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Natural Concepts Unify Cosmology and Quantum Mechanics

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In special relativity (SR), there is coordinate time t and proper time τ . Two facts deserve reflection: (1) Clocks measure τ , but the construct t is more common in the equations of physics than natural τ . (2) Cosmology is aware of the Hubble parameter H_θ , but the parameter τ is preferred to $\theta = 1/H_\theta$ in SR and general relativity (GR). **We show:** Euclidean relativity (ER) describes nature exclusively in natural concepts. We combine three steps to make ER work: (1) The new time coordinate is τ . (2) The new parameter is θ . (3) Observers experience projections from 4D Euclidean space (ES). Because of the different concepts, ER does not conflict with SR/GR. All energy moves through ES at the speed c . Absolute ES is experienced as a relative Euclidean spacetime: Each object experiences its 4D motion as proper time and the other three axes as proper space. Both the Lorentz factor γ and gravitational time dilation γ_{gr} are recovered in ER. Thus, relativistic effects based on γ or γ_{gr} are also predicted by ER. In ER, τ is the length of a 4D Euclidean vector “flow of proper time” τ . Clocks with the same τ are naturally synchronized. Clocks with different τ cannot be synchronized. Gravity makes its comeback as a force: Any acceleration rotates an object’s τ and curves its worldline in ES. τ is crucial for objects that are very far away or entangled. Information hidden in θ or τ is not available in SR/GR. ER solves the Hubble tension, the wave–particle duality, and the baryon asymmetry. On top, ER declares curved spacetime, cosmic inflation, expanding space, dark energy, and non-locality obsolete.

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

Clocks measure proper time τ . There are two options of how we can conceive of τ : either as the invariant parameter or else as a coordinate of spacetime. In special relativity (SR) [1] and general relativity (GR) [2], τ can be used to parameterize worldlines in spacetime. In Euclidean relativity (ER), τ is the time coordinate of spacetime. Cosmic time (absolute time that has elapsed uniformly since the Big Bang) parameterizes worldlines.

A new theory of spacetime must either disprove SR/GR or else not conflict with SR/GR. Because of the different concepts, ER does not conflict with SR/GR. Yet ER tells us that the scope of SR/GR is limited: We must apply ER to objects that are very far away (high-redshift supernovae) or entangled (moving in opposite 4D directions at the speed c). In such extreme situations, the 4D vector “flow of proper time” of ER is crucial. ER raises questions: (1) *What are the benefits of ER?* ER solves mysteries of cosmology and quantum mechanics (QM). (2) *Does ER predict relativistic effects?* Yes, the Lorentz factor and gravitational time dilation are recovered in ER. (3) *Does ER also make quantitative predictions?* Yes, ER predicts the 10 percent deviation in the published values of the Hubble constant.

Request to all readers: (1) *Read carefully.* I do not disprove SR/GR mathematically. I show that the scope of SR/GR is limited physically. (2) *Do not reject ER without disproving it.* A new theory deserves full consideration until it is disproven. Most physicists consider ER a waste of time because SR/GR have been confirmed again and again. The Hubble tension is a strong clue that ER is not a waste of time. (3) *Do not apply the concepts of SR/GR to ER.* One reviewer argued that spacetime could not be Euclidean because it is non-Euclidean in SR/GR. According to this logic, Earth could not orbit the sun because it does not orbit the sun in geocentrism. Another reviewer argued that new coordinates could not provide new insights because coordinates are only labels. In SR/GR, coordinates are labels that can be adjusted. In ER, coordinates are intrinsic properties that cannot be adjusted (they relate to absolute 4D Euclidean space). (4) *Be fair.* One paper cannot cover all of physics.

1. Introduction

Today’s concepts of space and time were coined by Albert Einstein. In SR, space and time are fused 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.

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 “distant collisions” (without physical contact) and a “character paradox” (confusion of photons, particles, and antiparticles). I show that the constraint is obsolete. There are no distant collisions once we take projections into account. There is no character paradox once we take the 4D vector “flow of proper time” (see Sect. 3) into account. In particular, an object is not necessarily an antiparticle if its proper time flows backward with respect to an observer (see Sect. 5.15). Montanus calculated the deflection of starlight and the precession of Mercury’s perihelion using a Euclidean metric [10, 11], but he failed to derive Maxwell’s equations [10]. His constraint deprives ER of its main feature: full symmetry in all four axes. Montanus used an observer’s coordinate time t as the parameter. The correct parameter in ER is absolute, cosmic time θ .

Almeida [12] studied geodesics in ER. Gersten [13] interpreted the Lorentz transformation as an SO(4) rotation. There is also an ER website: <https://euclideanrelativity.com/>. Previous formulations of ER merely swapped the coordinate t with the parameter τ . This is the first paper where we combine three steps to make ER work: (1) The new time coordinate is proper time τ . (2) The new parameter is cosmic time $\theta = 1/H_\theta$, where H_θ is the Hubble parameter. (3) Observers experience projections from 4D Euclidean space (ES). Most physicists still reject ER because dark energy and non-locality make today’s cosmology and QM work, the SO(4) symmetry in ER seems to exclude waves, and there seem to be paradoxes in ER. *This paper marks a turning point.* I show: Dark energy and non-locality are obsolete, SO(4) is compatible with waves, and projections avoid paradoxes.

The two postulates of ER: (1) All energy moves through ES at the speed of light c . (2) The laws of physics have the same form in each object’s reference frame. An object’s reference frame is spanned by its proper space and proper time. Unlike coordinate space and coordinate time in SR, proper space and proper time in ER are assembled to a Euclidean spacetime. My [first postulate](#) is stronger than the second postulate of SR: c is absolute and universal. My [second postulate](#) is not limited to inertial frames.

We consider two objects “r” and “b” in ES. Fig. 1 illustrates their respective reference frames. Each object experiences that axis in which it moves at the speed c as proper time. It experiences the other three axes as proper space. Proper space and proper time form its “reality”. There are as many realities as there are objects. Mathematically, an object’s proper space and proper time are two orthogonal projections from ES. Physically, three axes of ES are experienced as spatial and one axis is experienced as temporal. Measuring an object’s coordinates is equivalent to projecting it from ES to an observer’s reality.

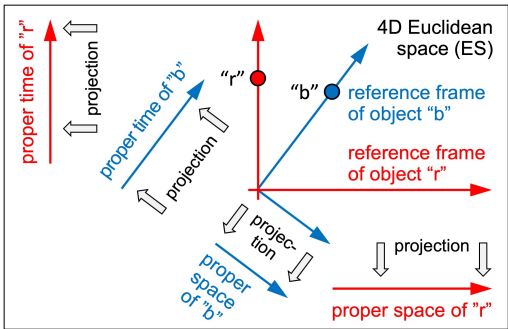


Figure 1. An object’s proper space and proper time are two orthogonal projections from ES.

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] influenced many philosophers. I am convinced that ER will reform both physics and philosophy. For a better readability, I refer to an observer as “he”. To compensate, I refer to nature as “she”.

2. Identifying an Issue in Special and General Relativity

In SR, the fourth coordinate of spacetime is 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

$$x'_1 = \gamma (x_1 - v_{3D} t) , \quad x'_2 = x_2 , \quad x'_3 = x_3 , \tag{2a}$$

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

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. Eqs. (2a–b) transform the coordinates from K to K'. There are covariant equations that transform the coordinates from K' to K. Mathematically, SR is correct. Physically, there is an issue in SR and also in GR: *The concepts of SR/GR fail to solve fundamental mysteries of physics*. There are coordinate-free formulations of SR [15] and also of GR [16], but there is no absolute time in SR/GR and thus no “holistic view” (in a holistic view, the spacetime diagram is universal for all observers at once). The view in SR and GR is “multi-egocentric” (SR/GR work for each observer, but there is no universal spacetime diagram). All observers’ views taken together do not make a holistic view because they still do not provide absolute time. Without absolute time, observers will not always agree on what is past and what is future. Physics paid a high price for dismissing absolute time: ER restores absolute time and solves 15 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: Geocentrism is the egocentric view of mankind. In the old days, it was natural to believe that all celestial bodies would orbit Earth. Only the astronomers wondered about the retrograde loops of some planets and claimed that Earth orbits the sun. Nowadays, engineers have improved the accuracy of our rulers and clocks. Today, it is natural to believe that the readings on our rulers and clocks would be sufficient to describe nature. I show: The readings on “natural rulers and clocks” (rulers and clocks that all objects of nature carry within themselves) describe nature even better. The human brain is smart, but it often takes itself as the center/measure of everything.

The analogy of the geocentric model to SR/GR is not perfect: While heliocentrism and geocentrism exclude each other, ER does not conflict with SR/GR. Yet the analogy is close: (1) After taking another planet as the center of the Universe (or after a transformation in SR/GR), the view is still geocentric (or else egocentric). (2) Retrograde loops are obsolete in heliocentrism, but they make geocentrism work. Dark energy and non-locality are obsolete in ER, but they make today’s cosmology and QM work. (3) Heliocentrism overcomes the limitation of a geocentric view. ER overcomes the limitation of a multi-egocentric view. (4) 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?*

3. The Physics of Euclidean Relativity

Unlike SR, ER cannot be derived from measuring instructions because the proper coordinates of other objects cannot be measured. We start with the metric of SR

$$c^2 d\tau^2 = c^2 dt^2 - dx_1^2 - dx_2^2 - dx_3^2 , \tag{3}$$

where $d\tau$ is an infinitesimal distance in proper time τ , whereas all dx_i ($i = 1, 2, 3$) and dt 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 a *man-made spacetime* because its coordinates

are constructs: An observer’s proper space is set equal to coordinate space, and his proper time is set equal to coordinate time. The drawback of this approach is that the coordinates of coordinate spacetime are not inherent in all rulers and clocks. Rulers measure proper length d_i and not x_i ($i = 1, 2, 3$). Clocks measure proper time τ and not t . We introduce ER by defining a Euclidean metric in four dimensions.

$$c^2 d\theta^2 = dd_1^2 + dd_2^2 + dd_3^2 + dd_4^2 , \tag{4}$$

where $d\theta$ is an infinitesimal distance in the parameter θ (to be given a meaning later on), whereas all dd_μ ($\mu = 1, 2, 3, 4$) are infinitesimal distances in 4D Euclidean space (ES). We prefer the indices 1–4 to 0–3 to stress the SO(4) symmetry. Each object is free to label the axes of its reference frame in ES. Observers are treated like objects! We assume: Each object labels the axis of its *current* 4D motion as d_4 and the other three axes as d_1, d_2, d_3 . Because of my [first postulate](#), the object always moves in the d_4 axis at the speed c . If its worldline in ES is curved, its reference frame continuously adapts to this curvature. Because of length contraction at the speed c (see [Sect. 4](#)), the d_4 axis disappears for itself and is experienced as proper time. An object moving in the d_4' axis at the speed c experiences d_4' as proper time. In ER, τ is the length of a 4D Euclidean vector “flow of proper time” τ .

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

$$\tau = d_4 \mathbf{u}/c^2 , \quad \tau' = d_4' \mathbf{u}'/c^2 , \tag{6}$$

where $\mathbf{u}$ is an object’s 4D velocity. In ER, speed is not defined as $v_i = dx_i/dt$ ($i = 1, 2, 3$), but as $u_\mu = dd_\mu/d\theta$ ($\mu = 1, 2, 3, 4$). Thus, Eq. (4) is nothing but my [first postulate](#)

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

In other words: Each object experiences its 4D motion as proper time τ and the other three axes as proper space d_1, d_2, d_3 . Thus, absolute ES is experienced as a relative Euclidean spacetime (EST). I call it “proper spacetime”. Proper spacetime d_1, d_2, d_3, τ is a *natural spacetime* because its coordinates are measured by and thus inherent in all rulers and clocks. The coordinates of EST are intrinsic properties of all objects. The fourth coordinate of EST is τ . The invariant parameter is θ . The metric tensor is the identity matrix.

Montanus [9–11] merely rearranged Eq. (3) to enforce a Euclidean metric. He did not distinguish between t and θ . He also rejected symmetric axes and promoted a spacetime where a pure time interval always remains a pure time interval. I show: Whatever is proper time to me, it can be one axis of proper space (or a mix of proper space and proper time) for you. Do not confuse ER with a Wick rotation [17], which keeps τ invariant.

Because of $t \neq \theta$, there is no continuous transition between Eqs. (3) and (4) nor between SR/GR and ER. This fact underlines that ER provides a unique description of nature. SR describes nature in man-made spacetime $x_1(\tau), x_2(\tau), x_3(\tau), t(\tau)$, where the parameter τ is object-related. GR is locally equivalent to SR. ER describes nature in natural spacetime $d_1(\theta), d_2(\theta), d_3(\theta), \tau(\theta)$, where θ is what I call the “cosmic evolution parameter”. As I will demonstrate in [Sect. 5](#), the parameter θ proves more powerful than the parameter τ . Only in proper coordinates can we access ES, but the proper coordinates of other objects cannot be measured. In my [Conclusions](#), I will explain why this is fine.

It is instructive to contrast three concepts of time. t is a subjective measure of time: An observer uses his clock as the master clock. τ is an objective measure of time: Clocks measure τ independently of observers. θ is the total distance covered in ES (length of a worldline) divided by c . As the invariant in Eq. (4), θ is a concept of absolute time. This is why I also call it “cosmic time”. In terms of cosmic time, there is no twin paradox. Twins share the same age in cosmic time θ . By referring to θ , observers always agree on what is past and what is future. Regarding causality, a finite c is incompatible with a coordinate “absolute time”, but compatible with a parameter “absolute time”.

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. Both clocks display “1.0”. Since “r” remains at $d_1 = 0$ and “b” remains at $d'_1 = 0$, there is $\tau = \theta$ for “r” and $\tau' = \theta$ for “b” according to Eq. (4). A uniformly moving clock always displays both its τ and θ . Yet τ is not the invariant in ER. Thus, d_4 of “r” is not equal to d_4 of “b”. In ER, θ is the invariant. Thus, d_4 of “r” is equal to d'_4 of “b”.

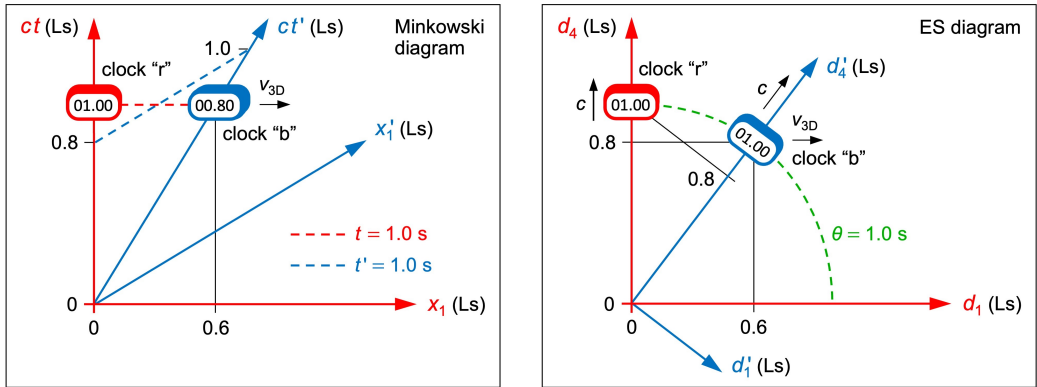


Figure 2. Minkowski diagram and ES diagram of two clocks “r” and “b”. **Left:** “b” is slow with respect to “r” in t' . Coordinate time is relative (“b” is at different positions in t and t'). **Right:** “b” is slow with respect to “r” in d_4 . Cosmic time is absolute (“r” and “b” are at the same position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

We now assume that an observer R (or B) moves with clock “r” (or else “b”). In SR and only for observer R (t and t' are defined by him), 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' . 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 . In SR and ER, “b” is slow with respect to “r”, but time dilation occurs in different axes. Experiments do not disclose that axis in which a clock is slow. Thus, both SR and ER describe time dilation correctly if they yield the same Lorentz factor. In Sect. 4, I show that the Lorentz factor is recovered in ER.

“Relativity” has different connotations in SR and ER: In SR, spatial and temporal distances are relative (they depend on the relative motion of observer and observed object). In ER, the angular orientation of an object’s frame of reference in ES is relative (it depends on the object’s 4D vector τ). Note that there are neither spatial nor temporal distances in ES. The distances in all four axes of ES are “pure distances”. Only in relative EST does an object experience d_1, d_2, d_3 as spatial and d_4 as temporal. There is also a great difference regarding clock synchronization: In SR, R can synchronize clock “b” to his clock “r” (same value of ct in Fig. 2 left). If he does, the clocks are not synchronized for B. In ER and independently of observers, clocks with the same τ are naturally synchronized. Clocks with different τ cannot be synchronized (different values of d_4 in Fig. 2 right).

But why does ER provide a holistic view? Eq. (4) is symmetric in all d_μ ($\mu = 1, 2, 3, 4$). 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. Fig. 2 right works for R and for B “at once” (at the same time θ): Not only are d_1 and d_4 orthogonal, but also d'_1 and d'_4 . The ES diagram is universal for all observers at once. Here the view is holistic. Note that the Michelson–Morley experiment [18] refutes a “luminiferous ether” (absolute 3D space), but not absolute ES.

Regarding waves, I was misled by editors who insisted that the $SO(4)$ symmetry of ES is incompatible with waves. $SO(4)$ is incompatible with waves that propagate as a function of a coordinate (such as coordinate time t), but compatible with waves that propagate as a function of the parameter θ . This is because Eq. (4) can be rewritten as

$$c^2 d\tau^2 = c^2 d\theta^2 - dd_1^2 - dd_2^2 - dd_3^2, \quad (8)$$

which is of the same form as Eq. (3). A great advantage of mathematics is that it remains the same if we just replace the variables. Thus, Maxwell's equations have the same form in ER as in today's physics except that θ replaces t and that waves can propagate in one out of four axes. Eq. (8) is not a "mathematical trick" that enables waves. Rather, Eq. (8) makes us aware that waves can propagate as a function of the parameter θ . A great difference between SR/GR and ER is that in ER all processes are a function of the parameter θ . I claim: *All objects are "wavematters" (pure energy) that propagate through and oscillate in ES as a function of the parameter θ .* In Sect. 5.13, I give evidence of my claim.

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. For a better readability, a rocket's width is drawn in d_4 (or d'_4), although its width is in d_2, d_3 (or else d'_2, d'_3).

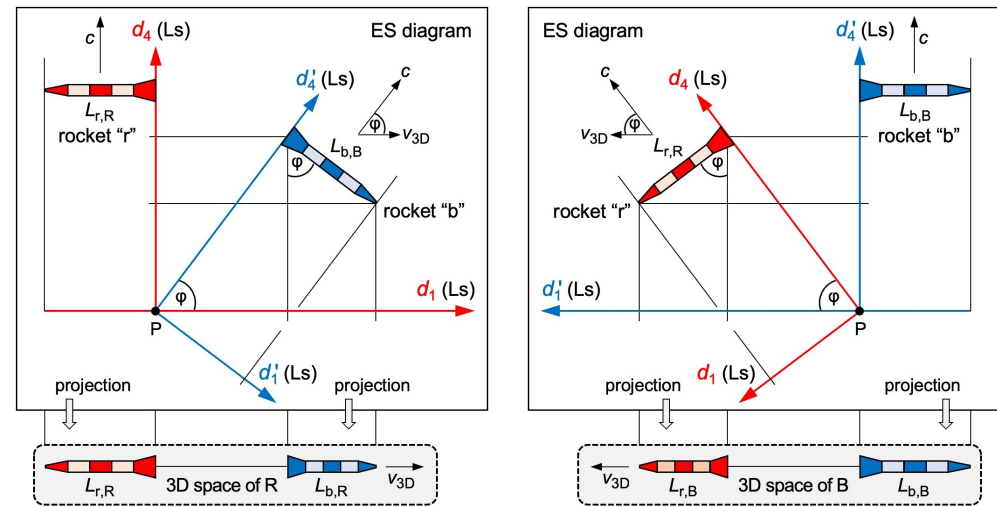


Figure 3. ES diagrams of two rockets "r" and "b". Observer R (or B) is in the rear end of "r" (or else "b"). **Left:** "r" moves in the d_4 axis. "b" moves in the d'_4 axis. In the 3D space of R, "b" contracts to $L_{b,R}$. **Right:** The ES diagram has been rotated only. In the 3D space of B, "r" contracts to $L_{r,B}$.

Up next, we verify: Projecting distances in ES to the axes d_1 and d_4 of an observer causes length contraction and 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 left to the d_1 axis.

$$\sin^2 \varphi + \cos^2 \varphi = (L_{b,R}/L_{b,B})^2 + (v_{3D}/c)^2 = 1, \quad (9)$$

$$L_{b,R} = \gamma^{-1} L_{b,B} \quad (\text{length contraction}), \quad (10)$$

where $\gamma = (1 - v_{3D}^2/c^2)^{-0.5}$ is the same Lorentz factor as in SR. In the reality of R, "b" contracts to $L_{b,R}$. Despite a different metric, we calculate the same γ as in SR. We ask: Which distances will R observe in the d_4 axis? We rotate "b" until it serves as a ruler for R in d_4 . In his 3D space, it contracts to zero length. 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 left to the d_4 axis.

$$\sin^2 \varphi + \cos^2 \varphi = (d_{4,B}/d'_{4,B})^2 + (v_{3D}/c)^2 = 1, \quad (11)$$

$$d_{4,B} = \gamma^{-1} d'_{4,B}, \quad (12)$$

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

$$d_{4,R} = \gamma d_{4,B} \quad (\text{time dilation}), \quad (13)$$

where $d_{4,R}$ is the distance that R moved in d_4 . Eqs. (10) and (13) tell us: γ is recovered in ER once we project ES to the axes d_1 and d_4 of an observer. Thus, ER predicts the same relativistic effects as SR. The two rockets only serve as an example. Other objects are projected the same way. For instance, the lifetime of a muon is recovered in ER when R is kept as the observer and the blue rocket is replaced by a muon. For orthogonal projections, the reader is referred to textbooks about geometry [19, 20].

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

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

$$d'_{4,R}(\theta) = d_{4,R}(\theta) \sin \varphi = d_{4,R}(\theta) \gamma^{-1}. \quad (14b)$$

Up next, I show that not only the Lorentz factor is recovered in ER, but also gravitational time dilation. Initially, our two clocks "r" and "b" shall be very far away from Earth (see Fig. 4). Eventually, "b" falls freely toward Earth and accelerates while maintaining the speed c in ES. Earth and "r" keep on moving in the d_4 axis at the speed c .

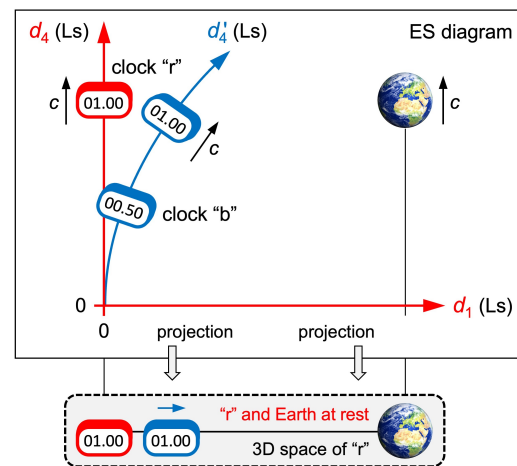


Figure 4. ES diagram of two clocks "r" and "b" and Earth. Clock "b" accelerates toward Earth. The d'_4 axis is drawn curved because it indicates the current 4D motion of "b".

Because of Eq. (7), all accelerations in ES are transversal. In particular, Eq. (7) tells us: *If an object accelerates in an observer's proper space, it automatically decelerates in his proper time.* The speed $u_{1,b}$ of "b" in d_1 increases at the expense of its speed $u_{4,b}$ in d_4 . In the gravitational field of Earth, the kinetic energy of "b" (mass m) in d_1 is

$$\frac{1}{2} m u_{1,b}^2 = G M m / R, \quad (15)$$

where G is the gravitational constant, M is the mass of Earth, and $R = d_{1,Earth} - d_{1,b}$ is the distance of "b" to the center of Earth in the 3D space of "r". Eq. (7) gives us

$$u_{4,b}^2 = c^2 - u_{1,b}^2 = c^2 - 2GM/R. \quad (16)$$

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

$$dd_{4,b}^2 = (c^2 - 2GM/R) (dd_{4,r}/c)^2, \quad (17)$$

$$dd_{4,r} = \gamma_{gr} dd_{4,b} \quad (\text{gravitational time dilation}), \quad (18)$$

where $\gamma_{gr} = (1 - 2GM/(Rc^2))^{-0.5}$ is the same dilation factor as in GR. Eq. (18) tells us: γ_{gr} is recovered in ER once we project ES to the d_4 axis of an observer. Yet in GR, gravity is the curvature of spacetime. In ER, gravity makes its comeback as a force: *Because of Eq. (7), any acceleration rotates an object's τ and curves its worldline in ES.* The $1/R^2$ law of gravity is maintained because ES is reduced to an observer's 3D space. Action at a distance is not an issue if field variations propagate at the speed c and as a function of θ .

Clock "b" is slow with respect to "r" in d_4 . Since "r" displays both its τ and θ , "b" is slow with respect to absolute time θ ! *An accelerated clock always displays its τ , but not θ .* This is why clocks placed next to each other display different times after being exposed to different gravitational fields. Since γ_{gr} does not depend on $u_{1,b}$, "b" is slow with respect to θ whether or not it stops moving relative to Earth. I invite theorists to show two things: (1) Gravitational waves [21] are compatible with ER. (2) Variational principles [22] are an alternative to derive ER. Here I showed: γ and γ_{gr} are recovered in ER.

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 accelerated 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] also supports ER. GPS works in ER just as well as in SR/GR.

Fig. 5 illustrates how to read ES diagrams. **Problem 1:** Two objects move through ES. "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 cannot catch up with "r" in the d_4 axis. *Can the 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. The wire moves in d_4 . The rocket's speed in d_4 is less than c . *Doesn't the wire eventually escape from the rocket?* **Problem 3:** Earth orbits the sun. The sun moves in d_4 . Earth's speed in d_4 is less than c . *Doesn't the sun eventually escape from Earth?*

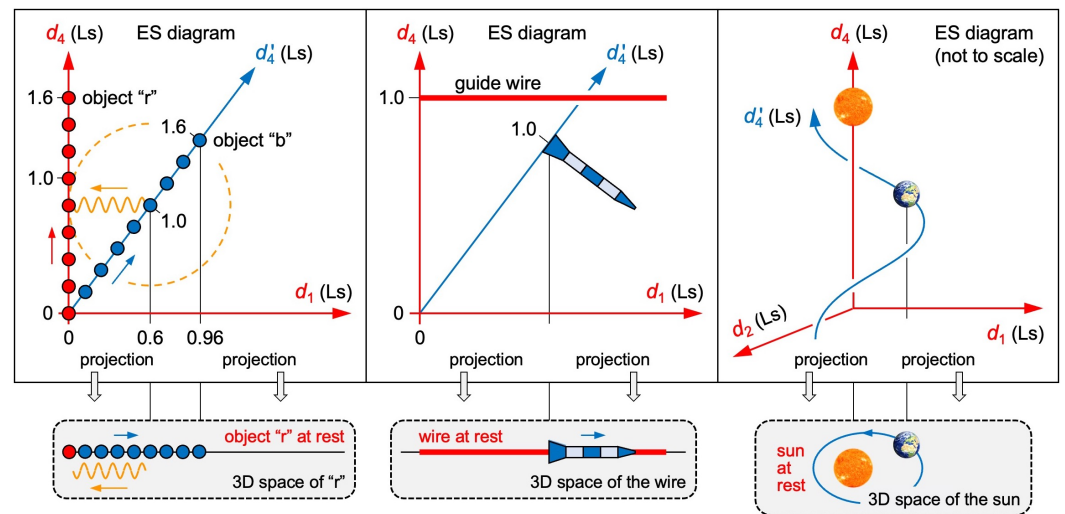


Figure 5. Three problems. **Left:** Objects "r" and "b" move through ES. The orange circle shows where a signal emitted by "b" at $\theta = 1.0$ s is at $\theta = 1.6$ s. In ES, the signal and "r" do not collide. In the 3D space of "r", they do. **Center:** In ES, the wire escapes from the rocket. In the 3D space of the wire, it does not. **Right:** In ES, the sun escapes from Earth. In the 3D space of the sun, it does not.

The last paragraph seems to reveal paradoxes in ER. The fallacy lies in the assumption that all four axes d_μ would be spatial at once. This is not the case. Only three axes of ES are experienced as spatial and one as temporal. We solve all 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. In Fig. 5 left, the signal collides with “r” in the 3D space of “r” when their positions in d_1, d_2, d_3, θ (not in d_4) coincide. This occurs when $\theta = 1.6$ s have passed since “r” left the origin. The collision also occurs in the 3D space of the signal (not shown). In the 3D space of the signal, “r” reverses its motion at $\theta = 1.0$ s. Collisions in 3D space do not show up as collisions in ES. This is because events are a function of θ , which is not an axis in ES diagrams. *ES diagrams do not show events, but each object’s flow of proper time.* The sun does not spatially escape from Earth. The sun and Earth age in slightly different 4D directions! Earth ages in varying 4D directions. This information is not available in SR/GR.

5. Outlining the Solutions to 15 Fundamental Mysteries

Einstein himself [2] suggested three tests to validate GR: gravitational redshift, starlight deflection, and the precession of Mercury’s perihelion. ER predicts the same gravitational redshift because γ_{gr} is recovered in ER (see Sect. 4). Regarding the other two effects, Montanus [10] showed that a Euclidean metric predicts the same deflection angle and the same precession rate as GR. He did not use θ as the parameter, but an observer’s τ (page 13 of [10]), which is set equal to t . *His approach is correct, but only as long as the 4D vector τ is not crucial.* The sun, Mercury, and Earth recede from the origin O of ES (see Sect. 5.6) in almost the same direction. Only in this case is τ not crucial and t just as good a parameter as θ . Thus, ER passes these three tests. On top, ER solves the following 15 mysteries.

5.1. The Nature of Time

Proper time τ is what clocks measure. Cosmic time θ is the total distance covered in ES (length of a worldline) divided by c . A uniformly moving clock always displays both its τ and θ . An accelerated clock always displays its τ , but not θ .

5.2. Time’s Arrow

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

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

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

$$E = \gamma mc^2 = E_{\text{kin}} + mc^2,$$

(19)

where E_{kin} is its kinetic energy in an observer’s coordinate space and mc^2 is its “rest energy”. The term mc^2 can be derived in SR, but SR cannot explain *why* there is a factor c^2 if the object does not move at the speed c in SR. ER gives us the missing clue: *No object is ever at rest.* Even if spacetime is different in SR and ER, the objects are the same. The factor c^2 tells us that the speed c is universal. This information is also present in SR, but hidden in the term mc^2 . In SR, mc^2 is an object’s kinetic energy in the observer’s ct axis.

5.4. Length Contraction and Time Dilation

In SR, length contraction and time dilation can be traced back to a man-made concept: Einstein’s clock synchronization. In ER, length contraction and time dilation are natural effects: They arise from projecting ES to the axes d_1 and d_4 of an observer.

5.5. Gravitational Time Dilation

In GR, gravitational time dilation can be traced back to a man-made concept: Einstein’s curved spacetime. In ER, gravitational time dilation is a natural effect: It arises from projecting ES to the d_4 axis of an observer. *In ER, curved spacetime is an obsolete concept.*

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

(21)

where $H_0 = c/r_0 = 1/\theta_0$ is the Hubble constant, $D_0 = D r_0/r$, and r_0 is today's radius of the 4D hypersphere. Eq. (21) is an improved Hubble–Lemaître law [25, 26]. Cosmology is aware of θ and H_θ . It is not yet aware that the 4D geometry is Euclidean, that θ is absolute, and that v_{3D} is equal to $H_0 D_0$ (not to $H_0 D$). *Out of two galaxies, the one farther away recedes faster, but each galaxy maintains its recession speed v_{3D} .* Time dilation is a consequence of Eq. (7): Since G moves in d_1 at the speed v_{3D} , it moves in d_4 at the speed $(c^2 - v_{3D}^2)^{0.5}$. Thus, a clock in the galaxy G is slow with respect to a clock on Earth in d_4 by the factor $c/(c^2 - v_{3D}^2)^{0.5} = \gamma$. 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? As in 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 Flat Universe

Two orthogonal projections from flat ES form an observer's reality. Thus, he experiences two structures: a flat universe (his proper space) and his proper time.

5.9. 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 Horizon Problem (Cosmic Homogeneity)

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 cosmic inflation. Without inflation, information could not have covered $2r_0$ since the Big Bang. The ER-based model applies 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 Hubble Tension

Up next, I show that ER predicts the 10 percent deviation in the published values of H_0 (known as the "Hubble tension"). We consider CMB measurements and distance ladder measurements. 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, but there is a systematic error in team B's value of H_0 . The error stems 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 , but we observe it today at the cosmic time θ_0 (see Fig. 6 right). While the supernova's light moved the distance D in $-d_1$, Earth moved the same distance D , but in $+d_4$ (same speed c according to my first postulate).

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

(22)

For a 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 z versus magnitude, which is like plotting v_{3D} versus D , its value of H_0 is roughly 10 percent too high. Team B's value of H_0 is not correct because Eq. (21) tells us: We must plot v_{3D} versus D_0 to get a straight line (blue points in Fig. 7). Ignoring the 4D Euclidean geometry in distance ladder measurements leads to an overestimation of H_0 by 10 percent. This solves the Hubble tension.

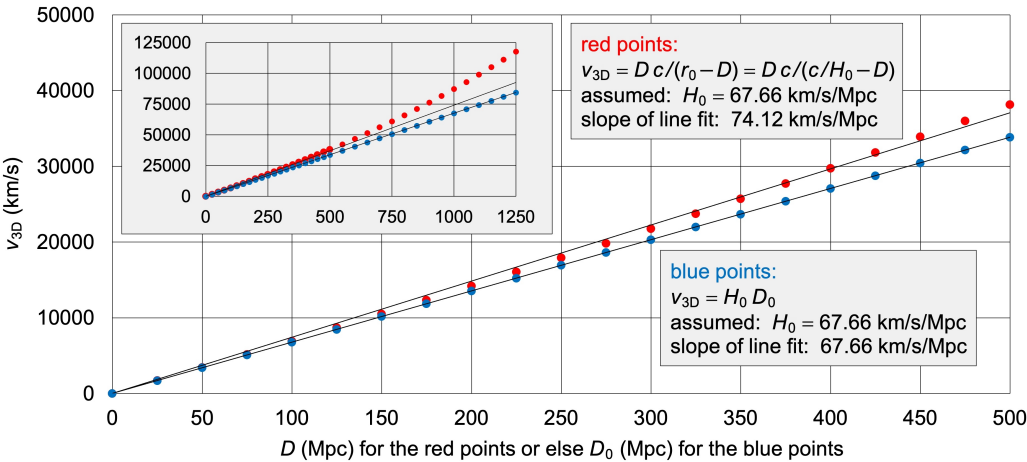


Figure 7. Hubble diagram of simulated supernovae. The horizontal axis is D for the red points or else D_0 for the blue points. The red points, calculated from Eq. (20), do not yield a straight line because H_θ is not a constant. The blue points, calculated from Eq. (21), yield a straight line.

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

$$v_{3D,0} = Dc/r_0 = H_0 D , \tag{23}$$

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

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

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

Because of Eq. (23), we also get a straight line by applying Eq. (25) and plotting $v_{3D,0}$ versus D . In addition, Fig. 7 tells us: The more high-redshift data are included in team B's calculation, the more the Hubble 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. Dark Energy

I now identify another systematic error, but this one is inherent in the Lambda-CDM model. It concerns the supposedly accelerating expansion of space and cannot be resolved within the Lambda-CDM model unless we postulate dark energy. Most cosmologists [31, 32] believe in an accelerating expansion because the recession speed v_{3D} increasingly deviates from a straight line when we plot v_{3D} versus D . An accelerating expansion would indeed stretch each wavelength even further and explain the deviations.

In ER, the cause of the deviations is far less speculative: The longer ago a supernova occurred, the more H_θ deviates from H_0 , and thus the more v_{3D} deviates from $v_{3D,0}$. If a star S_0 happens to be at the same distance of $D = 400$ Mpc today at which the supernova of S occurred, Eq. (25) tells us: S_0 recedes more slowly (27,064 km/s, the shortest arrow in Fig. 6 right) from d_4 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 τ of Earth than τ'' of S deviates from τ . As of today, cosmologists hold dark energy [33] responsible for an accelerating expansion of space. Dark energy has not been confirmed. It is a stopgap solution for an effect that the Lambda-CDM model cannot explain. Supernovae occurring earlier in cosmic time recede faster because of a larger H_θ in Eq. (20) and not because of dark energy.

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 space. 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 works well 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 v_{3D} with respect to Earth. Because of various effects (scattering, gravitational field, photon emission, pair production), some energy deviates from a radial motion in ES while maintaining the speed c . Gravitational attraction enables near-by galaxies to move toward our galaxy. Table 1 compares two models of cosmology. Note that “Universe” (Lambda-CDM model) and “universe” (ER-based model) are not the same thing. Each observer experiences three axes of ES as his universe. Cosmology benefits from ER. In Sects. 5.13 and 5.14, 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 models of cosmology.

5.13. The Wave–Particle Duality

The wave–particle duality was first discussed by Niels Bohr and Werner Heisenberg [34]. It has bothered physicists ever since. In some experiments, objects behave like waves. In others, the same objects behave like particles (known as the “wave–particle duality”). One object cannot be both because waves are distributed in space and capable of interference, whereas particles are localized in space and not capable of interference. To overcome the duality, we introduce another natural concept: All objects are “wavematters” (pure energy) that propagate through and oscillate in ES as a function of the parameter θ . In an observer’s view, wavematters reduce to wave packets if not tracked or else to particles if tracked.

In Fig. 8, observer R moves in the d_4 axis at the speed c . Three wavematters WM_1 , WM_2 , and WM_3 move in different 4D directions at the speed c . For a better readability, a wavematter's oscillation is drawn in the d_1, d_4 plane, although it can oscillate in any axis that is orthogonal to its propagation axis. WM_1 does not move relative to R. Thus, it is automatically tracked and reduces to a particle (P_1). In the 3D space of R, WM_2 and WM_3 reduce to wave packets (W_2, W_3) if not tracked or else to particles (P_2, P_3) if tracked. In the 3D space of R, W_2 moves at a speed less than c . Thus, W_2 is what Louis de Broglie called a "matter wave" [35]. Erwin Schrödinger formulated his Schrödinger equation to describe matter waves [36]. In the 3D space of R, both W_3 and P_3 move at the speed c . Thus, WM_3 is the only wavematter that reduces for R to an electromagnetic wave packet or else to a photon. Light gives us a good idea of how wavematters move through ES.

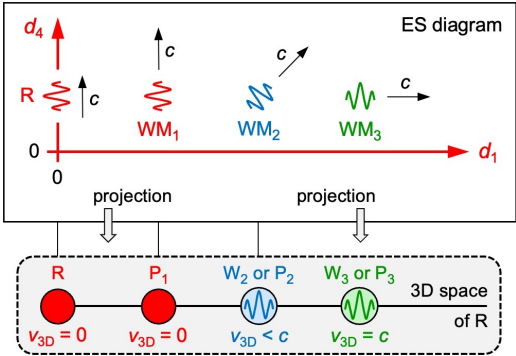


Figure 8. Wavematters. Observer R moves in the d_4 axis. In his 3D space, WM_2 and WM_3 reduce to wave packets (W_2, W_3) if not tracked or else to particles (P_2, P_3) if tracked. P_1 : possibly an atom of R. W_2 : matter wave. P_2 : possibly a moving atom. W_3 : electromagnetic wave packet. P_3 : photon.

Remarks: (1) "Wavematter" is not just a new word for the duality. It is a new concept, which tells us where the duality comes from and that it is experienced by observers only. Isn't it enriching to learn that particles, matter waves, photons, and electromagnetic waves all originate from a common concept? (2) In today's physics, there is no "photon's view". In ER, we can assign a 3D space and a proper time to each wavematter. In its view, its 4D motion disappears because of length contraction at the speed c . In its 3D space, it is always at rest and reduces to a particle. (3) In a particle, a wavematter's energy condenses to mass. Einstein taught that energy and mass are equivalent [37]. "Wavematter" is a natural concept that stands for the equivalence of a wave's energy and a particle's mass.

In double-slit experiments, light creates an interference pattern on a screen if it is not tracked through which slit single portions of energy are passing. The same applies if material objects, such as electrons, are sent through the double-slit [38]. *Here light and matter behave like waves.* In experiments on the photoelectric effect, an electron is released from a metal surface only if the energy of an incoming photon exceeds the binding energy of that electron. The photon must interact with that electron to release it. The interaction discloses their current position. They are tracked. *Here light and matter behave like particles.* Since an observer automatically tracks all objects that are slow in his 3D space, he classifies all slow objects—and thus all macroscopic objects—as matter. For a better readability, most of my ES diagrams do not show wavematters, but how they appear to observers.

5.14. Entanglement

It was Erwin Schrödinger who coined the word "entanglement" in his comment [39] on the Einstein–Podolsky–Rosen paradox [40]. The three authors argued that QM would not provide a complete description of reality. Schrödinger's neologism does not resolve the paradox, but it demonstrates our difficulties in comprehending QM. John Bell [41] showed that QM is incompatible with local hidden-variable theories. Meanwhile, it has been confirmed in several experiments [42–44] that entanglement violates locality in an observer's 3D space. Entanglement has been interpreted as a non-local effect ever since.

Up next, I show that ER untangles entanglement without the concept of non-locality. There is no violation of locality in ES, where all four axes are fully symmetric. In Fig. 9, observer R moves in the d_4 axis at the speed c . There are two pairs of wavematters. One pair was created at the point P and moves in opposite directions $\pm d'_4$ (equal to the axes $\pm d_1$ of R) at the speed c . The other pair was created at the point Q and moves in opposite directions $\pm d''_4$ at the speed c . In the 3D space of R, one pair reduces to entangled photons. The other pair reduces to entangled material objects, such as electrons. R has no idea how two entangled objects are able to “communicate” in no time.

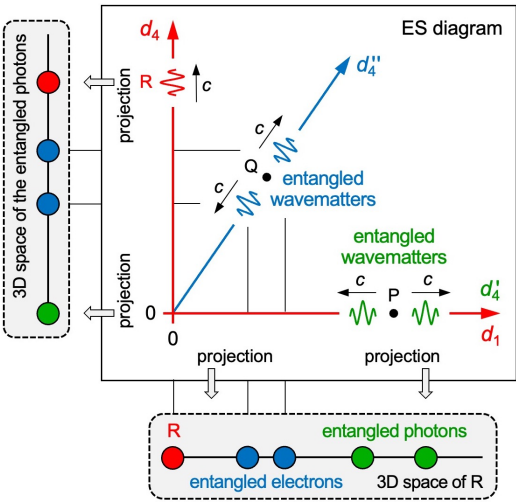


Figure 9. Entanglement. Observer R moves in the d_4 axis. In the 3D space of R, one pair of wavematters reduces to entangled photons. The other pair reduces to entangled electrons. In the photons’ 3D space (or electrons’ 3D space, not shown), the photons (or else electrons) stay together.

In the photons’ view (or electrons’ view), the d'_4 axis (or else the d''_4 axis) disappears because of length contraction at the speed c . Thus, each pair stays together in its respective 3D space. Entangled objects have never been spatially separated in their view, but their proper time flows in opposite 4D directions. This is how two entangled objects are able to communicate in no time. 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” (attributed to Einstein) in an observer’s 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 can differ from the observer’s 4D vector τ and his 3D space.* All of this is possible, but only in ES, where all four axes are fully symmetric. The SO(4) symmetry of ES solves entanglement. It explains the entanglement of photons just as well as the entanglement of material objects, such as atoms or electrons [45]. Any measurement on one entangled twin will terminate its existence or tilt the axis of its 4D motion. In either case, the twins will not move in opposite 4D directions anymore. The entanglement is destroyed. *In ER, non-locality is an obsolete concept.*

5.15. The Baryon Asymmetry

In the Lambda-CDM model, almost all matter was created shortly after $\theta = 0$, when the temperature was high enough to enable pair production. But this process creates equal amounts of particles and antiparticles, and the process of annihilation annihilates 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, wavematters reduce to wave packets or else to particles. Pair production creates particles and antiparticles, which annihilate each other very soon. Thus, there is one source of *long-lived particles* (reduction of wavematters), one source of *short-lived particles* (pair production), but 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 flows forward. ER predicts that any two wavematters created in pair production are entangled. This gives us a chance to falsify ER. Scientific theories must be falsifiable according to Karl Popper [46]. Note that an object moving in $-d_4$ is not necessarily an antiparticle. Its flow of proper time is reversed with respect to an observer moving in $+d_4$, but its physical charges are not necessarily reversed.

6. Conclusions

Modern physics lacks two qualities of time: absolute and vectorial. On the one hand, there is the cosmic evolution parameter θ (absolute time), which separates absolute past, present, and future. There is no absolute time in SR/GR. On the other hand, τ is the length of a 4D Euclidean vector “flow of proper time” τ . There is no τ in SR/GR. While SR/GR work for all observers, the 15 mysteries solved in Sect. 5 show that the scope of SR/GR is limited physically. The 4D vector τ is crucial for objects that are very far away or entangled. Information hidden in θ or τ is not available in SR/GR. It is very unlikely that 15 solutions in different (!) areas of physics are 15 coincidences. Some of these mysteries were solved without ER, but only by adding highly speculative concepts that now prove obsolete. ER declares curved spacetime, cosmic inflation, expanding space, dark energy, and non-locality obsolete. They are all subject to Occam’s razor. No exceptions.

It was a wise decision to award Einstein the Nobel Prize for his theory of the photoelectric effect [47] and not for SR/GR. ER penetrates to a deeper level. Einstein, one of the most brilliant physicists ever, did not realize that the metric of nature is Euclidean. In fact, his instruction for synchronizing clocks blocks access to ER. He sacrificed absolute space and time. ER restores absolute time, but sacrifices the absolute nature of particles, matter waves, photons, and electromagnetic waves. In retrospect, two unfortunate practices of physicists delayed the formulation of ER: (1) Clocks measure τ , but the construct t is more common in the equations of physics than natural τ . (2) Cosmology is aware of the Hubble parameter H_θ , but the parameter τ is preferred to $\theta = 1/H_\theta$ in SR and GR. For the first time ever, mankind now understands the nature of time: Cosmic time θ is the total distance covered in ES divided by c . The human brain is able to imagine that we move 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 showed in Eqs. (14a–b). 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 can be obsolete. I was often told that physics is all about observing. I disagree. We cannot observe quarks, can we? Regrettably, physicists have applied man-made concepts—which work well in everyday life—to the very distant 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.*

Comments: (1) Further studies on gravity are required, but this is no reason to reject ER. GR seems to solve gravity, but GR is incompatible with QM unless we add quantum gravity. Since ER solves mysteries of QM, quantum gravity is probably another obsolete concept. (2) In ES, there are no singularities and thus no black holes. Again, this fact is no reason to reject ER. Black holes can be supermassive objects without being singularities in spacetime. Singularities are a major point of conflict with QM. (3) Mysteries often disappear if the symmetry is matched. The symmetry group of natural spacetime is SO(4). (4) Absolute time puts an end to discussions about time travel. Does any other theory explain time’s arrow as beautifully as ER? (5) Physics does not ask: Why is my reality a projection or a wave function? Projections are far less speculative than curved spacetime plus cosmic inflation plus expanding space plus dark energy plus non-locality.

It seems as if Plato had anticipated ER in his *Allegory of the Cave* [48]: Mankind experiences projections and cannot observe any reality beyond. I laid the groundwork for ER and showed how powerful it is. Paradoxes are only virtual. The key question in science is this: How do we describe nature without adding highly speculative concepts? The answer leads to the truth. The true pillars of physics are ER and QM. Together they describe nature from the very distant down to the very small. SR/GR are good approximations as long as the 4D vector τ is not crucial. Introducing a holistic view to physics is what I consider my most valuable contribution. In SR/GR, there is no absolute time and thus no holistic view. Today's physics is stuck in its own concepts. It describes nature in a mixture of man-made concepts (x_1, x_2, x_3, t) and natural concepts (τ) . ER describes nature exclusively in natural concepts $(d_1, d_2, d_3, \tau, \theta)$. *Only in natural concepts does Mother Nature reveal her secrets.* Everyone is welcome to solve even more mysteries by describing her in natural concepts.

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Additional Comments: It takes open-minded reviewers to evaluate a theory that heralds a paradigm shift. Taking SR/GR for granted paralyzes progress. I apologize for numerous preprint versions, but I received little support only. The preprints document my path. The final version is all that is needed. I did not surrender when top journals rejected ER. Interestingly, I was never given any solid arguments that would disprove ER. Instead, I was advised to consult experts or to try a different journal. Were the editors afraid of publishing against the mainstream? Did they underestimate the benefits of ER? I was told that 15 solved mysteries are too much to be trustworthy. I disagree. Paradigm shifts often solve many mysteries at once. Even good friends refused to support me. Anyway, each setback motivated me to work out the benefits of ER even better. Finally, I succeeded in identifying an issue in SR/GR, which shows that Einstein's general relativity is not as general as it seems.

Some physicists are not ready to accept ER because the SO(4) symmetry of ES seems to exclude waves. ER does not exclude waves. SO(4) is compatible with waves that propagate as a function of the parameter θ . A well-known preprint archive suspended my submission privileges. I was penalized because I identified an issue in Einstein's SR and GR. The editor-in-chief of a top journal replied: "Publishing is for experts only." One editor rejected my paper because it would "demand too much" from the reviewers. A guest editor could not imagine that the Hubble tension is solved without GR. I do not blame anyone. Paradigm shifts are always hard to accept. In the long run, ER will prevail simply because it solves many fundamental mysteries of physics. These comments shall encourage young scientists to stand up for promising ideas even if it is hard work to oppose the mainstream. Peer reviewers told me that ER is "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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