR/GR (or after choosing another center of the Universe), the view is again egocentric (or else geocentric). (2) Retrograde loops make geocentrism work, but heliocentrism declares retrograde loops obsolete. Dark energy and non-locality make cosmology and QM work, but ER declares dark energy and non-locality obsolete. (3) The geocentric model was a dogma in the old days. SR/GR are dogmata today. *Have physicists not learned from history? Does history repeat itself?*

3. The Physics of Euclidean Relativity

ER cannot be derived from measurement instructions because the proper coordinates of other objects cannot be measured. We start with the non-Euclidean metric of SR

c^2 d\tau^2 = c^2 dt^2 - dx_1^2 - dx_2^2 - dx_3^2 , (3)

where d\tau is an infinitesimal distance in proper time \tau, whereas dt and dx_i (i = 1, 2, 3) are infinitesimal distances in an observer's coordinate space x_1, x_2, x_3 and coordinate time t. Coordinate spacetime x_1, x_2, x_3, t is empirical because its four coordinates are construed by an observer and thus not immanent in rulers and clocks. Rulers measure proper length. Clocks measure proper time. We introduce ER by defining its Euclidean metric

c^2 d\theta^2 = dd_1^2 + dd_2^2 + dd_3^2 + dd_4^2 , (4)

where d\theta is an infinitesimal distance in cosmic time \theta, whereas all dd_i (i = 1, 2, 3) and dd_4 = c d\tau are infinitesimal "pure distances". Now the role of proper time \tau is reversed: The new fourth coordinate is proper time \tau; the new invariant is absolute, cosmic time \theta; the new metric tensor is the identity matrix. I choose the symbol \theta because the initial of the Greek letter theta is "t" as in "time". I prefer the indices 1-4 to 0-3 to stress the full symmetry in all four coordinates. Any object's proper space d_1, d_2, d_3 and its proper time \tau span Euclidean spacetime d_1, d_2, d_3, d_4 (ES), where d_4 = c\tau. This spacetime is natural because its four coordinates d_\mu (\mu = 1, 2, 3, 4) are measured by and are thus immanent in rulers and clocks. Intrinsic rulers and clocks of all objects measure out natural spacetime! Eq. (4) is not a Wick rotation [18], where t is imaginary and \tau is the invariant.

Each object is free to label the axes of ES. We assume that it labels the axis of its current 4D motion as d_4. Since it does not move in its proper space, it moves in the d_4 axis at the speed c (my first postulate). Because of length contraction at the speed c (see Sect. 4), the d_4 axis disappears for itself and is experienced as proper time. Objects moving in the d'_4 axis at the speed c experience the d'_4 axis as proper time. Each object experiences its own 4D motion as proper time. In other words: An object's proper time flows in the direction of its 4D motion. For each object, there is a 4D vector "flow of proper time" \tau. Information is lost if the 4D vector \tau is ignored, as in SR/GR.

\tau = d_4/c , \quad \tau' = d'_4/c , (5)

\tau = d_4 \mathbf{u}/c^2 , \quad \tau' = d'_4 \mathbf{u}'/c^2 , (6)

where \mathbf{u} is an object's 4D velocity in ES. Speed is not defined as spatial distance divided by temporal distance but as any infinitesimal pure distance dd_\mu (\mu = 1, 2, 3, 4) divided by d\theta. There is u_\mu = dd_\mu/d\theta. Eq. (4) is not a random metric but my first postulate

u_1^2 + u_2^2 + u_3^2 + u_4^2 = c^2 . (7)

It is instructive to contrast the three concepts of time. Coordinate time t is a subjective measure of time: An observer uses his clock as the master clock. Proper time \tau is an objective measure of time: Clocks measure \tau independently of observers. Cosmic time \theta is the total distance covered in ES (length of a worldline) divided by c. By choosing \theta as the parameter, all observers agree on what is past and what is future. Since \theta is absolute, there is no twin paradox in ER. Twins are the same age in cosmic time. A finite c implies that none of the coordinates can be equal to absolute time, as in Newton's physics. However, a parameter "absolute time" is well compatible with a finite c.

Different concepts disable a unification of SR/GR and ER. SR describes nature in the empirical concepts x_1(\tau), x_2(\tau), x_3(\tau), t(\tau), where \tau is some evolution parameter and t is coordinate time. GR is locally equivalent to SR. ER describes nature in the natural concepts

$d_1(\theta), d_2(\theta), d_3(\theta), d_4(\theta)$, where θ is the “cosmic evolution parameter” and d_4 relates to proper time. Only in proper coordinates can we access ES, but the proper coordinates of other objects cannot be measured. In Sect. 6, I explain why this is fine.

We consider two identical clocks “r” (red clock) and “b” (blue clock). In SR, “r” moves in the ct axis. Clock “b” starts at $x_1 = 0$ and moves in the x_1 axis at a constant speed of $v_{3D} = 0.6c$. Fig. 2 left shows the instant when either clock moved 1.0 Ls (light seconds) in ct . Clock “b” moved 0.6 Ls in x_1 and 0.8 Ls in ct' . It displays “0.8”. In ER, “r” moves in the d_4 axis. Fig. 2 right shows the instant when either clock moved 1.0 s in its proper time, which is equal to cosmic time for either clock. Both clocks display “1.0”.

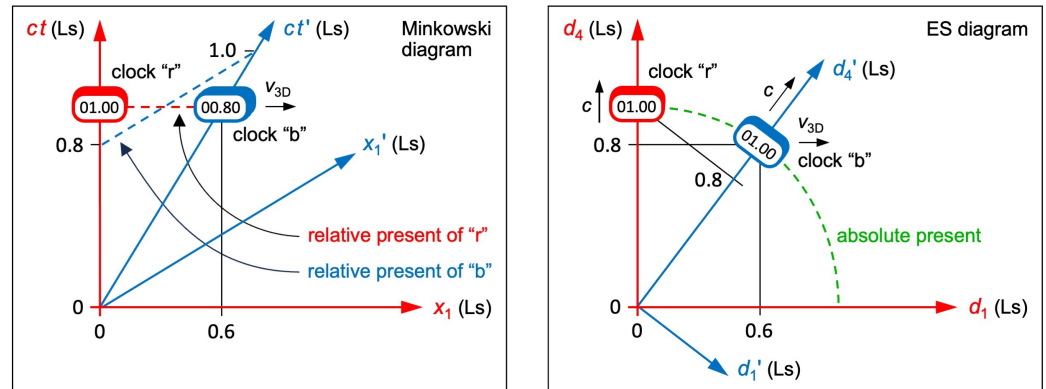


Fig. 2 Minkowski diagram and ES diagram of two clocks “r” and “b”. **Left:** “b” is slow with respect to “r” in t' . Coordinate time is relative (“b” is at different positions in t and t'). **Right:** “b” is slow with respect to “r” in d_4 . Cosmic time is absolute (“r” is in d_4 at the same position as “b” in d_4').

We now assume that an observer R (or B) moves with clock “r” (or else “b”). In SR and only from the perspective of R, clock “b” is at $ct' = 0.8$ Ls when “r” is at $ct = 1.0$ Ls (see Fig. 2 left). Thus, “b” is slow with respect to “r” in t' (of B). In ER and independently of observers, clock “b” is at $d_4 = 0.8$ Ls when “r” is at $d_4 = 1.0$ Ls (see Fig. 2 right). Thus, “b” is slow with respect to “r” in d_4 (of R). In SR and ER, “b” is slow with respect to “r”, but time dilation occurs in different axes. Experiments do not disclose the axis in which a clock is slow. This is why both SR and ER describe time dilation correctly—provided that they yield the same Lorentz factor. As I show in Sect. 4, they do.

But why does ER provide a holistic view? Well, Eq. (4) is fully symmetric in all four coordinates d_μ ($\mu = 1, 2, 3, 4$). I call them “pure distances” because ES itself does not distinguish between spatial and temporal. Only observers and objects experience three axes as spatial and one as temporal. R and B experience different axes as temporal. This is why Fig. 2 left works for R but not for B: A second Minkowski diagram is required, where x_1' and ct' are orthogonal. Here the view is multi-egocentric. In contrast, Fig. 2 right works for R and for B “at once” (at the same cosmic time θ). Not only are d_1 and d_4 orthogonal in Fig. 2 right but also d_1' and d_4' . Here the view is universal and thus holistic.

Gersten [13] showed that the Lorentz transformation can be considered an $SO(4)$ rotation in a mixed space X_1, X_2, X_3, T' , in which only the T' axis is primed. In ER, unmixed d_1', d_2', d_3', d_4' of an observed object are rotated with respect to an observer’s d_1, d_2, d_3, d_4 (see Sect. 4). There is also a noteworthy difference in the synchronization of clocks: In SR, each observer is able to synchronize a uniformly moving clock to his clock (same value of ct in Fig. 2 left). If he does, these clocks are not synchronized for the moving clock. In ER, clocks with the same 4D vector τ are always synchronized, whereas clocks with different τ and τ' are never synchronized (different values of d_4 in Fig. 2 right).

4. Geometric Effects in Euclidean Relativity

We consider two identical rockets “r” (red rocket) and “b” (blue rocket). Let observer R (or B) be in the rear end of “r” (or else “b”). The 3D space of R (or B) is spanned by d_1, d_2, d_3 (or else d_1', d_2', d_3'). We use “3D space” as a synonym of proper space. The proper time of R (or

B) relates to d_4 (or else d'_4) according to Eq. (5). Both rockets start at the same point P and at the same cosmic time θ_0 . They move relative to each other at the constant speed v_{3D} . R and B are free to label the axis of relative motion in 3D space. R (or B) labels it as d_1 (or else d'_1). The ES diagrams in Fig. 3 must fulfill my [two postulates](#) and the initial conditions (same P, same θ_0). This is achieved by rotating the red and the blue frame with respect to each other. Do not confuse ES diagrams with Minkowski diagrams. In ES diagrams, objects maintain proper length and clocks display proper time. To improve readability, a rocket's width is drawn in d_4 (or d'_4). Fig. 3 bottom shows the projection to 3D space.

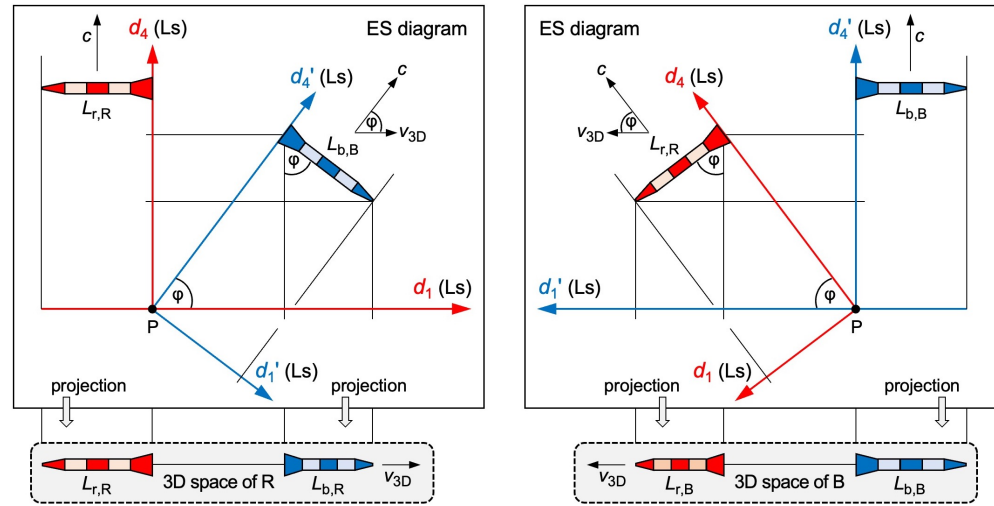


Fig. 3 ES diagrams of two rockets “r” and “b”. Observer R (or B) is in the rear end of “r” (or else “b”). **Top:** The rockets move in different 4D directions. **Bottom left:** Projection to the 3D space of R. “b” contracts to $L_{b,R}$. **Bottom right:** Projection to the 3D space of B. “r” contracts to $L_{r,B}$.

We now assume that N rockets “ r_i ” are launched from P at the same cosmic time θ_0 , where “ r_1 ” is equal to “r”. We also assume: The 4D vector τ_i of “ r_i ” ($2 \leq i \leq N$) is rotated with respect to τ_{i-1} of “ r_{i-1} ” by $\pi/2 - \varphi$. This implies that “ r_i ” recedes from “ r_{i-1} ” in the 3D space of “ r_{i-1} ” at the speed v_{3D} . If $N(\pi/2 - \varphi) > \pi/2$, some rockets move backward in d_4 . If one rocket “ r_i ” rotates by π , it stands still in the 3D space of “ r_1 ” and its 4D vector τ_i is reversed with respect to the 4D vector τ_1 of “ r_1 ”. This example shows that ER does not compete with SR. Our assumptions are not valid in SR: There is no “same cosmic time θ_0 ” and no 4D vector τ in SR. We can draw all “ r_i ” in a Minkowski diagram (launched at the same coordinate time), but our example is outside the scope of SR. Likewise, an example in empirical concepts is outside the scope of ER.

Up next, we verify: (1) Rotating the red and the blue frame with respect to each other causes length contraction. (2) The fact that proper time flows in different 4D directions for R and for B causes time dilation. Let $L_{b,R}$ (or $L_{b,B}$) be the length of rocket “b” for observer R (or else B). In a first step, we project “b” in Fig. 3 top left to the d_1 axis.

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

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

where $\gamma = (1 - v_{3D}^2/c^2)^{-0.5}$ is the same Lorentz factor as in SR. For R, rocket “b” contracts to $L_{b,R}$. But why do we calculate the same γ despite the Euclidean metric? Well, there is no length contraction in ES but in the projection to d_1 only. We now ask: Which distances will R observe in d_4 ? We rotate “b” until it serves as a ruler for R in d_4 . In his 3D space, this ruler contracts to a point: The d_4 axis disappears for R because of length contraction at the speed c . In a second step, we project “b” in Fig. 3 top left to the d_4 axis.

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

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

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

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

where $d_{4,R}$ is the distance that R moved in d_4 . Eqs. (9) and (12) tell us: γ is recovered in ER if we project ES to the axes d_1 and d_4 of an observer. This result is significant: **It tells us that ER predicts the same relativistic effects as SR.** The rockets serve as an example. All other objects are orthogonally projected the same way. For an overview of orthogonal projections, the reader is referred to geometry textbooks [19, 20].

We now transform the proper coordinates of observer R (unprimed) to those of observer B (primed). R cannot measure the proper coordinates of B, and vice versa, but we can calculate them from ES diagrams. For example, Fig. 3 top right tells us how to calculate the 4D motion of R in the proper coordinates of B and as a function of the parameter θ . The transformation is identical to a rotation in ES by the angle φ .

$$d'_{1,R}(\theta) = d_{4,R}(\theta) \cos \varphi = d_{4,R}(\theta) v_{3D}/c , \quad (13a)$$

$$d'_{2,R}(\theta) = d_{2,R}(\theta) , \quad d'_{3,R}(\theta) = d_{3,R}(\theta) , \quad (13b)$$

$$d'_{4,R}(\theta) = d_{4,R}(\theta) \sin \varphi = d_{4,R}(\theta) \gamma^{-1} . \quad (13c)$$

Up next, I show that not only the Lorentz factor is recovered in ER but also gravitational time dilation. We return to our two clocks "r" and "b". Clock "r" and Earth move in the d_4 axis of "r" at the speed c (see Fig. 4). Clock "b" accelerates in the d_1 axis of "r" toward Earth while maintaining the speed c . Because of Eq. (7), the speed $u_{1,b}$ of "b" in the d_1 axis increases at the expense of its speed $u_{4,b}$ in the d_4 axis.

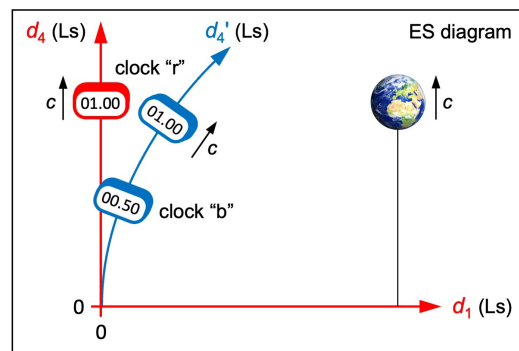


Fig. 4 ES diagram of two clocks "r" and "b". Clock "b" accelerates in the d_1 axis of "r" toward Earth. The d'_4 axis is curved because it indicates the current 4D motion of "b".

Initially, our two clocks shall be very far away from Earth. Eventually, clock "b" falls freely toward Earth. The kinetic energy of "b" in the d_1 axis of "r" is

$$\frac{1}{2} m u_{1,b}^2 = G M m / R , \quad (14)$$

where m is the mass of "b", G is the gravitational constant, M is the mass of Earth, and $R = d_{1,\text{Earth}} - d_{1,b}$ is the current 3D distance of "b" to Earth's center in the 3D space of "r". By applying Eq. (7), the equivalent to my first postulate, we obtain

$$u_{4,b}^2 = c^2 - u_{1,b}^2 = c^2 - 2GM/R . \quad (15)$$

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

$$dd_{4,b}^2 = (c^2 - 2GM/R) (dd_{4,r}/c)^2, \quad (16)$$

$$dd_{4,r} = \gamma_{gr} dd_{4,b} \quad (\text{gravitational time dilation}), \quad (17)$$

where $\gamma_{gr} = (1 - 2GM/(Rc^2))^{-0.5}$ is the same dilation factor as in GR. Eq. (17) tells us: γ_{gr} is recovered in ER if we project ES to the d_4 axis of an observer. This result is significant: **It tells us that ER predicts the same gravitational time dilation as GR.** However, there is a big difference: In GR, curved spacetime replaces gravitational fields. In ER, gravitational fields celebrate a comeback. Acceleration rotates an object's τ and curves its worldline in flat ES. "Action at a distance" is not an issue if any variation in field strength also spreads at the speed c . Gravitational waves [21] support the idea of GR that gravity is a feature of spacetime. In ER, the SO(4) symmetry of ES is incompatible with waves. *This is fine because we must apply SR/GR whenever we use empirical concepts.* The field equations of GR can be derived from the variation of an action [22]. As an experimental physicist, I invite theorists to apply variational principles in ER. It is my task to describe nature in natural concepts. Here I demonstrated that ER yields the same γ and γ_{gr} as SR/GR.

Summary of time dilation: In SR, a uniformly moving clock "b" is slow with respect to "r" in the time axis of "b". In GR, an accelerating clock "b" or else a clock "b" in a more curved spacetime is slow with respect to "r" in the time axis of "b". In ER, a clock "b" is slow with respect to "r" in the time axis of "r" (!) if the 4D vector τ' of "b" differs from the 4D vector τ of "r". Since both γ and γ_{gr} are recovered in ER, the Hafele–Keating experiment [23] supports ER too. GPS works in ER as well as in SR/GR.

Three problems tell us how to read ES diagrams (see Fig. 5). **Problem 1:** Two objects "r" and "b" move through ES at the speed c . "r" moves in d_4 . "b" emits a radio signal at $d_4' = 1.0$ Ls. The signal recedes radially from "b" in all axes as a function of θ , but it cannot catch up with "r" in the d_4 axis. *Can the radio signal and "r" collide in the 3D space of "r" if they do not collide in ES?* **Problem 2:** A rocket moves along a guide wire. In ES, both objects move at the speed c . The wire moves in d_4 . As the rocket covers distance in d_1 , its speed in d_4 is less than c . *Doesn't the wire escape from the rocket?* **Problem 3:** Earth orbits the sun. In ES, both objects move at the speed c . The sun moves in d_4 . As Earth covers distance in d_1 and d_2 , its speed in d_4 is less than c . *Doesn't the sun escape from Earth's orbit?*

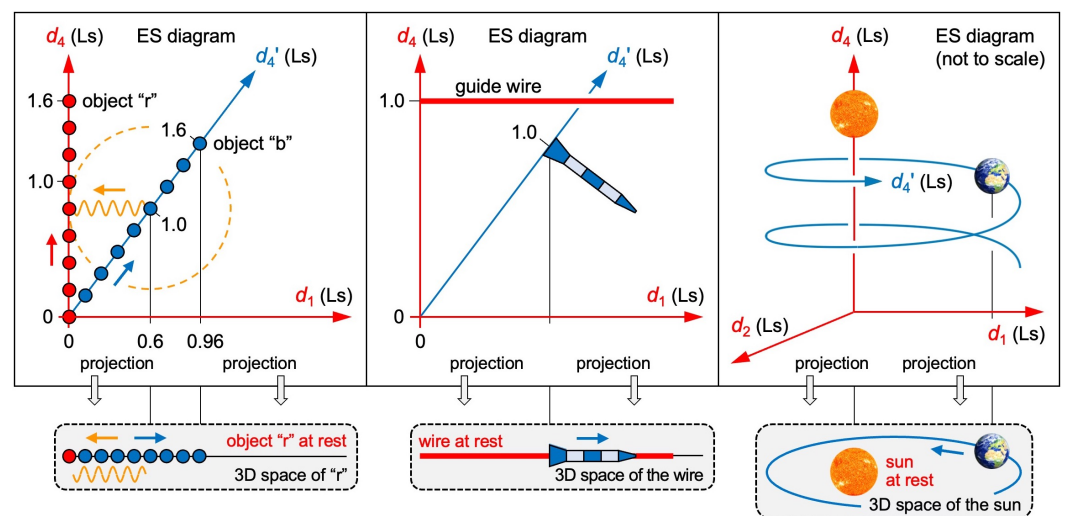


Fig. 5 Three problems. **Left:** In ES, an energy taking a detour (blue/orange arrow) does not collide with an energy moving straight (red arrow). In the 3D space of "r", it does. The circle shows a signal emitted by "b". **Center:** In ES, the wire escapes from the rocket. In the 3D space of the wire, it does not. **Right:** In ES, the sun escapes from Earth's orbit. In the 3D space of the sun, it does not.

The questions in the last paragraph seem to disclose geometric paradoxes. The fallacy lies in the assumption that all four axes d_μ ($\mu = 1, 2, 3, 4$) would be spatial at once. This is not the case. Observers experience only three of these axes as spatial and one as temporal. We solve all three problems by projecting ES to the 3D space of that object which moves in d_4 at the speed c . In its 3D space, it is always at rest. The radio signal collides with “r” in the 3D space of “r” if there is $d_{i,r} = d_{i,\text{signal}}$ ($i = 1, 2, 3$) at one instant in cosmic time θ . Thus, a collision is possible even if there is $d_{4,r} \neq d_{4,\text{signal}}$. In our example (see Fig. 5 left), the signal collides with “r” once $\theta = 1.6$ s have elapsed since “r” started from the origin. Collisions in 3D space do not show up as collisions in ES. Here is why ES diagrams do not contract physics: **ES diagrams do not show events but each object’s flow of proper time.** The wire does not *spatially* escape from the rocket. The sun does not *spatially* escape from Earth’s orbit. In Fig. 4, Earth does not *spatially* escape from clock “b”.

5. Outlining the Solutions to 15 Fundamental Mysteries

We recall that there is a 4D vector τ in ER, which is not available in SR/GR. In Sects. 5.1 through 5.15, ER solves 15 mysteries and declares four concepts obsolete.

5.1. The Mystery of Time

Proper time τ is what a clock measures. Cosmic time θ is the total distance covered in ES divided by c . Any clock always displays both quantities: its τ and θ . An observed clock’s 4D vector τ' may differ from the observer’s 4D vector τ . If it does, the observed clock is slow with respect to the observer’s clock in his time axis.

5.2. The Mystery of Time’s Arrow

“Time’s arrow” is a synonym of time moving only forward. Why does it move only forward? Here is the answer: Covered distance cannot decrease but only increase.

5.3. The Mystery of the Factor c^2 in the Energy Term mc^2

In SR, if forces are absent, the total energy E of an object (mass m) is given by

$$E = \gamma mc^2 = E_{\text{kin},3\text{D}} + mc^2 , \tag{18}$$

where $E_{\text{kin},3\text{D}}$ is its kinetic energy in an observer’s coordinate space and mc^2 is its energy at rest. The term mc^2 can be derived from SR, but SR does not tell us why there is a factor c^2 in the energy of objects that move at a speed less than c . ER is eye-opening: An object is never “at rest”. From its perspective, $E_{\text{kin},3\text{D}}$ is zero and mc^2 is its kinetic energy in d'_4 . The factor c^2 is a hint that it moves through ES at the speed c . In SR, there is also

$$E^2 = p^2 c^2 = p_{3\text{D}}^2 c^2 + m^2 c^4 , \tag{19}$$

where p is the total momentum of an object and $p_{3\text{D}}$ is its momentum in an observer’s coordinate space. Again, ER is eye-opening: From its perspective, $p_{3\text{D}}$ is zero and mc is its momentum in d'_4 . The factor c is a hint that it moves through ES at the speed c .

5.4. The Mystery of Length Contraction and Time Dilation

In SR, length contraction and time dilation can be traced back to Einstein’s instruction for synchronizing clocks. ER gives us a non-empirical explanation. It discloses that these effects stem from projecting worldlines in ES to the axes d_1 and d_4 of an observer.

5.5. The Mystery of Gravitational Time Dilation

In GR, gravitational time dilation stems from curved spacetime. ER discloses that this effect stems from projecting curved worldlines in ES to the d_4 axis of an observer. Eq. (7) tells us: *If an object accelerates in his proper space, it automatically decelerates in his proper time.* More studies are required to understand other gravitational effects in ER.

5.6. The Mystery of the Cosmic Microwave Background (CMB)

In the inflationary Lambda-CDM model, the Big Bang occurred “everywhere” (space inflated from a singularity). In Sects. 5.6 through 5.12, I outline an ER-based model of cosmology, in which the Big Bang is locatable: It injected a huge amount of energy into ES at an origin O. Cosmic time θ is the total time that has elapsed since the Big Bang. At $\theta = 0$, all energy started moving radially away from O. *The Big Bang was a singularity in providing energy and radial momentum.* Shortly after $\theta = 0$, energy was highly concentrated. While it became less concentrated, plasma particles were created in the projection to any 3D space. Recombination radiation was emitted that we still observe as CMB today [24].

The ER-based model must be able to answer these questions: (1) Why is the CMB so isotropic? (2) Why is the temperature of the CMB so low? (3) Why do we still observe the CMB today? Here are some possible answers: (1) The CMB is so isotropic because it has been scattered equally in the 3D space d_1, d_2, d_3 of Earth. (2) The temperature of the CMB is so low because the plasma particles had a very high recession speed v_{3D} (see Sect. 5.7) shortly after $\theta = 0$. (3) We still observe the CMB today because it reaches Earth after having covered the same distance in d_1, d_2, d_3 (multiple scattering) as Earth in d_4 .

5.7. The Mystery of the Hubble–Lemaître Law

In Fig. 6 left, Earth and a galaxy G recede from the origin O of ES. In Earth’s 3D space, G recedes from Earth at the speed v_{3D} . According to my [first postulate](#), v_{3D} relates to the 3D distance D of G to Earth as c relates to the radius r of a 4D hypersphere. All energy is within this hypersphere. Most energy is within its 3D hypersurface. Because of physical interactions, some energy accelerates transversally while maintaining the speed c .

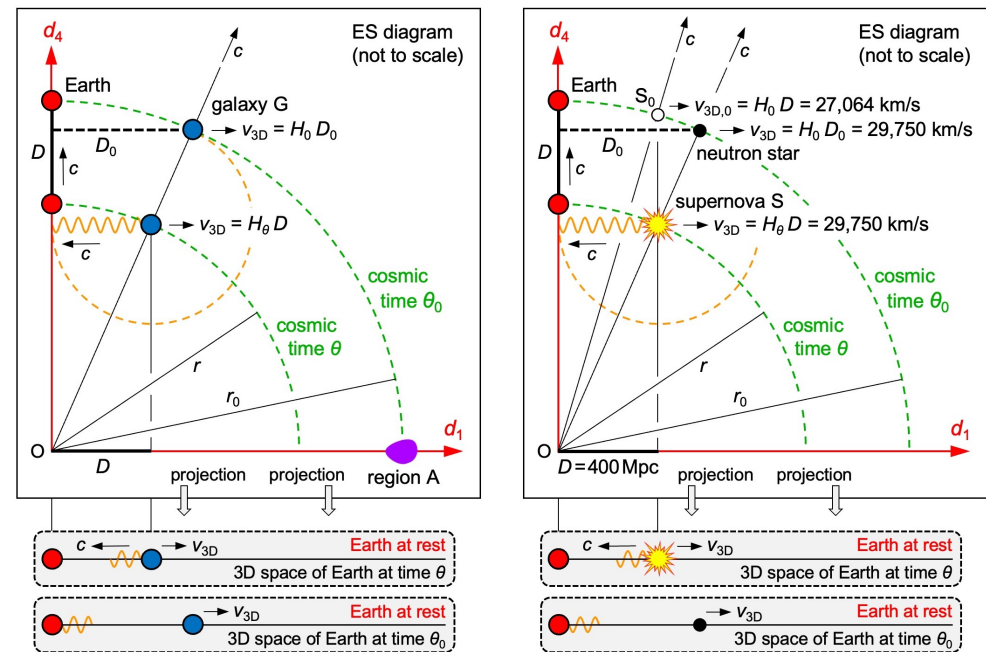


Fig. 6 ER-based model of cosmology. The green arcs show part of an expanding 3D hypersurface. The orange circles show where most of the energy emitted by G (or by S) at the time θ is today at the time θ_0 . **Left:** Galaxy G recedes from the origin O of ES at the speed c , and from the d_4 axis in particular at the speed v_{3D} . **Right:** If star S_0 happens to be at the same distance D today at which the supernova of star S occurred, S_0 recedes more slowly from Earth than S.

$$v_{3D} = D c / r = H_{\theta} D, \quad (20)$$

where $H_{\theta} = c/r = 1/\theta$ is the Hubble parameter. If we observe G today at the cosmic time θ_0 , the recession speed v_{3D} and c remain unchanged. Thus, Eq. (20) turns into

$$v_{3D} = D_0 c / r_0 = H_0 D_0, \quad (21)$$

where $H_0 = c/r_0 = 1/\theta_0$ is the Hubble constant, $D_0 = D r_0/r$ is today's 3D distance of G to Earth, and r_0 is today's radius of the 4D hypersphere. Eq. (21) is the improved Hubble–Lemaître law [25, 26]. Cosmologists are aware of θ and H_θ . They are not aware that the 4D geometry is Euclidean, that θ is absolute, and that v_{3D} is equal to $H_0 D_0$ (not $H_0 D$). Out of two galaxies, the one farther away recedes faster, but each galaxy maintains its speed v_{3D} . The d_4 values of Earth and an energy ΔE (emitted by G at the time θ) never match. Can ΔE and Earth collide in the 3D space of Earth if they do not collide in ES? The answer is the same as for Fig. 5 left: Collisions in 3D space do not show up as collisions in ES. ΔE collides with Earth once ΔE has covered the same distance in d_1 as Earth in d_4 .

5.8. The Mystery of the Flat Universe

An observer's view is created by orthogonally projecting ES to his proper space and to his proper time. Thus, he experiences two discrete structures: flat space and time.

5.9. The Mystery of Cosmic Inflation

Most cosmologists [27, 28] believe that an inflation of space shortly after the Big Bang explains the isotropic CMB, the flat universe, and large-scale structures. The latter inflated from quantum fluctuations. I just showed that ER explains the first two effects. ER even explains large-scale structures if the impacts of quantum fluctuations have been expanding like the 3D hypersurface. *In ER, cosmic inflation is an obsolete concept.*

5.10. The Mystery of Cosmic Homogeneity (Horizon Problem)

How can the universe be so homogeneous if there are causally disconnected regions? In the Lambda-CDM model, region A at $x_1 = +r_0$ and region B at $x_1 = -r_0$ are causally disconnected unless we postulate a cosmic inflation. Without inflation, information could not have covered $2r_0$ since the Big Bang. In the ER-based model, we use natural concepts: Region A is at $d_1 = +r_0$ (see Fig. 6 left). Region B is at $d_1 = -r_0$ (not shown in Fig. 6 left). For A and for B, their d'_4 axis (equal to Earth's d_1 axis) disappears because of length contraction at the speed c . Since A and B overlap spatially in their 3D space, they are causally connected. Note that their opposite 4D vectors "flow of proper time" do not affect causal connectivity as long as A and B overlap spatially.

5.11. The Mystery of the Hubble Tension

Up next, I explain the 10 percent deviation in the published values of H_0 (known as the "Hubble tension" or the " H_0 tension"). Let us compare CMB measurements (Planck space telescope) with calibrated distance ladder measurements (Hubble space telescope). According to team A [29], there is $H_0 = 67.66 \pm 0.42$ km/s/Mpc. According to team B [30], there is $H_0 = 73.04 \pm 1.04$ km/s/Mpc. Team B made efforts to minimize the error margins in the distance measurements. However, there is a systematic error in team B's calculation of H_0 , which arises from assuming a wrong cause of the redshifts.

We assume that team A's value of H_0 is correct. We simulate the supernova of a star S that occurred at a distance of $D = 400$ Mpc from Earth (see Fig. 6 right). The recession speed v_{3D} of S is calculated from measured redshifts. The redshift parameter $z = \Delta\lambda/\lambda$ tells us how each wavelength λ of the supernova's light is either stretched by an expanding space (team B) or else Doppler-redshifted by receding objects (ER-based model). The supernova occurred at the cosmic time θ (arc called "past"), but we observe it at the cosmic time θ_0 (arc called "present"). While the supernova's light moved the distance D in d_1 , Earth moved the same distance D but in d_4 (my first postulate). There is

$$1/H_\theta = r/c = (r_0 - D)/c = 1/H_0 - D/c . \tag{22}$$

For a very short distance of $D = 400$ kpc, Eq. (22) tells us that H_θ deviates from H_0 by only 0.009 percent. When plotting v_{3D} versus D for distances from 0 Mpc to 500 Mpc in steps of 25 Mpc (red points in Fig. 7), the slope of a straight-line fit through the origin

is roughly 10 percent greater than H_0 . Since team B calculates H_0 from relating z to magnitude, which is like plotting v_{3D} versus D , its value of H_0 is roughly 10 percent too high. Team B's value is not correct because, according to Eq. (21), we must plot v_{3D} versus D_0 (!) to get a straight line (blue points in Fig. 7). Ignoring the 4D Euclidean geometry leads to an overestimation of the Hubble constant. This solves the Hubble tension.

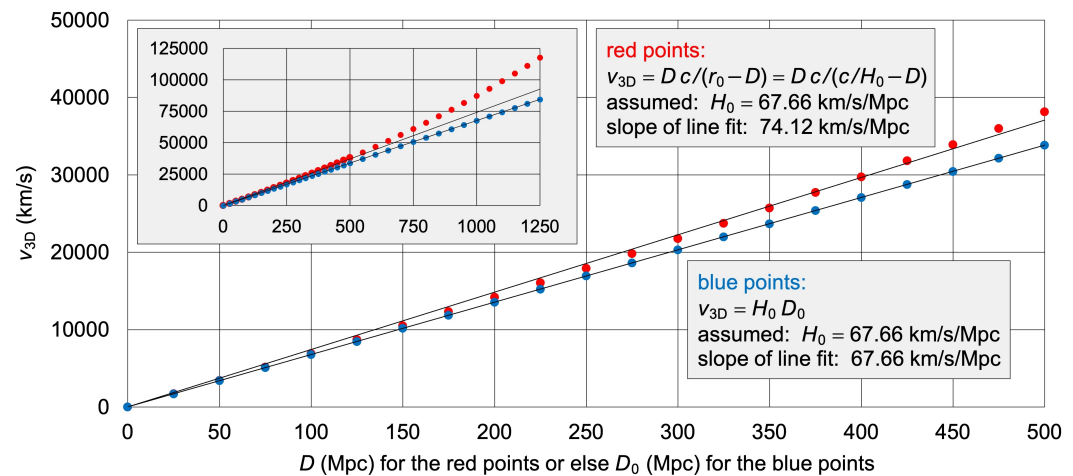


Fig. 7 Hubble diagram of simulated supernovae. The horizontal axis is D for the red points or else D_0 for the blue points. The red points, calculated from Eq. (20), do not yield a straight line because H_θ is not a constant. The blue points, calculated from Eq. (21), yield a straight line.

Since we cannot measure D_0 (observable magnitudes relate to D and not to D_0), the easiest way to fix the calculation of team B is to rewrite Eq. (21) as

$$v_{3D,0} = D c / r_0 = H_0 D, \quad (23)$$

where $v_{3D,0}$ is today's 3D speed of another star S_0 (see Fig. 6 right) that happens to be at the same distance D today at which the supernova of star S occurred. I kindly ask team B to recalculate H_0 after converting all v_{3D} to $v_{3D,0}$ with Eqs. (22), (23), and (20).

$$H_\theta = H_0 c / (c - H_0 D) = H_0 / (1 - v_{3D,0}/c), \quad (24)$$

$$v_{3D,0} = v_{3D} / (1 + v_{3D}/c). \quad (25)$$

By applying Eq. (25) and plotting $v_{3D,0}$ versus D , we also get a straight line according to Eq. (23). In addition, Fig. 7 tells us: The more high-redshift data are included in team B's calculation, the more the H_0 tension increases. The moment of the supernova is irrelevant to team B's calculation. In the Lambda-CDM model, all that counts is the duration of the light's journey to Earth (z increases during the journey). In the ER-based model, all that counts is the moment of the supernova. Wavelengths are redshifted by the Doppler effect (z is constant during the journey). Space is not expanding. Energy recedes from the location of the Big Bang in ES. *In ER, expanding space is an obsolete concept.*

5.12. The Mystery of Dark Energy

Team B can fix the systematic error in its calculation of H_0 by converting all v_{3D} to $v_{3D,0}$ according to Eq. (25). I now reveal another systematic error, but it is inherent in the Lambda-CDM model. It stems from assuming an accelerating expansion of space and can be fixed only by replacing this model with the ER-based model unless we postulate a dark energy. Most cosmologists [31, 32] believe in an accelerating expansion because the calculated recession speeds v_{3D} deviate from a straight line in the Hubble diagram (if v_{3D} is plotted versus D) and because the deviations increase with D . An accelerating expansion would indeed stretch each wavelength even further and explain the deviations.

In ER, the explanation of the deviations is less speculative: The older the redshift data are, the more H_θ deviates from H_0 , and the more v_{3D} deviates from $v_{3D,0}$. If another star S_0 (see Fig. 6 right) happens to be at the same distance of $D = 400$ Mpc today at which the supernova of star S occurred, Eq. (25) tells us: S_0 recedes more slowly (27,064 km/s) from Earth than S (29,750 km/s). It does so because of the 4D Euclidean geometry: The 4D vector τ' of S_0 deviates less from Earth's 4D vector τ than the 4D vector τ'' of S . As long as cosmologists are not aware of ER, they hold dark energy [33] responsible for an accelerating expansion of space. Dark energy has not been confirmed. It is a stopgap for an effect that the Lambda-CDM model cannot explain. Older supernovae recede faster not because of an accelerating expansion but because of a larger H_θ in Eq. (20).

The Hubble tension and dark energy are solved exactly the same way: In Eq. (21), we must not confuse D_0 with D . Because of Eq. (20) and because of $H_\theta = c/(r_0 - D)$, the recession speed v_{3D} is not proportional to D but to $D/(r_0 - D)$. This is why the red points in Fig. 7 run away from a straight line. Any expansion of space (uniform or else accelerating) is only virtual 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 particular prize was given for an illusion that stems from interpreting astronomical observations in the wrong concepts. Most galaxies recede from Earth, but they do so uniformly in a non-expanding spacetime. In ER, dark energy is an obsolete concept.

The Hubble tension and dark energy are solved by taking the 4D Euclidean geometry into account, and the 4D vector τ in particular. These results cast doubt on the Lambda-CDM model. GR itself is correct as long as τ is not crucial, but it is crucial for high-redshift supernovae. Space is not driven by dark energy. Galaxies are driven by their momentum and maintain their recession speed with respect to Earth. Because of physical interactions, some energy accelerates transversally while maintaining the speed c . This enables nearby galaxies to move toward Earth. Table 1 compares two models. Note that "the Universe" is not the same as "universe". Each observer experiences three axes of ES as his universe. Cosmology benefits from ER. Up next, I show that QM also benefits from ER.

Inflationary Lambda-CDM model based on GR	ER-based model of cosmology
The Big Bang was the beginning of the Universe.	The Big Bang was an injection of energy into ES.
The Big Bang occurred "everywhere".	The Big Bang can be localized (origin O of ES).
There are two competing values of H_0 .	H_0 is approximately 67–68 km/s/Mpc.
The Universe: spacetime and all energy.	Synonyms of universe: proper space, 3D space.
Spacetime is non-Euclidean.	Spacetime is Euclidean.
There is no absolute time.	Cosmic time is absolute.
Shortly after the Big Bang, space was inflating.	There is no inflation of space.
Today, there is an accelerating expansion of space.	There is no expansion of space.
Space is driven by dark energy.	Galaxies are driven by their momentum.
Dark energy has not been confirmed.	There is no dark energy.

Table 1 Comparing two different models of cosmology.

5.13. The Mystery of the Wave–Particle Duality

The wave–particle duality was first discussed by Niels Bohr and Werner Heisenberg [34], and it has bothered physicists ever since. Electromagnetic waves are oscillations of an electromagnetic field propagating through space at the speed c . In some experiments, objects behave like waves. In others, the same objects behave like particles (known as the "wave–particle duality"). In today's physics, objects cannot be both because a wave's energy is distributed in space, whereas a particle's energy is localized in space.

Natural concepts solve the wave–particle duality: Proper space/time (pure distance) replace coordinate space/time. "Wavematters" (pure energy) replace wave/particle. Fig. 8 illustrates a single wavematter. In an observer's view ("external view"), each wavematter "reduces" (collapses) to a wave packet if not tracked or else a particle if tracked. As a wave

packet, it propagates in the observer's x_1 axis at the speed c and it oscillates in his axes x_2 and x_3 (electromagnetic field). It does so in his coordinate space as a function of his coordinate time. In the wavematter's view ("internal view"), the axis of its 4D motion disappears because of length contraction at the speed c . In its 3D space, it is always at rest. Thus, it deems itself particle at rest. Note that there are neither waves nor particles in ES. The wave-particle duality is experienced by observers only.

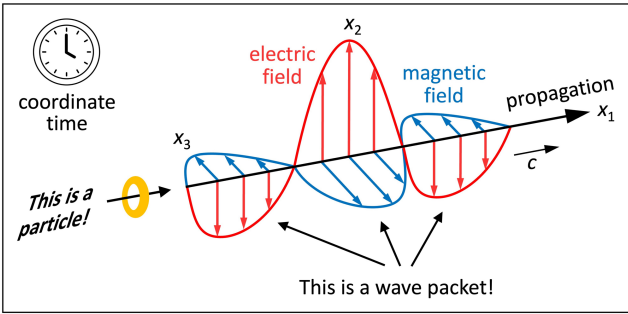


Fig. 8 Illustration of a single wavematter. In an observer's view, it reduces to a wave packet or else a particle. As a wave packet, it propagates and oscillates as a function of his coordinate time. In the wavematter's view (moving through the orange pinhole at the speed c), it is a particle at rest.

Wave and particle are empirical concepts, like coordinate space and coordinate time. They are relative too: *What I deem wave, deems itself particle at rest*. For each wavematter, its pure energy "condenses" (concentrates) to what we call "mass". Albert Einstein taught us that energy and mass are equivalent [35]. Likewise, a wave's polarization and a particle's spin are equivalent. The word "wavematter" phrases these equivalences.

In a double-slit experiment, the wavematters pass through a double-slit and produce an interference pattern on some screen. An observer deems them waves as long as he does not track through which slit each wavematter is passing. *Here the external view applies*. The photoelectric effect is different. Of course, I can externally witness how a photon releases an electron from a metal surface, but the physical effect is all up to the photon: The electron is released only if the photon energy exceeds the electron's binding energy. *Here the internal view of the photon is the crucial view*. The photon behaves like a particle.

The wave-particle duality is also observed in matter, such as electrons [36]. Electrons are wavematters too. They behave like waves as long as they are not tracked. Once they are tracked, they behave like particles. Since an observer automatically tracks objects that are slow in his 3D space, he deems all slow (and thus all macroscopic) objects matter rather than waves. To improve readability, I do not sketch any wavematters in the ES diagrams. I sketch what they are deemed by observers (clocks, rockets, galaxies, etc.).

5.14. The Mystery of Non-Locality

It was Erwin Schrödinger who coined the word "entanglement" in his comment [37] on the Einstein-Podolsky-Rosen paradox [38]. The three authors argued that QM would not provide a complete description of reality. Schrödinger's neologism does not solve the paradox, but it demonstrates our difficulties in comprehending QM. John Bell [39] showed that QM is incompatible with local hidden-variable theories. Meanwhile, it has been confirmed in several experiments [40-42] that entanglement violates locality in an observer's 3D space. Entanglement has been considered a non-local effect ever since.

Up next, I show that there is no violation in four dimensions. All we need to untangle entanglement is ER: Non-locality becomes obsolete because all four d_μ ($\mu = 1, 2, 3, 4$) are interchangeable. Fig. 9 illustrates two wavematters that were created at once at the same point P. They move in opposite 4D directions $\pm d'_4$ at the speed c . It turns out that these wavematters are automatically entangled. For an observer moving in any direction other than $\pm d'_4$ (external view), the two wavematters are spatially separated. The observer has no idea how they are able to "communicate" with each other in no time.

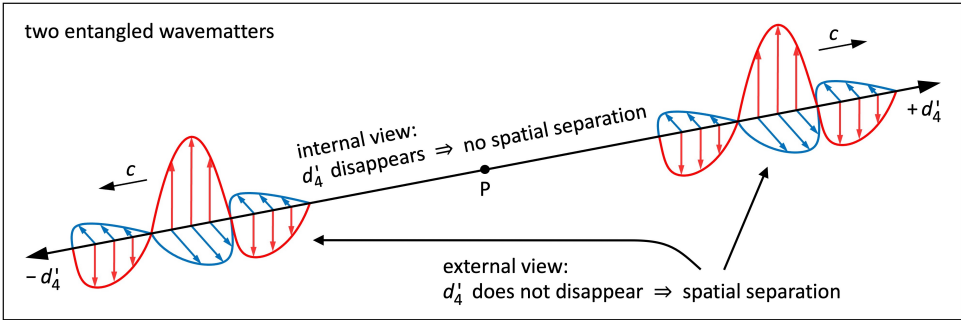


Fig. 9 For an observer moving in any direction other than $\pm d'_4$ (external view), wavematters moving in $\pm d'_4$ at the speed c are spatially separated. For the entangled wavematters (internal view), their d'_4 axis disappears. The twins have never been spatially separated in their view.

For the entangled wavematters (internal view), their d'_4 axis disappears because of length contraction at the speed c . Since the twins stay together spatially in their 3D space spanned by d'_1, d'_2, d'_3 , they are able to communicate with each other in no time. The twins have never been spatially separated in their view, but their proper time flows in opposite 4D directions. Note that their opposite 4D vectors “flow of proper time” do not affect local communication as long as the twins stay together spatially. There is a “spooky action at a distance” (phrase attributed to Einstein) from the external view only.

The horizon problem and entanglement are solved exactly the same way: *An observed region’s (or an observed object’s) 4D vector τ' and its 3D space may differ from the observer’s 4D vector τ and his 3D space.* This is possible only if all four d_μ ($\mu = 1, 2, 3, 4$) are interchangeable. The $SO(4)$ symmetry of ES solves entanglement. ER also explains the entanglement of matter, such as electrons [43]. Entangled electrons move in opposite 4D directions $\pm d'_4$ at the speed c . Any measurement tilts the axis of 4D motion of one twin and destroys the entanglement. *In ER, non-locality is an obsolete concept.*

5.15. The Mystery of the Baryon Asymmetry

In the Lambda-CDM model, almost all matter was created shortly after the Big Bang, when the temperature was high enough to enable pair production. But this process creates equal amounts of particles and antiparticles. So, why do we observe more baryons than antibaryons (known as the “baryon asymmetry”)? In an observer’s view, all wavematters reduce to waves or else particles. Pair production creates particles and antiparticles, which annihilate each other very soon. *In total, there is one source of long-lived particles (reduction of wavematters) and one source of short-lived particles (pair production), but there is only one source of short-lived antiparticles (pair production).* This solves the baryon asymmetry.

ER also tells us why an antiparticle’s proper time seems “to flow backward”: Proper time flows in opposite 4D directions for any two wavematters created in pair production. The antiparticle’s 4D vector τ'' is reversed with respect to the particle’s 4D vector τ' . In the antiparticle’s view, its proper time moves forward. Note that galaxies moving in $-d_4$ (not shown in Fig. 6 left) are not made up of antimatter. Only their flow of proper time is reversed with respect to galaxies moving in $+d_4$. Their physical charges are not reversed. ER predicts that any two wavematters created in pair production are entangled. This gives us a chance to falsify ER. All scientific theories must be falsifiable [44].

6. Conclusions

ER solves many unsolved mysteries (time’s arrow, the Hubble tension, the wave–particle duality, the baryon asymmetry) and other mysteries that are already solved but only by adding obsolete concepts (cosmic inflation, expanding space, dark energy, non-locality). This is a perfect example of where to apply Occam’s razor. It shaves off obsolete concepts. Period. SR/GR are considered two of the greatest achievements of physics because they have been confirmed over and over. I showed that SR/GR do not provide a holistic view. Physics got stuck in its own concepts. Its stagnation is of its own making.

It was a wise decision to award Albert Einstein the Nobel Prize for his theory of the photoelectric effect [45] and not for SR/GR. I showed that ER penetrates to a deeper level. Einstein—one of the most brilliant physicists ever—failed to realize that the fundamental metric chosen by Mother Nature is Euclidean. Einstein sacrificed absolute space and time. ER restores absolute, cosmic time, but it sacrifices the absolute nature of wave and particle. For the first time ever, mankind understands the nature of time: Cosmic time is the total distance covered in ES divided by c . *The human brain is able to imagine that we move through ES at the speed c .* With that said, conflicts of mankind become all so small.

Is ER a physical or a metaphysical theory? This is a very good question because only in proper coordinates can we access ES, but the proper coordinates of other objects cannot be measured. I now explain why this is fine: We can always calculate these proper coordinates from ES diagrams as I demonstrated in Eqs. (13a–c). Measuring is an observer’s source of knowledge, but ER tells us not to interpret too much into whatever we measure. Measurements are wedded to observers, whose concepts may be obsolete. I was told that physics is all about observing. I disagree. We cannot observe the quantum world, can we? Unfortunately, physicists have applied empirical concepts—which work well in everyday life—to the very far and the very small. This is why cosmology and QM benefit the most from ER. *ER is a physical theory because it solves fundamental mysteries of physics.*

To sum it all up: (1) Acceleration rotates an object’s τ and curves its worldline in flat ES. (2) Information hidden in τ solves 15 mysteries. It is extremely unlikely that 15 solutions in different (!) areas of physics are just 15 coincidences. (3) Different concepts disable a unification of SR/GR and ER. Either scope is limited. We must not apply SR/GR but ER whenever τ is crucial (high-redshift supernovae, entanglement). We must not apply ER but SR/GR whenever we use empirical concepts. Thus, we must not blindly trust SR/GR as if they were dogmata. *Only in natural concepts does nature disclose her secrets.*

Final remarks: (1) I only touched on gravity. We must not reject ER because gravity is still an issue. GR seems to solve gravity, but GR is incompatible with QM unless we add another speculative concept (quantum gravity). More studies are required to understand gravitational effects in ER. (2) Mysteries often disappear once the symmetry is matched. The symmetry group for describing nature in natural concepts is SO(4). (3) The invariant θ finally puts an end to all discussions about time travel. Does any other theory solve the mystery of time’s arrow as beautifully as ER? (4) Physics does not ask: Why is my reality a projection? Nor does it ask: Why is it a wave function? Projections are less speculative than postulating cosmic inflation and expanding space and dark energy and non-locality. (5) It seems that Greek philosopher Plato anticipated ER with his *Allegory of the Cave* [46]: Mankind experiences projections and cannot observe any reality beyond.

The primary question behind my theory is: How does all our insight fit together without adding highly speculative concepts? I trust that this very question leads us to the truth. I laid the groundwork for ER and showed how powerful it is. Paradoxes are only virtual. The true pillars of physics are ER, SR/GR (for an observer’s view), and QM. Together they describe Mother Nature from the very far to the very small. Introducing a holistic view to physics is probably the most significant achievement of this paper. All observers’ views taken together do not make a holistic view because they still do not provide absolute time. Everyone is welcome to solve even more mysteries by applying ER.

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Comments: It takes open-minded, courageous editors and peer reviewers to evaluate a theory that heralds a paradigm shift. Whoever adheres to established concepts paralyzes the scientific progress. I did not surrender when top journals rejected my theory. Interestingly, I was never given any solid arguments that would disprove my theory. Rather, I was asked to try a different journal. Were the editors dazzled by the success of SR/GR? Did they underestimate the benefits of ER? I was told that

15 solved mysteries are too much to be trustworthy. I disagree. The natural concepts of ER herald a paradigm shift, and paradigm shifts often solve several mysteries at once. It seems to me that most editors were afraid of considering concepts that are off the mainstream. Even good friends refused to support me. Anyway, each setback inspired me to work out the benefits of ER even better. Finally, I succeeded in disclosing an issue in SR/GR and also in formulating a holistic theory of spacetime, which shows that Einstein's general relativity is not as general as it seems.

Some physicists have difficulties in accepting ER because the SO(4) symmetry of ES is incompatible with waves. ER does not dispute waves. In an observer's view, wavematters reduce to waves or else particles. A well-known preprint archive suspended my submission privileges. I was penalized because I disclosed an issue in Einstein's SR and GR. The editor-in-chief of a top journal replied: "Publishing is for experts only." One editor could not imagine that the H_0 tension is solved without GR. Another editor rejected my paper because it would demand too much from the peer reviewers. I do not blame anyone. Paradigm shifts are always hard to accept. These comments shall encourage young scientists to stand up for promising ideas even if opposing the mainstream is very hard work. Peer reviewers called my theory "unscholarly research", "fake science", and "too simple to be true". *Simplicity and truth are not mutually exclusive. Beauty is when they go hand in hand together.*

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