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Natural Spacetime: Describing Nature in Natural Concepts

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Today's physics describes nature in "empirical concepts" (based on observation), such as coordinate space/time, wave/particle, force/field. There are coordinate-free formulations of special and general relativity (SR/GR), but there is no absolute time in SR/GR and thus no "holistic view" (universal for all objects and at the *same* instant in time). **Here I show:** Euclidean relativity (ER) provides a holistic view by describing nature in "natural concepts" (immanent in all objects). "Pure distance" (proper space/time) replaces coordinate space/time. Pure energy replaces wave/particle. Process is a promising concept to replace force/field. Any object's proper space d_1, d_2, d_3 and its proper time τ span a natural, Euclidean spacetime (ES) d_1, d_2, d_3, d_4, where $d_4 = c\tau$. For each object, there is a relative 4D vector "flow of proper time" $\boldsymbol{\tau}$. The new 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. *Information is lost in projections giving rise to mysteries.* ER explains the 10% deviation in the published values of H_0, and it declares dark energy and non-locality obsolete. **I conclude:** (1) Information hidden in the 4D vector $\boldsymbol{\tau}$ (not available in SR/GR) solves 15 mysteries. (2) An acceleration rotates $\boldsymbol{\tau}$ and curves an object's worldline in flat ES. (3) ER complements SR/GR. We must apply ER if there are significantly different 4D vectors $\boldsymbol{\tau}$ and $\boldsymbol{\tau}'$, as in high-redshift supernovae or entanglement. We must apply SR/GR if 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 and at the *same* instant in time). Euclidean relativity (ER) takes the second approach and provides a holistic view. The editors of top journals pointed out to me that physical theories must build upon SR/GR. 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, but ER does not address empirical concepts, such as waves. These concepts are handled by SR/GR. ER does not compete with SR/GR. (2) *What are the benefits of ER?* ER solves 15 mysteries, such as the Hubble tension, dark energy, non-locality, and the baryon asymmetry. ER tells us that we must not apply the empirical concepts of SR/GR to objects that are very far away (high-redshift supernovae) or that move in opposite 4D directions at the speed c (entanglement). In such extreme situations, the 4D vector "flow of proper time" of ER is crucial. (3) *Does ER make quantitative predictions?* ER explains the 10 percent deviation in the published values of H_0. Other 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 new spacetime.* In ER, spacetime is flat and the worldlines are curved. (4) *Do not apply the concepts of SR/GR to ER.* One reviewer claimed that spacetime cannot be Euclidean because in SR/GR spacetime is non-Euclidean. This is as if he claimed that Earth cannot orbit the sun because in geocentrism the sun orbits Earth. (5) *Appreciate illustrations.* As a geometric theory, ER complies with the stringency of math. (6) *Be objective.* Experts may feel offended. (7) *Be fair.* A paper cannot cover all of physics. SR/GR have been tested for 100+ years. ER deserves the same chance. I apologize for my many preprint versions. I received little support. The final version is all you need. Previous versions show my path. The trickiest part is to cherish the 4D vector "flow of proper time".

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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.

Two postulates of ER: (1) All energy moves through Euclidean spacetime (ES) at the speed 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". An observer's view is created by orthogonally projecting ES to his proper space and to his proper time. In ER, nature is described in any object's proper space/time. In SR, those two projections are considered coordinate space/time and reassembled to a non-Euclidean spacetime. *Information is lost in projections giving rise to mysteries.* My first postulate is stronger than the second SR postulate: c is absolute and universal. My second postulate refers to each observer's view rather than to inertial frames. In addition, I apply three natural concepts: "Pure distance" (proper space/time) replaces coordinate space/time. Pure energy (see Sect. 5.13) replaces wave/particle. Process is a promising concept to replace force/field. To improve readability, all 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. Note that ER complements SR/GR. Thus, we must not play SR/GR off against ER. One may ask: What is ER good for? *ER solves mysteries that are rooted in ES.*

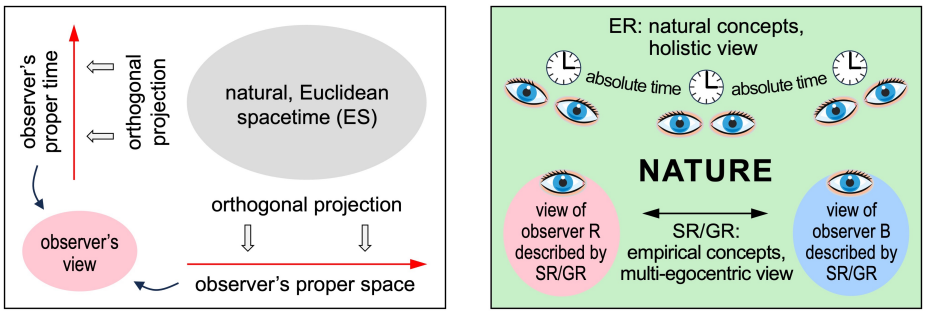

Fig. 1 Euclidean spacetime and observer's view. **Left:** How to create an observer's view. **Right:** ER and SR/GR describe nature in different concepts.

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. Montanus confirmed that ER predicts the precession of Mercury's perihelion [10] and other relativistic effects [11], but he failed to set up 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. We must not reject ER because there are no waves in ES. ER does not dispute waves. In an observer's view, "wavematters" (see Sect. 5.13) reduce to waves or particles. Yet, 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

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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

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

$$x_2' = x_2 \ , \qquad x_3' = x_3 \ , \tag{2b}$$

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

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. (1) and (2a–c) are correct for observers in K. There are covariant equations for observers in 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 SR [16] and GR [17], but there is no absolute time in SR/GR and thus no "holistic view" (I repeat the very important definition: universal for all objects and at the *same* instant in time). The view in SR/GR is "multi-egocentric": SR and 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 has 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 in SR/GR 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, while ER complements SR/GR. 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 both concepts obsolete (see Sects. 5.12 and 5.14). (3) The geocentric model was a dogma in the old days. SR and GR are dogmata nowadays. *Have physicists not learned from history? Does history repeat itself?*

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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

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

where $\mathrm{d}\tau$ is an infinitesimal distance in proper time τ, whereas $\mathrm{d}t$ and $\mathrm{d}x_i$ $(i = 1, 2, 3)$ 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

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

where $\mathrm{d}\theta$ is an infinitesimal distance in cosmic time θ, whereas all $\mathrm{d}d_i$ $(i = 1, 2, 3)$ and $\mathrm{d}d_4 = c\,\mathrm{d}\tau$ are infinitesimal "pure distances". Now the role of proper time τ is reversed: The new fourth coordinate is proper time τ; the new invariant is absolute, cosmic time θ; the new metric tensor is the identity matrix. I choose the symbol θ 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 symmetry in all coordinates. Any object's proper space d_1, d_2, d_3 and its proper time τ span Euclidean spacetime (ES) d_1, d_2, d_3, d_4, where $d_4 = c\tau$. ES is *natural* because its four coordinates d_μ $(\mu = 1, 2, 3, 4)$ are measured by (immanent in) rulers and clocks. Internal rulers and clocks of all objects are used to describe Mother Nature! We must not confuse Eq. (4) with a Wick rotation [18], where t is imaginary and τ 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. Thus, there is a relative 4D vector "flow of proper time" $\boldsymbol{\tau}$.

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

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

where $\boldsymbol{u}$ is an object's 4D velocity in ES. There is $u_\mu = \mathrm{d}d_\mu/\mathrm{d}\theta$, where θ is cosmic time. Speed is not a spatial coordinate divided by the fourth coordinate but any coordinate divided by the invariant. Thus, Eq. (4) is not a random metric but my first postulate

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

An observer's view is created by orthogonally projecting ES to his proper space and to his proper time. Thus, his view can be construed from ES, but not vice versa. Different concepts make it impossible to merge ER and SR. ER describes nature in natural concepts $d_1(\theta), d_2(\theta), d_3(\theta), d_4(\theta)$, where θ is the parameter and d_4 is related to τ. SR describes nature in empirical concepts $x_1(\tau), x_2(\tau), x_3(\tau), t(\tau)$, where τ is the parameter and t is coordinate 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.

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 τ is an objective measure of time: Clocks measure τ independently of observers. Cosmic time θ is the total distance covered in ES (length of a worldline) divided by c. By taking θ as the parameter, all observers will agree on what is past and what is future. Since θ is absolute, there is no twin paradox in ER. *Twins are the same age in cosmic time.*

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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 $v_{3D} = 0.6\ c$. 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".

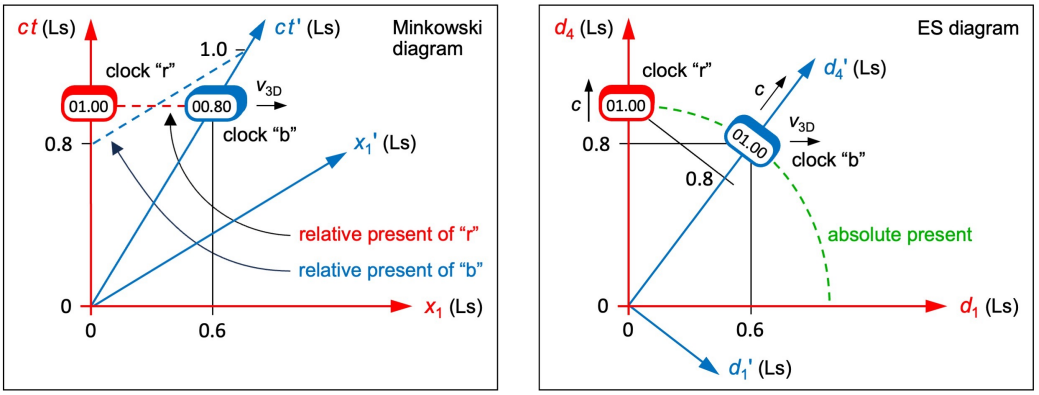

Fig. 2 Minkowski diagram and ES diagram of two clocks "r" and "b". **Left:** "b" is slow with respect to "r" in t'. Coordinate time is relative ("b" is at different positions in t and t'). **Right:** "b" is slow with respect to "r" in d_4. Cosmic time is absolute ("r" is in d_4 at the same position as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

We now assume that an observer R (or B) is moving with the clock "r" (or else "b"). In SR and only from R's perspective, 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. Thus, SR and ER may claim that they describe time dilation correctly.

But why does ER provide a holistic view? Well, ES is independent of observers and thus absolute. Only the two orthogonal projections are relative. Absolute ES shows up in its rotational symmetry: Fig. 2 right works for R and for B "at once" (at the *same* instant in cosmic time θ), that is, it provides a universal view. The view in Fig. 2 left is not universal: A second Minkowski diagram is required for B, where the axes x_1' and ct' are orthogonal. Absolute ES also shows up in Eq. (4): All four d_μ ($\mu = 1, 2, 3, 4$) are interchangeable. Only observers experience the "pure distances" d_μ as spatial or temporal.

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 $\boldsymbol{\tau}$ are always synchronized, whereas clocks with different $\boldsymbol{\tau}$ and $\boldsymbol{\tau}'$ 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

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(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.

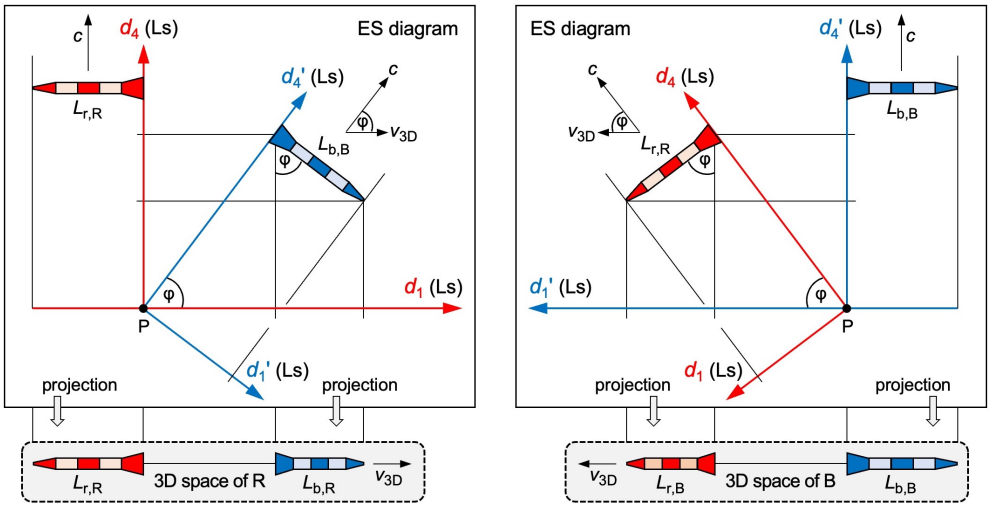

Fig. 3 ES diagrams of two rockets "r" and "b". Observer R (or B) is in the rear end of "r" (or else "b"). **Top:** "r" and "b" move in different 4D directions. **Bottom left:** Projection to the 3D space of R. "b" contracts to $L_{b,R}$. **Bottom right:** Projection to the 3D space of B. "r" contracts 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: Each rocket "r_i" ($2 \le i \le N$) is rotated in ES with respect to "r_{i-1}" by $\pi/2 - \varphi$. This implies that each rocket "r_i" recedes from "r_{i-1}" in the 3D space of "r_{i-1}" (to the right) and at the speed v_{3D}. If $N(\pi/2 - \varphi) > \pi/2$, some rockets move backward in d_4. If one rocket rotates by π, it stands still in the 3D space of "r_1" and its 4D vector $\boldsymbol{\tau}'$ is reversed with respect to $\boldsymbol{\tau}$ of "r_1". This example shows that ER does not compete with SR: Our first assumption is not valid in SR because there is no "same cosmic time" in SR. We can draw all "r_i" in a Minkowski diagram (launched at the same instant in *coordinate* time), but our original example is outside the scope of empirical concepts. Likewise, an example in SR is outside the scope of natural concepts.

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 the rocket "b" for the observer R (or else B). In a first step, we project "b" in Fig. 3 top left to the d_1 axis.

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

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

where $\gamma = (1 - v_{3D}^2/c^2)^{-0.5}$ is the same Lorentz factor as in SR. For R, the rocket "b" contracts to $L_{b,R}$. Which distances will R observe in d_4? We mentally continue the rotation of the rocket "b" until $v_{3D} = c$, that is, until "b" 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.

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

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

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

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

where $d_{4,\mathrm{R}}$ 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. 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].

Up next, we transform the proper coordinates of observer R to those of B. We recall that R (or B) is in the rear end of the rocket "r" (or else "b"). We refer to Fig. 3 again, but we now calculate the 4D motion of R and of B as a function of the parameter θ. R and B start at the point P. The starting time is θ_0. R cannot measure the proper coordinates of B, and vice versa, but we can calculate them from the ES diagrams in Fig. 3.

$$d'_{1,\mathrm{B}}(\theta) \;=\; d'_{1,\mathrm{B}}(\theta_0)\ , \tag{13a}$$

$$d'_{2,\mathrm{B}}(\theta) \;=\; d'_{2,\mathrm{B}}(\theta_0)\ , \qquad d'_{3,\mathrm{B}}(\theta) \;=\; d'_{3,\mathrm{B}}(\theta_0)\ , \tag{13b}$$

$$d'_{4,\mathrm{B}}(\theta) \;=\; d'_{4,\mathrm{B}}(\theta_0) \;+\; c\,(\theta - \theta_0)\ . \tag{13c}$$

To transform the proper coordinates of observer R (unprimed) to those of B (primed), we calculate R's 4D motion in the blue frame of Fig. 3 top right.

$$d'_{1,\mathrm{R}}(\theta) \;=\; d_{4,\mathrm{R}}(\theta)\,\cos\varphi \;=\; d_{4,\mathrm{R}}(\theta)\; v_{3\mathrm{D}}/c\ , \tag{14a}$$

$$d'_{2,\mathrm{R}}(\theta) \;=\; d_{2,\mathrm{R}}(\theta)\ , \qquad d'_{3,\mathrm{R}}(\theta) \;=\; d_{3,\mathrm{R}}(\theta)\ , \tag{14b}$$

$$d'_{4,\mathrm{R}}(\theta) \;=\; d_{4,\mathrm{R}}(\theta)\,\sin\varphi \;=\; d_{4,\mathrm{R}}(\theta)\;\gamma^{-1}\ . \tag{14c}$$

To understand how an acceleration manifests itself in ES, we return to our two clocks. Clock "r" and Earth move in the d_4 axis of "r" at the speed c (see Fig. 4), but clock "b" accelerates in the d_1 axis of "r" toward Earth while maintaining the speed c. Because of Eq. (7), the speed $u_{1,\mathrm{b}}$ of "b" in d_1 increases at the expense of its speed $u_{4,\mathrm{b}}$ in d_4.

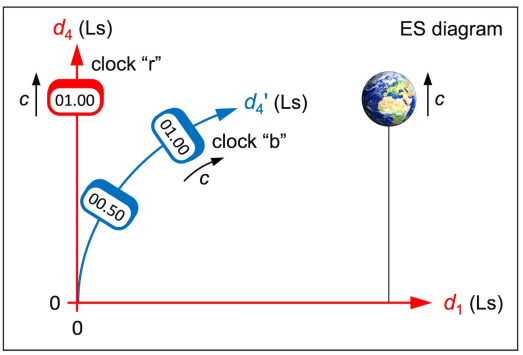

Fig. 4 ES diagram of two clocks "r" and "b". Clock "r" and Earth move in the d_4 axis of "r" at the speed c. Clock "b" accelerates in the d_1 axis of "r" toward Earth.

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 wave is an empirical concept and thus handled by SR/GR. *We must apply SR/GR if we use empirical concepts*. However, a natural concept of force/field has to be defined, which manifests itself as a force/field in an observer's view. Process is a promising concept to replace force/field. A typical process is the transfer of energy or momentum [22]. As an example, we recover gravitational time dilation in ER. We consider the process "transfer of potential energy to kinetic energy". Initially, our clocks "r" and "b" shall be very far away from Earth. Eventually, "b" falls freely toward Earth (see Fig. 4). The kinetic energy of "b" in d_1 is

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$$\tfrac{1}{2}mu_{1,\mathrm{b}}^2 = GMm/R \ , \tag{15}$$

where m is the mass of "b", G is the gravitational constant, M is the mass of Earth, and R is the distance of "b" to Earth's center. By applying Eq. (7), we obtain

$$u_{4,\mathrm{b}}^2 = c^2 - u_{1,\mathrm{b}}^2 = c^2 - 2GM/R \ . \tag{16}$$

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

$$\mathrm{d}d_{4,\mathrm{b}}^2 = (c^2 - 2GM/R)\,(\mathrm{d}d_{4,\mathrm{r}}/c)^2 \ , \tag{17}$$

$$\mathrm{d}d_{4,\mathrm{r}} = \gamma_{\mathrm{gr}}\,\mathrm{d}d_{4,\mathrm{b}} \qquad \text{(gravitational time dilation)}, \tag{18}$$

where $\gamma_{\mathrm{gr}} = (1 - 2GM/(Rc^2))^{-0.5}$ is the same dilation factor as in GR. Eq. (18) tells us: γ_{gr} is recovered in ER if we project ES to the d_4 axis of an observer. As in GR, the mass M causes gravitational time dilation. Yet there is a big difference: In GR, spacetime is curved. In ER, an acceleration rotates $\boldsymbol{\tau}$ and curves an object's worldline in flat ES. More studies are required to confirm that process is the natural concept of force/field.

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 $\boldsymbol{\tau}'$ of "b" differs from the 4D vector $\boldsymbol{\tau}$ 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 teach us how to read ES diagrams (see Fig. 5). Problem 1: In ES, two objects "r" and "b" move at the speed c. "r" moves in its d_4 axis. "b" emits a radio signal at $d_4' = 1.0$ Ls. The signal recedes from "b" at the speed c but cannot catch up with "r" in the d_4 axis. *Can "r" and the radio signal collide in the 3D space of "r" if they don't 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 its d_4 axis. 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 its d_4 axis. 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?*

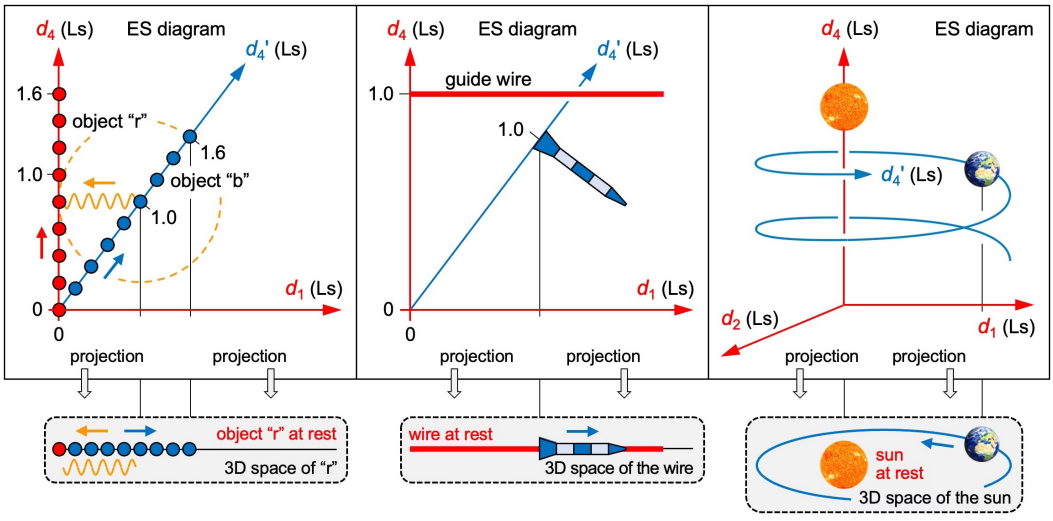

Fig. 5 Solving three problems in ER. **Left:** In ES, an energy taking a detour (blue and orange arrow) cannot collide with an energy moving straight (red arrow). In the 3D space of "r", it can. **Center:** In ES, the guide wire escapes from the rocket. In the 3D space of the wire, it does not. **Right:** In ES, the sun escapes from Earth's orbit. In the 3D space of the sun, it does not.

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The questions in the last paragraph seem to disclose paradoxes in ER. The fallacy lies in the assumption that all four axes of ES would be spatial at once. This is not the case. An observer experiences three out of four axes of ES as spatial and the remaining axis as temporal. We solve all problems by projecting ES to the 3D space of the object that moves in d_4 at the speed c. In its 3D space, it is always at rest. The radio signal collides with "r" if there is $d_{i,\mathrm{r}} = d_{i,\mathrm{signal}}$ $(i = 1, 2, 3)$ at the same instant in cosmic time θ. Thus, a collision is possible even if there is $d_{4,\mathrm{r}} \neq d_{4,\mathrm{signal}}$. In our example (see Fig. 5 left), the signal collides with "r" when $\theta = 1.6\ \mathrm{s}$ have elapsed since "r" and "b" started from the origin. Collisions in 3D space do not show up as collisions in ES. **ES diagrams do not show events but each object's flow of proper time.** This is why ES diagrams do not contradict physics. Bearing this in mind, we comprehend that the guide wire does not *spatially* escape from the rocket and that the sun does not *spatially* escape from Earth's orbit.

5. Outlining the Solutions to 15 Fundamental Mysteries

We recall that cosmic time is the correct parameter for a holistic view. In Sects. 5.1 through 5.15, ER solves 15 mysteries. I also show that ER 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 proper time τ and θ. An observed clock's 4D vector $\boldsymbol{\tau}'$ may differ from an observer's 4D vector $\boldsymbol{\tau}$. 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. The arrow stems from the fact that 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

$$E = \gamma mc^2 = E_{\mathrm{kin,3D}} + mc^2 \ , \tag{19}$$

where $E_{\mathrm{kin,3D}}$ 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, $E_{\mathrm{kin,3D}}$ 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

$$E^2 = p^2\,c^2 = p_{3\mathrm{D}}^2\,c^2 + m^2\,c^4 \ , \tag{20}$$

where p is the total momentum of an object and $p_{3\mathrm{D}}$ is its momentum in an observer's coordinate space. Again, ER is eye-opening: From its perspective, $p_{3\mathrm{D}}$ 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.

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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 was moving away from O, 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 in this hypersphere. A considerable amount of energy is within its hypersurface.

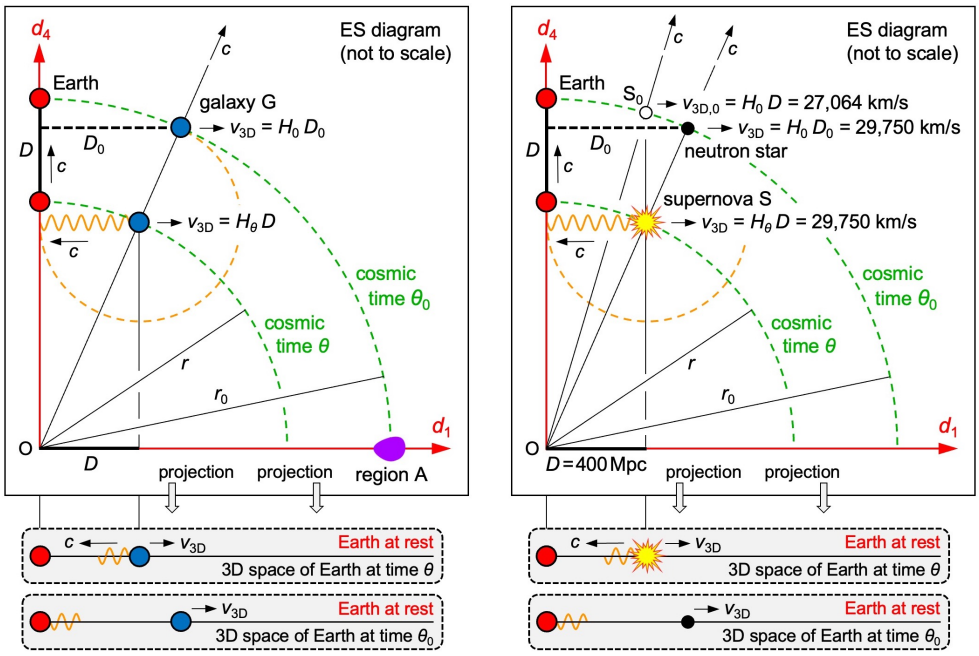

Fig. 6 ER-based model of cosmology. The green arcs show part of an expanding 3D hypersurface. The orange circles show where most of the energy emitted by G (or by S) at the time θ is today at the time θ_0. **Left:** Galaxy G recedes from the origin O of ES at the speed c, and from the d_4 axis in particular 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.

$$v_{3D} = D\,c/r = H_\theta\,D\ , \tag{21}$$

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. (21) turns into

$$v_{3D} = D_0\,c/r_0 = H_0\,D_0\ , \tag{22}$$

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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. (22) 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 Earth and ΔE collide in the 3D space of Earth if they don't 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. Earth and ΔE collide when 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 of space? In the Lambda-CDM model, a region A at $x_1 = +r_0$ and a region B at $x_1 = -r_0$ are causally disconnected unless we postulate a cosmic inflation. Without it, information could not have covered $2r_0$ since the Big Bang. ER does not require a cosmic inflation: In Fig. 6 left, A is at $d_1 = +r_0$ and B is at $d_1 = -r_0$ (not shown). From A's or B's perspective, their d_4' axis (which is equal to Earth's d_1 axis) disappears because of length contraction at the speed c. *A and B are causally connected because they overlap spatially from either perspective.* Their opposite 4D vectors $+\boldsymbol{\tau}'$ and $-\boldsymbol{\tau}'$ do not affect causal connectivity.

5.11. The Mystery of the Hubble Tension

Up next, I explain the 10 percent deviation in the published values of H_0 (also 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

$$1/H_\theta \;=\; r/c \;=\; (r_0 - D)/c \;=\; 1/H_0 \;-\; D/c\ . \qquad (23)$$

For a very short distance of $D = 400$ kpc, Eq. (23) 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

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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. *This solves the Hubble tension.* Team B's value is not correct because, according to Eq. (22), we must plot v_{3D} versus D_0 (!) to get a straight line (blue points in Fig. 7). Ignoring that the 4D geometry is Euclidean leads to an overestimation of the Hubble constant.

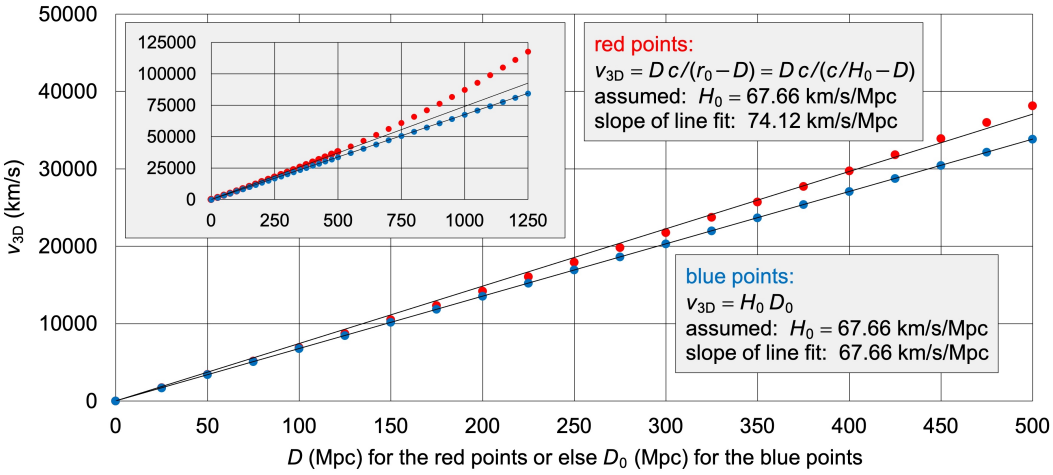

Fig. 7 Hubble diagram of simulated supernovae. The horizontal axis is D for the red points or else D_0 for the blue points. The red points, calculated from Eq. (21), do not yield a straight line because H_θ is not a constant. The blue points, calculated from Eq. (22), yield a straight line.

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. (22) as

$$v_{3D,0} = D\,c/r_0 = H_0\,D\ , \tag{24}$$

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. (23), (24), and (21).

$$H_\theta = H_0\,c/(c - H_0\,D) = H_0/(1 - v_{3D,0}/c)\ , \tag{25}$$

$$v_{3D,0} = v_{3D}/(1 + v_{3D}/c)\ . \tag{26}$$

By applying Eq. (26) and plotting $v_{3D,0}$ versus D, we also get a straight line according to Eq. (24). 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. (26). 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.

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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. (26) 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 $\boldsymbol{\tau}'$ of S_0 deviates less from Earth's 4D vector $\boldsymbol{\tau}$ than the 4D vector $\boldsymbol{\tau}''$ 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. (21).

The Hubble tension and dark energy are solved exactly the same way: *In Eq. (22), we must not confuse D_0 with D.* Because of Eq. (21) 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 mysteries of the H_0 tension and dark energy are solved by taking the 4D Euclidean geometry into account, and the 4D vector $\boldsymbol{\tau}$ in particular. These results cast doubt on the Lambda-CDM model. GR itself is correct, but we must not apply its empirical concepts to high-redshift supernovae. Space is not driven by dark energy. Galaxies are driven by their momentum. Because of physical interactions, some energy accelerated transversally while maintaining the speed c. This enables near-by galaxies to move toward Earth. Two models of cosmology are compared in Table 1. Note that "the Universe" is not the same as "his universe". Each observer experiences three out of four 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 (also 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.

I solve the duality by applying natural concepts: "Pure distance" (proper space/time) replaces coordinate space/time. Pure energy replaces wave/particle. Pure energy is made up of "wavematters" (see Fig. 8). In an observer's view ("external view"), each wavematter reduces to either a wave or a particle depending on whether or not it is tracked. As a

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wave (if it is not tracked), it propagates in his 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. In ES, there are no waves and no particles but wavematters only. Only observers experience the duality.

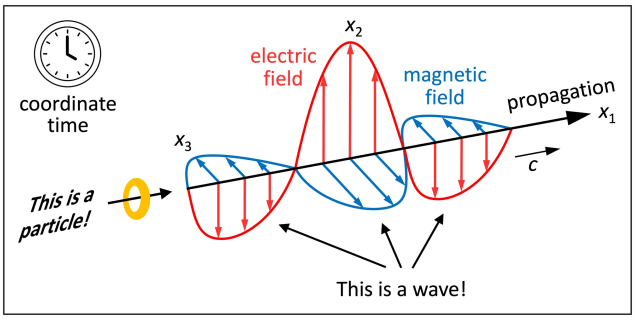

Fig. 8 Illustration of a wavematter. In an observer's view, it reduces to either a wave or a particle. As a wave (shown here), it propagates and it oscillates as a function of his coordinate time. In the wavematter's view (view through the yellow pinhole), it is a particle at rest.

Wave and particle are empirical concepts, just 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". Einstein taught us that energy and mass are equivalent [35]. Likewise, a wave's polarization and a particle's spin are equivalent. My neologism "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 a point P. They move away from each other in opposite 4D directions $\pm d_4'$ at the speed c. It turns out that they 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.

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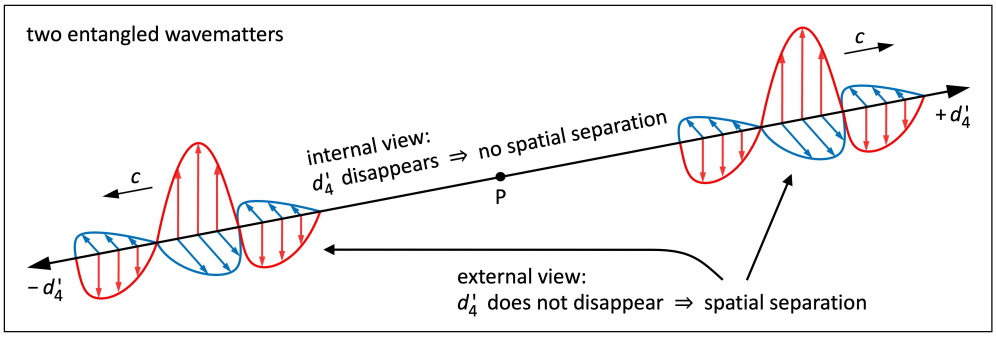

Fig. 9 Two wavematters moving in $\pm d_4'$ at the speed c are spatially separated for an observer moving in any direction other than $\pm d_4'$ (external view). For each wavematter (internal view), the d_4' axis disappears. From the internal view, the twins have never been spatially separated.

For each wavematter (internal view), the d_4' axis disappears because of length contraction at the speed c. In their common (!) 3D space spanned by d_1', d_2', d_3', either of them is at the very same position as its twin. From the internal view, the twins have never been *spatially* separated, but their proper time flows in opposite 4D directions. While the twins stay together spatially, they "communicate" with each other in no time. Their opposite 4D vectors $+\boldsymbol{\tau}'$ and $-\boldsymbol{\tau}'$ do not affect local "communication". There is a "spooky action at a distance" (phrase attributed to Einstein) from the external view only.

This time, the horizon problem and entanglement are solved exactly the same way: *An observed region's (or object's) 4D vector* $\boldsymbol{\tau}'$ *and its 3D space may differ from an observer's 4D vector* $\boldsymbol{\tau}$ *and his 3D space.* This is possible only if all four d_μ ($\mu = 1, 2, 3, 4$) are interchangeable. ER also explains the entanglement of matter, such as electrons [43]. In an observer's 3D space, electrons move at a speed less than c. In their $\pm d_4'$ axis, electrons move at the speed c. Any measurement tilts the axis of 4D motion of one twin and thus 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. Only then was the temperature high enough to enable pair production. Yet pair production creates equal amounts of baryons and antibaryons. So, why do we observe more baryons than antibaryons today (also known as the "baryon asymmetry")? ER scores again: Energy manifests itself as wavematters, and each wavematter deems itself particle at rest. Thus, the baryon asymmetry was caused by the Big Bang.

But why do wavematters not deem themselves antiparticles at rest? Well, antiparticles are not the opposite of particles but particles with the opposite electric charge. They are created in pair production and add up to a very small percentage of all wavematters. Being an antiparticle is relative: *What I deem antiparticle, deems itself particle.* Therefore, the "character paradox" [10] is reasonable and must not be considered a paradox. ER also tells us why it seems that an antiparticle's time flows backward: Proper time flows in opposite 4D directions for any two wavematters created in pair production. Wavematters moving in opposite 4D directions should be entangled (see Sect. 5.14). This prediction gives us a chance to falsify ER. 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.

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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–14c). 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) Information hidden in the 4D vector $\boldsymbol{\tau}$ solves 15 mysteries. It is very unlikely that 15 solutions in different (!) specialties are 15 coincidences. (2) An acceleration rotates $\boldsymbol{\tau}$ and curves an object's worldline in flat ES. (3) ER complements SR/GR. We must apply ER if there are significantly different 4D vectors $\boldsymbol{\tau}$ and $\boldsymbol{\tau}'$, as in high-redshift supernovae or entanglement. We must apply SR/GR if we use empirical concepts. SR tells us that we must not apply Newton's physics at speeds close to c. ER tells us that we must not apply Einstein's empirical concepts to objects that are very far away (high-redshift supernovae) or that move in opposite 4D directions at the speed c (entanglement). The scope of SR/GR is limited. Nature discloses her secrets in natural concepts.

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) I only touched on processes. I gave one example in Sect. 4. More studies are required to confirm that process is the natural concept of force/field. (3) Mysteries often disappear if we match the symmetry. The symmetry group in cosmology and QM is SO(4). (4) The new invariant θ puts an end to all discussions about time travel. Does any other theory solve the mystery of time's arrow as beautifully as ER? (5) 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. It seems that Plato's *Allegory of the Cave* [46] is true: 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 particles. A well-known preprint archive suspended my submission privileges. I was penalized because I dared to disclose an issue in Einstein's SR/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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