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Posted Date: 4 March 2026

doi: 10.20944/preprints202207.0399.v103

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One Theory Fits All—from the Very Distant to the Very Small

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Special and general relativity (SR/GR) work for observers, but they do not provide diagrams of nature that work for all observers. This is because they do not describe nature as an absolute manifold, where all action is due to an absolute parameter. We show: Euclidean relativity (ER) achieves precisely that. It describes a mathematical Master Reality, which is *absolute* 4D Euclidean space (ES). All objects move through ES at the dimensionless speed C . There is no time coordinate in ES. All action in ES is due to an *absolute*, external evolution parameter θ . In addition, ER describes an observer's physical reality. He experiences two projections from ES as space and time: The axis of his current 4D motion is his proper time τ . Three orthogonal axes make up his 3D space x_1, x_2, x_3 . Without gravity, his reality is the Minkowskian reassembly of his axes x_1, x_2, x_3, τ . In this τ -based Minkowskian spacetime (τ -MS), τ is the time coordinate and θ converts to parameter time ϑ . Minkowski spacetime and τ -MS are mathematically identical. Thus, ER retains the SR formalism. ER also retains the GR formalism, but only locally (τ defines a specific physical reference frame). The Einstein field equations hold true in physical realities, but not in ES. ER reproduces both the Lorentz factor and gravitational time dilation. ER rejects cosmic inflation, expanding space, dark energy, and non-locality. Nevertheless, ER predicts time's arrow, galactic motion, the Hubble tension, and entanglement. Thus, ER significantly improves cosmology and quantum mechanics. We conclude: ER is indispensable for unifying physics.

Keywords: cosmology; spacetime; special relativity; general relativity; Hubble tension; dark energy

Clocks measure proper time τ . There are two ways to interpret proper time: In special and general relativity (SR/GR) [1, 2], τ can be used to parameterize an object's worldline in spacetime. In Euclidean relativity (ER), τ is the time coordinate of spacetime. ER provides observer-independent diagrams of nature. There are no such diagrams in SR/GR.

Why do we need ER? SR/GR work for observers, but physics is more than just observing. We need ER to describe (a) cosmic homogeneity, (b) very distant objects (high-redshift supernovae), and (c) entanglement. To understand these phenomena, a 4D Euclidean vector "flow of proper time" must be taken into account. For instance, entangled objects have never been separated spatially from their perspective, but their proper time flows in opposite 4D directions. *What is the key message of ER?* There is a mathematical reality beyond all physical realities. *Does ER make quantitative predictions?* Yes, ER predicts the ten percent discrepancy in the published values of the Hubble constant (see Sect. 5.10).

Request to all readers: Take these five pieces of advice to heart. Top journals ignored them. (1) *Do not apply the concepts of SR/GR to ER.* The only standards for a scientific theory are its own concepts and empirical facts. (2) *Do not play SR/GR off against ER.* ER provides relevant information that is not available in GR. (3) *Do not reject ER because it goes beyond an observer's reality.* ER is a physical theory because it predicts what we observe. (4) *Be curious.* New coordinates can unlock new insights. In SR/GR, coordinates are merely labels that can be adjusted to simplify computations. In ER, coordinates are inherent properties of objects. They cannot be adjusted because they refer to absolute 4D Euclidean space. (5) *Be fair.* One paper cannot cover all of physics. Future papers can build upon our work.

1. Introduction

The concepts of space and time in today’s physics were coined by Albert Einstein. In SR, a flat spacetime is described by the Minkowski metric. The geometric framework for SR is Minkowski spacetime [3]. The muon lifetime [4] is an example that supports SR. In GR, a curved spacetime is described by the Einstein tensor. The deflection of starlight [5] and the accuracy of GPS [6] are two examples that support GR. Quantum field theory [7] unifies classical field theory, SR, and quantum mechanics (QM), but not GR.

Newburgh and Phipps [8] pioneer ER. Montanus [9, 10] adds a restriction: He considers a preferred reference frame in which a pure time interval is a pure time interval for all observers (see page 351 of [9]). By doing so, he deprives ER of its key feature: *full symmetry in all four axes*. Montanus claims (see page 17 of [11]): The preferred frame avoids “distant collisions” (without physical contact) and a character paradox (confusion of photons, particles, antiparticles). Our formulation of ER does not prefer any frame. There are no distant collisions: Only three axes are experienced as spatial. There is no character paradox: Characters manifest themselves in physical realities only. Montanus [10] derives the deflection of starlight and the precession of Mercury’s perihelion. He even tries to derive Maxwell’s equations in 4D Euclidean space [11], but fails because of its SO(4) symmetry.

Almeida [12] analyses geodesics in 4D Euclidean space. Gersten [13] shows that the Lorentz transformation is an SO(4) rotation in a mixed space x_1, x_2, x_3, t' , where t' is the Lorentz transform of t . There is also a website about ER: <https://euclideanrelativity.com>. Previous formulations of ER [8–13] merely rearrange the Minkowski metric of SR to give it a Euclidean appearance. Here we propose three steps to make ER work: (1) There is a mathematical Master Reality beyond all physical realities. (2) An observer experiences two projections from the Master Reality as space and time. (3) Without gravity, an observer’s physical reality is the Minkowskian reassembly of his space and his time.

To date, ER has been rejected for various reasons: (a) GR has been confirmed over and over again. (b) There seem to be paradoxes in ER. (c) ER does not yet reproduce all of GR’s predictions. Physics is at a turning point: (a) No theory is set in stone. (b) Projections avoid paradoxes. (c) ER is a new, promising theory, while SR/GR have been tested for 100+ years. Thus, SR/GR naturally have a head start. If this were a fair argument for rejecting ER, then GR would also have to be rejected until GR-based cosmology reproduces all of ER’s predictions, such as the Hubble tension. The same standards apply to all theories.

It is instructive to compare three settings for describing motion. In *Newton’s physics*, all objects move through 3D Euclidean space as a function of time. There is no speed limit. In *Einstein’s physics*, all objects move through 4D non-Euclidean spacetime as a function of an internal parameter. The speed limit is c . In *Euclidean relativity*, all objects move through 4D Euclidean space as a function of an external parameter. The 4D speed of everything is dimensionless C . Einstein’s physics reduces to Newton’s physics when the speeds are very low and the gravitational fields are very weak. ER reduces to Einstein’s physics when we restrict our description of nature to the perspectives of observers.

2. Coordinate Time and Its Shortcomings

In § 1 of SR [1], Einstein considers a reference frame “in which the equations of Newton’s physics apply” (to a first approximation). If an object is at rest in this frame, its position in 3D space is determined using rigid rods and a 3D Euclidean geometry. If we also want to describe an object’s motion, we have to define time. Einstein gives an instruction on how to synchronize clocks at the points P and Q. At a coordinate time t_P , a light signal 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

$$x'_1 = \gamma (x_1 - v_1 t) , \quad x'_2 = x_2 , \quad x'_3 = x_3 , \tag{2a}$$

$$t' = \gamma (t - v_1 x_1/c^2) , \tag{2b}$$

where K' moves relative to K in x_1 at the constant speed v_1 and $\gamma = (1 - v_1^2/c^2)^{-0.5}$ is the Lorentz factor. Eqs. (2a–b) transform the coordinates from K to K'. Covariant equations transform the coordinates from K' to K. The metric of Minkowski spacetime is

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

where $d\tau$ is an infinitesimal change in the invariant τ , and all dx_i ($i = 1, 2, 3$) and dt are infinitesimal distances in coordinate space x_1, x_2, x_3 and coordinate time t . Minkowski spacetime x_1, x_2, x_3, t is a construct because t is a man-made concept: t is a label that is not inherent in clocks. In GR, t retains its function as a label. We identify four shortcomings of t : (1) SR/GR work for observers, but they do not provide diagrams of nature that work for all observers. (2) GR-based cosmology fails to predict time's arrow and the Hubble tension. Other empirical facts are predicted, but only by postulating highly speculative concepts (cosmic inflation, expanding space, dark energy). (3) t -based QM postulates another highly speculative concept (non-locality). (4) GR is incompatible with QM.

SR/GR provide a “multi-egocentric description” (definition: nature is described as a relative manifold). Coordinate-free formulations of SR/GR [14, 15] still lack absolute space and absolute time. ER provides a “universal description” (definition: nature is described as an absolute manifold). Physics has paid a very high price for sticking to coordinate time: ER predicts empirical facts (see Sect. 5) without postulating highly speculative concepts. On top, ER predicts time's arrow and the Hubble tension. Thus, the shortcomings are real. Michelson and Morley [16] refute the “aether” (absolute 3D space), but they do not refute absolute 4D space embedding countless 3D spaces with relative orientations.

SR/GR do not make false predictions. The shortcomings have much in common with the shortcomings of geocentrism: SR/GR require unnecessary concepts and cannot explain all observations. In the old days, it was believed that all celestial bodies orbited Earth. Only astronomers wondered about the retrograde loops of planets and claimed: Earth orbits the sun! Nowadays, it is believed that the universe is expanding. It is our turn to wonder: *What could the universe expand into?* The standard answer is: The universe is expanding by creating new space within itself. Since spacetime is a 4D entity, time would also have to expand, but the Friedmann–Lemaître–Robertson–Walker (FLRW) metric [17] scales only the space components. Physics is at an impasse and struggles to break new ground.

The analogy between geocentrism and multi-egocentrism in SR/GR is not perfect, but it fits well: (1) After taking another planet as the center or after a transformation in SR/GR, the description is still geocentric or else egocentric. (2) Retrograde loops make geocentrism work, but heliocentrism can do without them. Dark energy and non-locality make cosmology and QM work, but ER can do without them. (3) Heliocentrism is not centered in Earth. ER is not centered in observers. (4) Heliocentrism overcomes geocentrism. ER overcomes multi-egocentrism. (5) Geocentrism was a dogma in the old days. SR/GR are dogmata nowadays. One may ask: *Didn't physics learn from history? Does history repeat itself?*

3. The Physics of Euclidean Relativity

Einstein merges 3D Euclidean space and coordinate time into a non-Euclidean spacetime. This step has far-reaching consequences because it also affects GR. There is an alternative description of nature that omits coordinate time t . Here is how we proceed: To determine an object’s position in an observer’s 3D space, we use the same rigid rods and the same 3D geometry (Euclidean geometry) as in SR. Regarding the time coordinate, we do not use t , but the proper time τ measured by clocks. That is, we do not construct time.

The ER postulates: (1) *All objects move through 4D Euclidean space (ES) at the dimensionless speed C .* There is no time coordinate in ES. All action in ES is due to an absolute, external “evolution parameter” θ . An observer experiences two orthogonal projections [18, 19] from ES as space and time: The axis of his current 4D motion is his proper time τ . Three orthogonal axes make up his 3D space x_1, x_2, x_3 . (2) *The laws of physics have the same form in the physical realities of observers who move uniformly through ES.* Without gravity, an observer’s physical reality is the Minkowskian reassembly of his 3D space and his proper time (see below). Observing is synonymous with projecting ES onto his reality. His 3D space is the same in SR and ER (Euclidean 3D space). Our [first postulate](#) is stronger than the second SR postulate: C is absolute and universal. Our [second postulate](#) refers to physical realities. Variational principles [20] could be another way to derive ER. The metric of ES is

$$C^2 d\theta^2 = dX_1^2 + dX_2^2 + dX_3^2 + dX_4^2 , \tag{4}$$

where $d\theta$ is an infinitesimal change in the invariant θ , and all dX_μ ($\mu = 1, 2, 3, 4$) are infinitesimal distances in ES. We prefer the four indices 1–4 to 0–3 to emphasize the SO(4) symmetry of ES. We fit ER to experimental data by setting $C = 299\,792\,458$. We define an object’s 4D Euclidean vector “proper velocity” $\mathbf{U}$ in ES. Its four components $U_\mu = dX_\mu/d\theta$ are “proper speed”. Thus, Eq. (4) is equivalent to our [first postulate](#).

$$U_1^2 + U_2^2 + U_3^2 + U_4^2 = C^2 . \tag{5}$$

ES is a mathematical reality: C , θ , X_μ , and U_μ ($\mu = 1, 2, 3, 4$) are dimensionless. Every object is free to label the axes of its reference frame in ES. We consider two objects “r” (red) and “b” (blue). We may assume that “r” (or “b”) labels the axis of its *current* 4D motion as X_4 (or else X'_4) and three orthogonal axes as X_1, X_2, X_3 (or else X'_1, X'_2, X'_3). According to our [first postulate](#), “r” (or “b”) always moves in the X_4 (or else X'_4) axis at the speed C . Because of length contraction at the speed C (see [Sect. 4](#)), “r” does not experience X_4 as space, but as what we call “time”. “r” experiences X_1, X_2, X_3 as space. If an object’s world-line in ES is curved, all four axes continuously adapt to the current curvature.

To accomplish the transition from ES to an observer’s physical reality, we add SI units to X_1, X_2, X_3, X_4 , thus obtaining x_1, x_2, x_3, x_4 . Then, we *reassemble* the axes x_1, x_2, x_3, x_4 in a Minkowski way (we assign opposite signs to space and time in the metric) to form τ -based Minkowskian spacetime x_1, x_2, x_3, τ (τ -MS) with $\tau = x_4/c$. The adjective “Minkowskian” refers to the metric. In τ -MS, τ is the time coordinate and θ converts to “parameter time” ϑ . An observer does not experience ES, but τ -MS. The metric of τ -MS is

$$c^2 d\vartheta^2 = c^2 d\tau^2 - dx_1^2 - dx_2^2 - dx_3^2 , \tag{6}$$

which differs from Eq. (3) only in that τ is replaced by ϑ , and t is replaced by τ . In τ -MS, $c = 299\,792\,458$ m/s. The following conversions apply to the quantities in τ -MS.

$$\vartheta \; = \; \theta \text{ in seconds (s) ,}$$

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$$x_\mu \; = \; X_\mu \; (\mu = 1, 2, 3, 4) \text{ in light seconds (Ls) .}$$

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The metrics in Eqs. (3) and (6) have the same form. We conclude: *Minkowski spacetime and τ -MS are mathematically identical*. Thus, ER retains the SR formalism, but τ is the time coordinate and ϑ is the parameter. In particular, Maxwell’s equations retain their form in τ -MS. Eqs. (8a–d) show Maxwell’s equations in the new time coordinate τ .

$$\nabla \boldsymbol{E} \; = \; \rho / \varepsilon_0 \; ,$$

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196

$$\nabla \boldsymbol{B} \; = \; 0 \; ,$$

197

198

$$\nabla \times \boldsymbol{E} \; = \; - \partial \boldsymbol{B} / \partial \tau \; ,$$

199

200

$$\nabla \times \boldsymbol{B} \; = \; \mu_0 \; (\boldsymbol{J} + \varepsilon_0 \; \partial \boldsymbol{E} / \partial \tau) \; ,$$

201

202

where $\boldsymbol{E}$ is the electric field, $\boldsymbol{B}$ is the magnetic field, ρ is the electric charge density, ε_0 is the vacuum permittivity, μ_0 is the vacuum permeability, and $\boldsymbol{J}$ is the current density. The great advantage of mathematics is that derived equations also retain their form when a variable is replaced. Thus, the wave equation for the electric field in τ -MS is

$$\partial^2 \boldsymbol{E} / \partial \tau^2 \; - \; c^2 \; \Delta \boldsymbol{E} \; = \; 0 \; ,$$

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$$\Delta \; = \; \partial^2 / \partial x_1^2 + \partial^2 / \partial x_2^2 + \partial^2 / \partial x_3^2 \; .$$

210

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ER describes two realities: a mathematical reality and an observer’s physical reality. Without gravity, the latter is τ -MS. Note that the SO(4) symmetry of ES is not compatible with waves, while the SO(1,3) symmetry of τ -MS is. Thus, waves exist in physical realities only. *How do we synchronize clocks in ER?* We do not synchronize clocks in ER. They measure proper time by themselves! An object’s τ flows in the direction of its 4D motion. Thus, it makes sense to define a 4D Euclidean vector “flow of proper time” $\boldsymbol{T}$.

$$\boldsymbol{T} \; = \; \boldsymbol{U} / c \; .$$

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τ -MS is not a construct because proper time τ is a natural concept: τ is inherent in clocks. The internal clocks of all objects, such as biological clocks, measure proper time τ . In SR, the coordinates are $x_1(\tau), x_2(\tau), x_3(\tau), t(\tau)$, where t is a man-made concept of time and τ serves as an internal parameter. In ER, the coordinates are $x_1(\vartheta), x_2(\vartheta), x_3(\vartheta), \tau(\vartheta)$, where τ is a natural concept of time and ϑ serves as an external parameter.

It is instructive to compare θ , ϑ , and τ . The *evolution parameter* θ is the invariant in ES and thus absolute. In ES, clocks are odometers that display θ . *Parameter time* ϑ is the invariant in τ -MS and thus absolute. *Proper time* τ is the time axis in τ -MS. An observer experiences projections only: Every clock measures its proper time τ' , but this τ' is projected onto his time axis τ . Thus, every clock displays τ (not τ') in his τ -MS. *A clock can display different values in ES and τ -MS because the projections contract all traveled distances*. An observer does not move in his axes x_1, x_2, x_3 . Thus, his clock displays τ and ϑ . Since Minkowski spacetime and τ -MS are mathematically identical, Eqs. (3) and (6) give us

$$d\vartheta = dt \quad (\text{if spacetime is Minkowskian}). \tag{11}$$

Remarks: (1) Mathematically, ES is a 4D Euclidean manifold. Physically, three axes of ES are experienced as spatial and one as temporal. (2) ES is not observable. However, ES diagrams give us an idea of how objects (clocks, rockets) move through ES. (3) Parameter time ϑ is not a fifth dimension. In SR/GR, the parameter τ is not a fifth dimension either. (4) In the standard notation of SR/GR, time is *always* the first (or fourth) coordinate. The same applies to τ -MS, but *any one* axis of ES can be the preimage of the time axis in τ -MS. The variable preimage of the time axis justifies the 4D vector T , which is missing in SR/GR. (5) Do not confuse ER with a Wick rotation [21], where τ is the parameter.

We consider two clocks “r” and “b” that move uniformly through 3D space. In SR, “r” moves in the ct axis. “b” moves at the speed $v_1 = 0.6\,c$. Fig. 1 left shows that instant when both clocks moved 1.0 Ls in ct . “b” moved 0.8 Ls in ct' . Thus, “b” displays “0.8”. In ER, “r” moves in the X_4 axis. “b” moves at the speed $U_1 = 0.6\,C$. Fig. 1 right shows that instant when 1.0 has elapsed in the parameter θ since both clocks left the origin of the diagram. “r” moved 1.0 Ls in $c\tau$. Thus, “r” displays “1.0” in the reality of “r”. “b” moved 0.8 Ls in $c\tau$ and 1.0 Ls in $c\tau'$. Thus, “b” displays “0.8” in the reality of “r” and “1.0” in the reality of “b” (not shown). Red digits on “b” indicate that “b” is read in the reality of “r”.

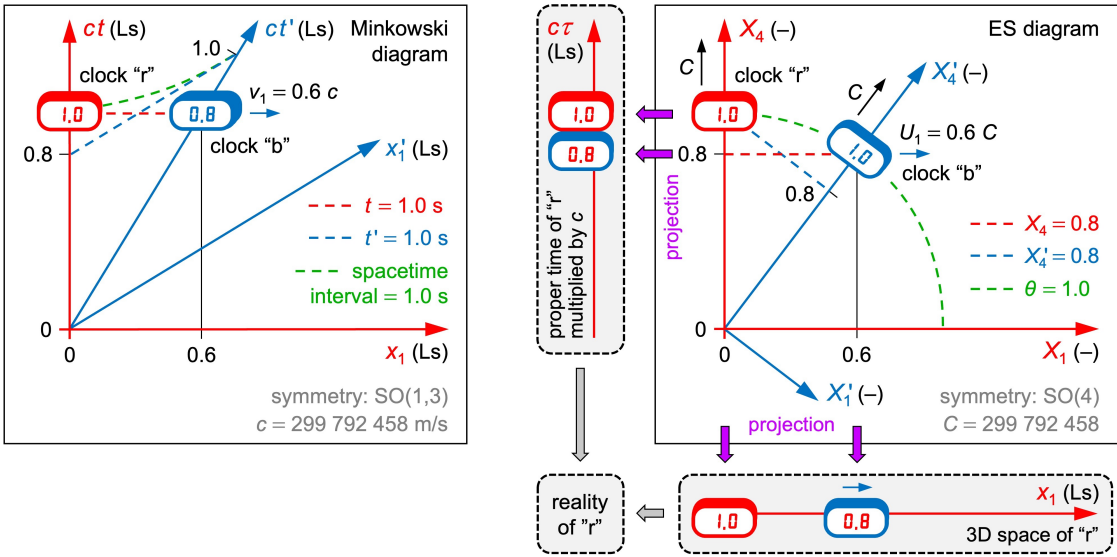


Fig. 1 Minkowski diagram and ES diagram of two uniformly moving clocks. **Left:** “b” is slow with respect to “r” in t' . Coordinate time is relative (“b” is at different positions in t and t'). **Right:** “b” is slow with respect to “r” in X_4 . The evolution parameter is absolute (both clocks are at $\theta = 1.0$)

We assume that observer R (or B) moves with clock “r” (or else “b”). In SR and only for R (“b” measures τ' and not t'), B is at $ct' = 0.8$ Ls when R is at $ct = 1.0$ Ls (see Fig. 1 left). Thus, “b” is slow with respect to “r” in t' . In ER and independently of observers, B is at $X_4 = 0.8$ when R is at $X_4 = 1.0$ (see Fig. 1 right). Thus, “b” is slow with respect to “r” in X_4 . In SR and ER, “b” is slow with respect to “r”, but time dilates in different axes. Experiments do not reveal in which axis a clock is slow. If “b” reverses its x_1 motion at $x_1 = 0.6$ Ls, it hits “r” at $x_1 = 0$. In this instant (not shown), “r” and “b” display “2.0” in ES. However, “r” displays “2.0” and “b” displays “1.6” in the reality of “r”. This twin paradox is resolved in the same way as in SR: “b” experienced a deceleration and an acceleration.

ES is absolute. According to our definition in Sect. 2, the description in ER is universal. Why is it beneficial? R and B experience different axes as temporal. This is why Fig. 1 left

works for R only. In SR, a second Minkowski diagram is required for B, in which the axes x'_1 and ct' are orthogonal. Here the description is multi-egocentric. Physicists do not care that two diagrams are required because there is no simultaneity (no “at once”) for these two observers in SR. In ER, Fig. 1 right works for R and for B “at once” (at the same $\theta = 1.0$). Not only are the axes X_1 and X_4 orthogonal, but also the axes X'_1 and X'_4 . ES diagrams are observer-independent Master Diagrams of nature. They show a mathematical Master Reality beyond all physical realities. Here the description is universal. Master Diagrams can be projected onto any observer’s reality. This is a huge benefit (see Sect. 5).

4. Relativistic Effects and Field Equations

We consider two rockets “r” and “b” that move uniformly through ES. Observer R (or B) is in the rear end of “r” (or else “b”). R (or B) experiences X_1, X_2, X_3 (or else X'_1, X'_2, X'_3) as his 3D space. R (or B) experiences X_4 (or else X'_4) as his proper time. Both rockets start at the same point P and at the same θ . They move relative to each other at the constant speed U_1 . The ES diagrams in Fig. 2 must satisfy our two postulates and the two initial conditions (same P, same θ). This is achieved by rotating the red and blue frames against each other. In ES diagrams, objects retain proper length. For better readability, a rocket’s width is drawn in X_4 (or X'_4) although it should be drawn in X_2 and X_3 (or else X'_2 and X'_3).

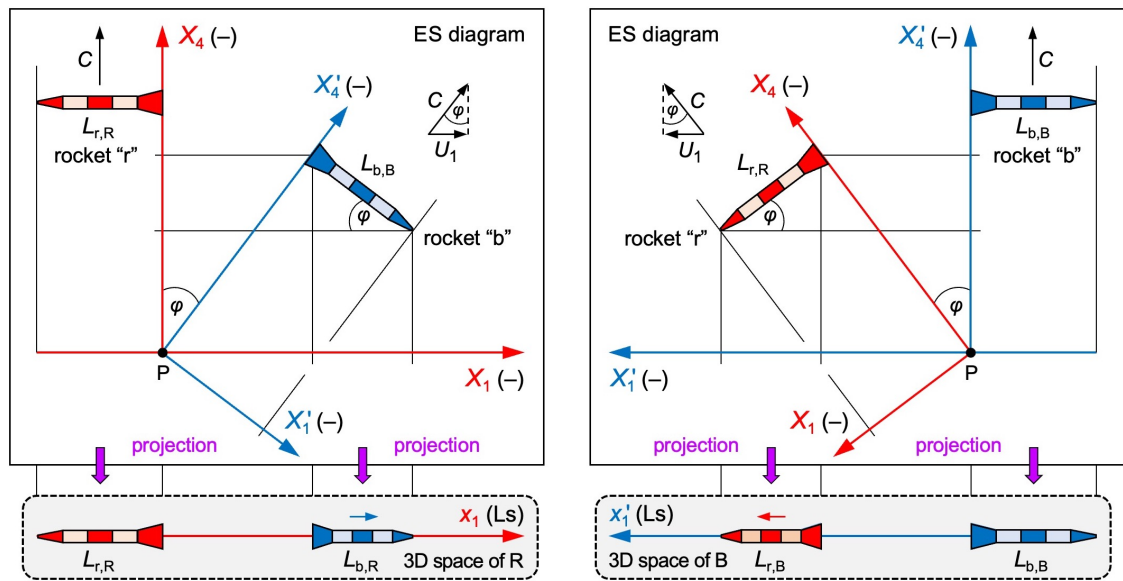


Fig. 2 ES diagrams of two uniformly moving rockets. Observer R (or B) is in the rear end of “r” (or else “b”). **Top left and right:** “r” and “b” move at the speed C , but in different 4D directions. The ES diagrams are identical. **Bottom left:** In the projection onto the 3D space of R, “b” contracts to $L_{b,R}$. **Bottom right:** In the projection onto the 3D space of B, “r” contracts to $L_{r,B}$.

Up next, we show: Projecting distances in ES onto the axes X_1 and X_4 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 $L_{b,B}$ onto the X_1 axis (see Fig. 2 left).

$$\sin^2 \varphi + \cos^2 \varphi = (U_1/C)^2 + (L_{b,R}/L_{b,B})^2 = 1, \quad (12)$$

$$L_{b,R} = \gamma_{ER}^{-1} L_{b,B} \quad (\text{length contraction}), \quad (13)$$

where $\gamma_{ER} = (1 - U_1^2/C^2)^{-0.5}$ has the same form as γ in SR. $\gamma_{ER} = \gamma$ if $U_1/C = v_1/c$. The numerical values of C and c are equal. From $U_1 = dX_1/d\theta$, $v_1 = dx_1/dt$, and Eqs. (7a–b),

we derive: $U_1/C = v_1/c$ if $d\vartheta = dt$. According to Eq. (11), $d\vartheta = dt$ if spacetime is Minkowskian. Since “r” and “b” move uniformly, they experience a Minkowskian spacetime. We conclude: *ER reproduces the Lorentz factor*. Orthogonal projections are not injective. Thus, ES is the Master Reality. In a second step, we project B’s motion onto the X_4 axis.

$$\sin^2 \varphi + \cos^2 \varphi = (U_1/C)^2 + (X_{4,B}/X'_{4,B})^2 = 1 \quad (14)$$

$$X_{4,B} = \gamma_{ER}^{-1} X'_{4,B} \quad (15)$$

where $X_{4,B}$ (or $X'_{4,B}$) is the distance that B traveled in X_4 (or else X'_4). With $X'_{4,B} = X_{4,R}$ (R and B travel the same distance in ES, but in different 4D directions), we calculate

$$X_{4,R} = \gamma_{ER} X_{4,B} \quad (\text{time dilation}), \quad (16)$$

where $X_{4,R}$ is the distance that R traveled in X_4 . Eqs. (13) and (16) tell us: ER reproduces length contraction and time dilation. *Can R observe distances in X_4 ?* We rotate “b” until it serves as a ruler in X_4 . In the 3D space of R, this ruler contracts to zero length: The X_4 axis disappears because of length contraction at the speed C . Our rockets serve as an example. To calculate the lifetime of a muon, we replace “b” with a muon and apply Eq. (16).

We now transform the coordinates of R (unprimed) to the ones of B (primed). R cannot measure the proper time τ' ticking for B, and vice versa, but we can calculate τ' from ES diagrams. Fig. 2 right tells us how to calculate the 4D motion of R in the coordinates of B. The transformation is shown in Eqs. (17a–b). It is a Euclidean 4D rotation by the angle φ . Adding multiple rotations does not violate Einstein’s relativistic addition of velocities. In $SO(4)$, 4D rotations are additive. In $SO(1,3)$, velocities are not additive.

$$X'_{1,R}(\theta) = X_{4,R}(\theta) \sin \varphi = X_{4,R}(\theta) U_1/C \quad (17a)$$

$$X'_{4,R}(\theta) = X_{4,R}(\theta) \cos \varphi = X_{4,R}(\theta) \gamma_{ER}^{-1} \quad (17b)$$

Up next, we show: ER predicts the same gravitational time dilation as GR. We assume that initially our clocks “r” and “b” are very far away from Earth (see Fig. 3). Eventually, “b” falls freely toward Earth. “r” and Earth keep on moving in the X_4 axis.

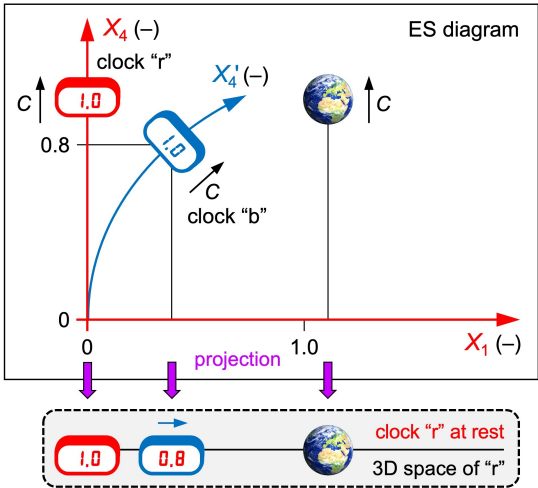


Fig. 3 ES diagram of two clocks and Earth. “b” falls freely toward Earth. It experiences gravity as an acceleration of everything else. Its X'_4 axis is curved because X'_4 indicates its current 4D motion

Because of Eq. (5), all accelerations in ES are transversal: The speed $U_{1,b}$ of clock “b” in X_1 increases at the expense of its speed $U_{4,b}$ in X_4 . We make two reasonable assumptions: (1) *The field equation in ES is Poisson’s equation.* (2) *Energy is conserved in ES.* The first assumption is reasonable because there is no time coordinate in ES. In particular, “action at a distance” is not a problem: Information is instantaneous in ES. Only in an observer’s spacetime does the time coordinate τ cause a delay. The second assumption is reasonable because no energy is gained or lost when projecting ES. The field equation in ES is

$$\Delta\Phi = 4\pi G\rho \quad (\text{Poisson’s equation}), \quad (18)$$

where Φ is the gravitational potential, G is the gravitational constant, and ρ is the mass density in a considered volume. Note that Φ , G , and ρ are dimensionless quantities. We now interpret Earth as a dimensionless point mass M_{Earth} . In this case, Poisson’s equation is solved by Newton’s gravitational potential, as in classical mechanics.

$$\Phi = -GM_{\text{Earth}}/R, \quad (19)$$

where R is the distance of “b” to Earth in the X_1 axis. Φ follows a $1/R$ law because ES is projected onto an observer’s 3D space. Relativistic effects are caused by projecting ES. There are no relativistic effects in ES. Thus, the kinetic energy of “b” in the X_1 axis is the same as in classical mechanics. Our second assumption and Eq. (5) give us

$$\frac{1}{2}M_b U_{1,b}^2 = GM_b M_{\text{Earth}}/R \quad (\text{conservation of energy}), \quad (20)$$

$$U_{4,b}^2 = C^2 - U_{1,b}^2 = C^2 - 2GM_{\text{Earth}}/R, \quad (21)$$

where M_b is the mass of “b”. Adding a third assumption ($U_{4,b}/C = v_{4,b}/c$) gives us

$$v_{4,b}^2 = c^2 - 2c^2 GM_{\text{Earth}}/RC^2. \quad (22)$$

where $v_{4,b}$ is the speed of “b” in the time axis of “r”. With the two speeds $v_{4,b} = dx_{4,b}/d\vartheta$ and $c = dx_{4,r}/d\vartheta$, we calculate from Eq. (22)

$$dx_{4,b}^2 = (c^2 - 2c^2 GM_{\text{Earth}}/RC^2) (dx_{4,r}/c)^2, \quad (23)$$

$$dx_{4,r} = \gamma_{\text{grav}} dx_{4,b} \quad (\text{gravitational time dilation}), \quad (24)$$

where $\gamma_{\text{grav}} = (1 - 2GM_{\text{Earth}}/(RC^2))^{-0.5}$ has the same form as in GR. Since we assumed $U_{4,b}/C = v_{4,b}/c$ in Eq. (22), the same reasoning applies as in our calculation of the Lorentz factor: $U_{4,b}/C = v_{4,b}/c$ if $d\vartheta = dt$. According to Eq. (11), $d\vartheta = dt$ if spacetime is Minkowskian. Spacetime in GR is locally Minkowskian. We conclude: *ER reproduces gravitational time dilation, but only locally.* We showed that ER reproduces both factors γ and γ_{grav} . Thus, the Hafele–Keating experiment [22] does not only support SR/GR, but also ER.

What do the Einstein field equations (EFE) look like in ER? The EFE are tensor equations [23]. They are coordinate-invariant. In particular, they hold true in any valid, smooth, and invertible coordinate system, including those systems that use an observer’s proper time τ as the time coordinate. Thus, the EFE hold true in his physical reality, but not in ES. Even in GR, τ is sometimes used as the time coordinate. Comoving observers [24] or collapsing

stars [25] are two examples. Clocks measure proper time τ . Using τ as the time coordinate of spacetime makes the metric locally Minkowskian. In GR, the EFE are

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu}/c^4 \ ,$$

(25)

where $G_{\mu\nu}$ is the Einstein tensor, Λ is the cosmological constant, $g_{\mu\nu}$ is the metric tensor, and $T_{\mu\nu}$ is the stress–energy tensor. If we use an observer’s τ as the time coordinate, the EFE hold true, but only locally (τ defines a specific physical reference frame). In this case, the time component of the metric tensor is $g_{00} = +1$ or else -1 , depending on the signature. Thus, gravity curves an observer’s spacetime in GR and ER. However, there is a catch: τ is a local quantity. In a gravitational field, clocks cannot be synchronized in τ . Since we do not synchronize clocks in ER (see Sect. 3), the catch becomes irrelevant. We may trust that clocks measure proper time. We conclude: *ER retains the GR formalism, but only locally.* Both GR and ER have advantages and disadvantages: In GR, the EFE are universal, but the diagrams are observer-specific. In ER, the diagrams are universal, but the EFE are observer-specific. *Which disadvantage is worse?* Sect. 5 tells us: Universal diagrams are indispensable. We will not discuss the EFE in more detail, as they are not required in Sect. 5.

ER also predicts gravitational waves [26]. In GR, a weak field allows us to decompose the metric into a flat Minkowski metric $\eta_{\mu\nu}$ plus a small perturbation $h_{\mu\nu}$ [15, 27].

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu} \quad (\text{with } |h_{\mu\nu}| \ll 1).$$

(26)

Since $\eta_{\mu\nu}$ is Minkowskian and coordinate time t is only a label, we can again use an observer’s τ as the time coordinate. In fact, it has been shown that τ relates the mathematical perturbation of spacetime to observable quantities, such as the strain in an interferometer [28]. ER supports the idea that gravity is carried by gravitons [29] and manifests itself as waves in spacetime, but further studies on this topic are required.

Fig. 4 teaches us how to read ES diagrams. Problem 1: A rocket moves along a guide wire. We assume that the wire moves in X_4 at the speed C . Since the rocket moves in X_1 and X_4 , its speed U_4 is less than C . *Doesn’t the wire escape from the rocket?* Problem 2: Earth orbits the sun. We assume that the sun moves in X_4 at the speed C . Since Earth moves in X_1 , X_2 , and X_4 , its speed U_4 is less than C . *Doesn’t the sun escape from Earth?*

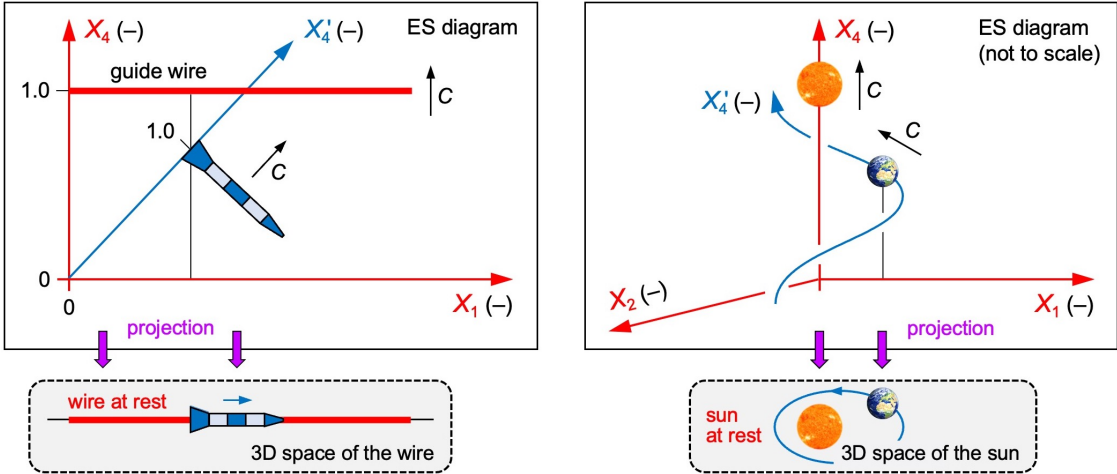


Fig. 4 Two problems. **Left:** In the 3D space of the wire, the rocket moves along the wire. In ES, the wire escapes from the rocket. **Right:** In the 3D space of the sun, Earth orbits the sun. In ES, the sun escapes from Earth. This drawing ignores the fact that the sun orbits the center of the Milky Way

The last paragraph seems to reveal paradoxes. The fallacy lies in assuming that all four axes of ES are experienced as spatial at once. We solve the two problems by projecting ES onto the 3D space of that object which moves in X_4 at the speed C . In Fig. 4 left, the guide wire does not escape from the rocket spatially. They age in different directions! The only relevant quantities for guiding the rocket are X_1, X_2, X_3, θ . In the projection onto 3D space, X_4 is projected away. Collisions in 3D space do not show up as collisions in ES because θ is a parameter. In τ -MS, two objects collide when their positions in 3D space and ϑ coincide. As in SR/GR, τ can be different. In Fig. 4 right, the sun does not escape from Earth spatially. They age in different and changing directions! The same applies to Earth and “b” in Fig. 3. *ES diagrams do not show events, but an object’s position and its 4D vector T .*

5. Empirical Evidence for Euclidean Relativity

Here we show that ER predicts 12 empirical facts. In particular, ER passes those three tests that Albert Einstein himself proposes to validate GR (see § 22 of [2]): gravitational redshift, the deflection of starlight, and the precession of Mercury’s perihelion.

5.1. Time’s Arrow

“Time’s arrow” stands for time that flows only forward. *Why can’t time flow backward?* Experienced time is the distance traveled in absolute ES divided by C . A distance traveled in absolute ES cannot be “untraveled” because θ is a monotonically increasing, absolute parameter. There is no such absolute parameter in SR/GR.

5.2. Gravitational Redshift

Gravitational redshift is the decrease in frequency of radiation emerging from a gravitational well. Frequency is related to time. Since ER locally reproduces the gravitational time dilation of GR (see Sect. 4), ER locally predicts gravitational redshift.

5.3. Deflection of Starlight

Montanus [10] uses a Euclidean metric to derive the deflection of starlight by a spherical mass. On page 1387 of [10], he calculates the deflection angle ψ .

$$\psi = 4\mu/R \text{ ,} \tag{27}$$

where μ is half the Schwarzschild radius and R is the closest approach. Since [10] is published, we do not repeat the calculation. Montanus uses the parameter t (see page 1368 of [10]). For starlight deflected by the sun and observed on Earth, t is as good a parameter as ϑ : *Because of their high speed C , the sun and Earth move almost uniformly through ES.* Thus, $d\vartheta \cong dt$ according to Eq. (11). We conclude: ER and GR predict the same ψ .

5.4. Precession of Mercury’s Perihelion

Montanus [10] uses a Euclidean metric to derive the precession of orbits. On page 1389 of [10], he calculates the additional orbital angle φ covered per revolution.

$$\varphi = 6\pi\mu/(L(1 - e^2)) \text{ ,} \tag{28}$$

where L is the semimajor axis and e is the eccentricity. For Mercury, Montanus estimates $\varphi \cong 42.9''$ per century (see page 72 of [11]). Since [11] is not peer reviewed, further studies are required. Again, t is as good a parameter as ϑ : *Because of its high speed C , Mercury also moves almost uniformly through ES.* We conclude: ER and GR predict the same φ .

5.5. Cosmic Microwave Background (CMB)

Today’s standard model of cosmology, the Lambda-CDM model [30, 31], is based on GR. In this model, the universe inflated from a singularity. The Big Bang occurred “everywhere”. In Sects. 5.5 to 5.11, we outline an ER-based model of cosmology, in which the Big Bang can be localized: It injected a huge amount of energy into ES at an origin O. Parameter time has been ticking uniformly since the Big Bang. The Big Bang was a singularity in providing energy and radial momentum. Ever since the Big Bang ($\theta = 0$), energy has been moving through ES at the speed C . Shortly after $\theta = 0$, all energy was highly concentrated. While it receded from the origin O, it became less concentrated and reduced to plasma particles. Recombination radiation was emitted that we observe as CMB today [32].

The ER-based model must be able to answer several questions: (1) Why is the CMB so isotropic? (2) Why is the CMB temperature so low? (3) Why do we still observe the CMB today? Some possible answers: (1) The CMB is scattered equally in the 3D space of Earth. (2) The plasma particles receded from O in ES at very high speeds (Doppler redshift, see Sect. 5.11). (3) Some of the recombination radiation reaches Earth after traveling the same distance in X_1, X_2, X_3 (multiple scattering) as the Milky Way in X_4 (for the axes, see Fig. 5).

5.6. Hubble–Lemaître Law

The Milky Way and a galaxy G recede from O at the speed C (see Fig. 5 left). G recedes from the X_4 axis of the Milky Way at the speed U_1 . D (or D_0) is the distance of G to the Milky Way in the 3D space of the Milky Way at a specific value θ (or else θ_0). U_1 is to D as C is to the radius $C\theta$ of a 3D hypersurface. All energy is within the 4D hypersphere. Its radius is parameterized by θ . Because of various effects (gravitation, scattering, photon emission, pair production), some energy does not recede radially anymore.

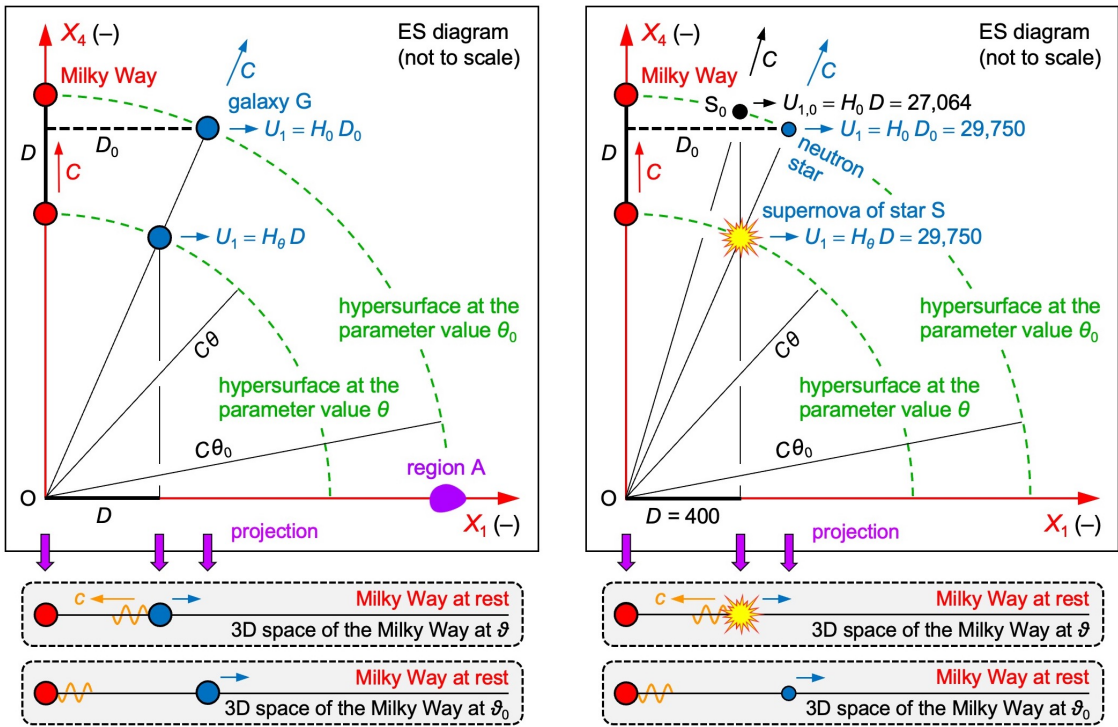


Fig. 5 ER-based model of cosmology. The green arcs show a 3D hypersurface that is expanding from the origin O of ES (location of the Big Bang) at the speed C . **Left:** A galaxy G recedes from O at the speed C and from the X_4 axis at the speed U_1 . **Right:** If a star S_0 happens to be at the same distance D today at which the supernova of S occurred, S_0 recedes more slowly from X_4 than S

$$U_1 = CD/C\theta = D/\theta = H_\theta D , \tag{29}$$

where $H_\theta = 1/\theta$ is the ER-equivalent to the Hubble parameter. If we observe the galaxy G today (we denote “today” by the value θ_0 and thus by the parameter time ϑ_0), the two speeds U_1 and C remain unchanged. Thus, Eq. (29) turns into

$$U_1 = CD_0/C\theta_0 = D_0/\theta_0 = H_0 D_0 , \tag{30}$$

where $H_0 = 1/\theta_0$ is the ER-equivalent to the Hubble constant, $D_0 = D \theta_0/\theta$, and $C\theta_0$ is today’s radius of the hypersurface. Eq. (30) is an improved Hubble–Lemaître law [33, 34]. Cosmologists are already aware of the Hubble parameter. They are not yet aware that (a) the 4D geometry is Euclidean, (b) θ and ϑ are absolute, and (c) Eq. (30) relates U_1 to D_0 (not D). Of two galaxies, the more distant one recedes faster, but each galaxy maintains its recession speed. G moves in X_4 at the speed $(C^2 - U_1^2)^{0.5}$. Thus, a clock in G is slow with respect to a clock in the Milky Way in X_4 by the factor $C/(C^2 - U_1^2)^{0.5} = \gamma_{\text{ER}}$. In the 3D space of the Milky Way, any light emitted by G at the parameter time ϑ (orange wave in Fig. 5 left) moves at the speed c and arrives at the Milky Way at the parameter time ϑ_0 .

5.7. Flat Universe

An observer experiences neither ES nor the curved 3D hypersurface. His physical reality is a flat universe: his 3D space and his proper time. This statement holds true even if his worldline is curved in ES, as for the accelerating clock “b” in Fig. 3.

5.8. Large-Scale Structures

Most cosmologists [35, 36] believe that an inflation of space shortly after the Big Bang is responsible for the isotropic CMB, the flat universe, and large-scale structures. The latter are said to have inflated from quantum fluctuations. We showed that ER predicts the isotropic CMB and the flat universe. ER also predicts large-scale structures if the fluctuations have been expanding with the hypersphere. **ER rejects cosmic inflation.**

5.9. Cosmic Homogeneity (Horizon Problem)

How can the universe be so homogeneous on large scales? In the Lambda-CDM model, two regions A and B at “opposite sides” of the universe are causally disconnected unless we postulate a cosmic inflation. Otherwise, information could not have been transferred. In the ER-based model, A is at $X_1 = +C\theta_0$ (see Fig. 5 left) and B is at $X_1 = -C\theta_0$ (not shown). A and B experience X_1 (equal to their X'_4) as their time axis. For A and for B, the X'_4 axis disappears because of length contraction at the speed C . From their perspective, A and B have never been separated spatially, but their proper time flows in opposite 4D directions. This is how the two regions A and B are causally connected. Their opposite 4D vectors $\boldsymbol{T}$ do not affect causal connectivity as long as A and B stay together spatially.

5.10. Hubble Tension

Up next, we show: ER predicts the ten percent discrepancy in the published values of the Hubble constant (Hubble tension, H_0 tension). We consider CMB measurements and distance ladder measurements. The values do not match: 67.66 ± 0.42 km/s/Mpc according to team A [37]. 73.04 ± 1.04 km/s/Mpc according to team B [38]. Team B made efforts to minimize the error margins in the distance measurements, but there is a systematic error in its calculation: Team B assumes an incorrect cause of the redshifts.

We assume that team A's value is correct. We now simulate the supernova of a star S, which occurred at a distance of $D = 400$ (corresponding to 400 Mpc in the 3D space of the Milky Way) from the Milky Way (see Fig. 5 right). The recession speed of S is calculated from the measured redshift. The redshift parameter $z = \Delta\lambda/\lambda$ tells us how a wavelength of the supernova's light is either stretched by an expanding space (team B) or else Doppler-redshifted by receding objects (ER-based model). We assume that the supernova occurred at a specific value θ , but we observe it today at θ_0 . While the supernova's light traveled the distance D in $-X_1$, the Milky Way traveled the same distance D in $+X_4$.

According to Eq. (29), we now plot U_1 versus D for distances from 0 to 500 in steps of 25 (red points in Fig. 6). The slope of a straight-line fit through the origin is roughly ten percent higher than 67.66. This is because H_θ is not a constant. If we compare the supernovae of two stars S and S', the more distant one recedes faster, but each star maintains its recession speed U_1 . We ignore the fact that stars orbit the center of their galaxy. To a first approximation, S and S' thus experience a Minkowskian spacetime. According to Eq. (11), $d\theta = dt$. Thus, as shown in Sect. 4, U_1/c in our plot is equal to v_1/c , which is calculated from the redshift. According to Eq. (30), we must plot U_1 versus D_0 to get a straight line (blue points). Since team B does not take Eq. (30) into account, its value of H_0 is roughly ten percent too high. Ignoring the 4D Euclidean geometry in the distance ladder measurements overestimates the value of H_0 . This line of reasoning explains the Hubble tension.

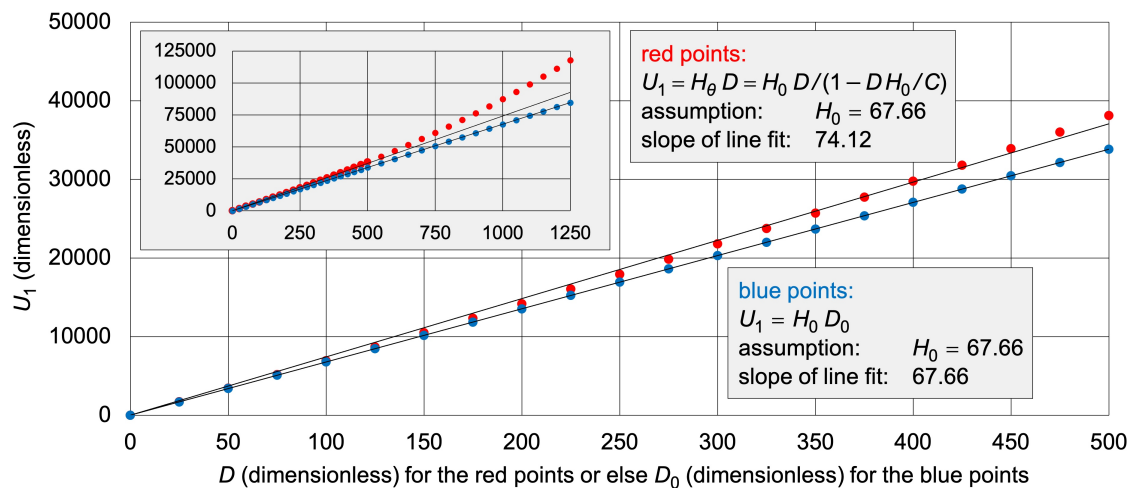


Fig. 6 Hubble diagram of simulated supernovae. The red points, as calculated according to Eq. (29), do not form a straight line. Because of Eqs. (29) and (32), U_1 is not proportional to D . The blue points, as calculated according to Eq. (30), do form a straight line because U_1 is proportional to D_0 .

Eq. (30) requires the knowledge of D_0 , but measurable magnitudes of supernovae are related to D . We solve this technical difficulty by rewriting Eq. (30) as

$$U_{1,0} = H_0 D , \quad (31)$$

where $U_{1,0}$ is the recession speed in X_1 of a star S_0 that happens to be at the same distance D today at which the supernova of S occurred (see Fig. 5 right). We calculate

$$H_\theta = C/C\theta = C/(C\theta_0 - D) = H_0/(1 - DH_0/C) . \quad (32)$$

Inserting H_θ from Eq. (29), H_0 from Eq. (31), and $U_1/c = v_1/c$ into Eq. (32) gives us

$$U_{1,0} = U_1/(1 + U_1/C) ,$$

(33)

$$U_{1,0} = v_1 C/(c(1 + v_1/c)) .$$

(34)

We kindly ask team B to convert v_1 to $U_{1,0}$ according to Eq. (34). Because of Eq. (31), plotting $U_{1,0}$ versus D yields the correct value of H_0 . Fig. 6 also tells us: The more high-redshift data are taken into account, the more the Hubble tension increases.

5.11. Cosmological Redshift

Up next, we identify a second systematic error. This error is even more serious than team B’s error in the value of H_0 . It concerns the supposed accelerating expansion of space and cannot be resolved within the Lambda-CDM model unless we postulate a dark energy. Most cosmologists [39, 40] believe in an accelerating expansion of space because the recession speeds increasingly deviate from a straight line when plotted versus the distance D . Indeed, an accelerating expansion of space would stretch each wavelength even further, thus causing these deviations. In the Lambda-CDM model, the moment of the supernova is irrelevant. All that matters is the duration of the light’s journey to Earth.

In the ER-based model, all that matters is the moment of the supernova. Its light is redshifted by the Doppler effect. The longer ago a supernova occurred, the more H_θ deviates from H_0 , and thus the more U_1 deviates from $U_{1,0}$. If a star S_0 happens to be at the same distance of $D = 400$ today at which the supernova of S occurred, Eq. (33) tells us: S_0 recedes more slowly ($U_{1,0} = 27,064$, the shortest arrow in Fig. 5 right) from X_4 than S ($U_1 = 29,750$). It does so because of the 4D Euclidean geometry. The 4D vector T' of S_0 differs less from T of the Milky Way than T'' of S differs from T . Physicists “invented” a dark energy [41] to explain an accelerating expansion of space. Dark energy is a stopgap solution for an effect that the Lambda-CDM model cannot explain. Earlier supernovae recede faster because of a greater value of H_θ and not because of a dark energy.

Cosmological redshift and the Hubble tension have the same physical background: In Eq. (30), we must not confuse D_0 with D . Because of Eqs. (29) and (32), U_1 is not proportional to the distance D , but to $D/(1 - DH_0/C)$. Any expansion of space—uniform or else accelerating—is only virtual even if the Nobel Prize in Physics 2011 was awarded “for the discovery of the accelerating expansion of the Universe through observations of distant supernovae”. This particular prize was awarded for an illusion. Most galaxies recede from the Milky Way, but they do so uniformly in non-expanding ES. ER clearly identifies dark energy, the driving force behind the supposed accelerating expansion, as an illusion. Most energy recedes radially from the origin O of ES because of the radial momentum provided by the Big Bang. **ER rejects expanding space and dark energy.**

Cosmological redshift and the Hubble tension are very strong empirical evidence that challenges the Lambda-CDM model. They force us to take the 4D Euclidean geometry into account, and T in particular. GR works well if T is irrelevant, but T'' of a high-redshift supernova differs greatly from T of the Milky Way. Space is not driven by dark energy. Each galaxy is driven by its momentum and maintains its recession speed. Because of various effects (gravitation, scattering, photon emission, pair production), some energy does not recede radially anymore. Gravitational attraction enables nearby galaxies to move toward our galaxy. Table 1 compares two models of cosmology. The ER-based model rejects cosmic inflation, expanding space, and dark energy. Thus, ER significantly improves cosmology. In Sect. 5.12, we show that ER also improves QM.

Inflationary Lambda-CDM model based on GR	ER-based model of cosmology
There is no absolute space.	4D Euclidean space is absolute.
There is no absolute time.	Parameter time is absolute.
The Big Bang was the beginning of everything.	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).
Shortly after the Big Bang, space was inflating.	There is no cosmic inflation.
Today, there is an accelerating expansion of space.	There is no expanding space.
Dark energy causes the accelerating expansion.	There is no dark energy.
Distant galaxies accelerate with respect to Earth.	Distant galaxies maintain their recession speed.
This model does not predict the Hubble tension.	This model predicts the Hubble tension.

Table 1 Comparing two models of cosmology

5.12. Quantum Entanglement

Erwin Schrödinger coins the word “entanglement” in a comment [42] on the Einstein–Podolsky–Rosen paradox [43]. These three authors argue that QM does not provide a complete description of reality. Schrödinger’s neologism does not resolve the paradox, but it highlights our enormous difficulties in comprehending QM. John Bell [44] shows that QM is incompatible with local hidden-variable theories. Meanwhile, several experiments [45–47] have confirmed that entanglement violates locality in an observer’s 3D space. Quantum entanglement has been interpreted as a “non-local effect” ever since.

Up next, we show: ER “untangles” entanglement without the concept of non-locality. There is no violation of locality in 4D (!) space, where all four axes are fully symmetric. In Fig. 7, observer R moves in the X_4 axis at the speed C . We consider two pairs of objects. The first pair was created at the point P and moves in opposite directions $\pm X'_4$ (equal to $\pm X_1$ of R) at the speed C . The second pair was created at the point Q and moves in opposite directions $\pm X''_4$ at the speed C . In his 3D space, R experiences the first pair as entangled photons. In his 3D space, R experiences the second pair as entangled material objects, such as electrons. In his 3D space, either pair is separated spatially. R has no idea how two entangled objects are able to “communicate” with each other in no time.

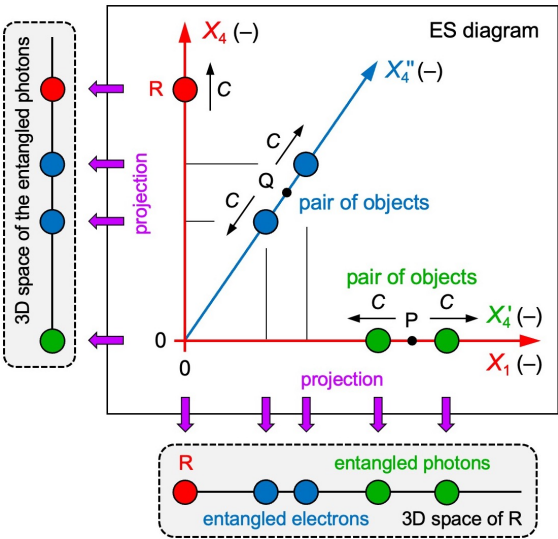


Fig. 7 Entanglement. Observer R moves in X_4 . In his 3D space, he experiences one pair as entangled photons. He experiences the other pair as entangled electrons. In the photons’ 3D space, the photons stay together spatially. In the electrons’ 3D space (not shown), the electrons stay together spatially

For the photons (or electrons), the X'_4 (or else X''_4) axis disappears because of length contraction at the speed C . From their perspective, the entangled objects have never been separated spatially, but their proper time flows in opposite 4D directions. This is how they communicate with each other in no time. Their opposite 4D vectors $\mathbf{T}$ do not affect local communication as long as the twins stay together spatially. There is a “spooky action at a distance” (this phrase is attributed to Albert Einstein) for observers only.

Entanglement and cosmic homogeneity have the same physical background: An observed object’s (or region’s) 4D vector $\mathbf{T}'$ and its 3D space may have rotated with respect to an observer’s 4D vector $\mathbf{T}$ and his 3D space. This is possible in ES only, where all axes are fully symmetric. The SO(4) symmetry of ES enables the entanglement of photons and other objects [48]. ER predicts that any two objects created in pair production are entangled. This gives us a chance to falsify ER. Any measurement terminates one twin or rotates its 4D vector $\mathbf{T}$. The entanglement is destroyed. **ER rejects non-locality.**

6. Conclusions

ER retains the formalism of SR. ER also retains the formalism of GR, but only locally. There are three key differences between ER and SR/GR: (1) ER describes a mathematical Master Reality (ES). The physical reality of an observer is derived from the Master Reality. Gravity curves an observer’s spacetime, as in GR. Without gravity, the physical reality is flat τ -MS. (2) ER omits coordinate time t . In the physical reality, proper time τ is the time coordinate and θ converts to parameter time ϑ . (3) In ER, there is absolute space (ES), an absolute evolution parameter (θ), and a 4D vector “flow of proper time” ($\mathbf{T}$). Information hidden in ES, θ , and $\mathbf{T}$ is not available in SR/GR. ES is relevant for modeling the physical reality. θ is relevant for modeling galactic motion in the physical reality. $\mathbf{T}$ is relevant for understanding cosmic homogeneity, cosmological redshift, and entanglement.

ER reproduces the Lorentz factor and –locally– the gravitational time dilation of GR. Thus, either GR or else ER is an approximation. GR is probably that approximation because θ (or ϑ) suits QM better than t . For instance, time is not an operator in the Schrödinger equation, but an external parameter. θ and ϑ are such parameters. There is none in GR. In summary, we propose (a) replacing Minkowski spacetime with τ -MS, (b) using ER in cosmology, and (c) using ER in QM. It is obvious that one paper cannot cover all of physics. It is also obvious that 12 predicted empirical facts in different (!) areas of physics are most likely not 12 coincidences. Some of these 12 facts can be predicted without ER, but only by postulating cosmic inflation, expanding space, dark energy, and non-locality. ER rejects all four highly speculative concepts. Occam’s razor makes no exceptions.

Einstein was awarded the Nobel Prize in Physics 1921 for his theory of the photoelectric effect [49] and not for SR/GR. Our results show that ER penetrates to a “deeper level”. Einstein, one of the most brilliant physicists ever, did not realize that nature’s fundamental metric is Euclidean. He sacrificed absolute space and absolute time. ER reinstates absolute space (not 3D space, but 4D space) and absolute time (not a time coordinate, but parameter time). In retrospect, it was man-made coordinate time that delayed the formulation of ER. For the first time, humanity understands the true nature of time: *Experienced time is the distance traveled in ES divided by C* . The human brain is able to imagine that we all move at the speed of light. Against this backdrop, human conflicts fade into insignificance.

Is ER a physical or a metaphysical theory? That is a very good question because only in proper coordinates can we access ES, but the proper time τ' ticking for another object cannot be measured. And yet, we can calculate τ' from ES diagrams, $\tau' = x'_4/c$, and the Eqs. (7b) and (17b). ES diagrams are observer-independent Master Diagrams of nature. It

is true that observing is our primary source of knowledge, but concepts can mislead us if they originate from observing. Physics is more than just observing. For instance, we cannot observe time. Coordinate time t works well in everyday life, but unfortunately t has also been applied to the very distant and to the very small. For this reason, cosmology and QM benefit most from ER. *ER is a physical theory because it predicts what we observe.*

It seems as if Greek philosopher Plato anticipated ER in his famous *Cave Allegory* [50]: Humanity experiences projections, but it cannot observe the Master Reality beyond these projections. We laid the foundation for ER and demonstrated its strength. Paradoxes are only virtual. The key question in science is this: *How can we describe nature without postulating highly speculative concepts?* The answer leads us to the truth. ER describes nature from the very distant to the very small. Thus, ER is indispensable for unifying physics. Everyone is invited to test ER. Only in ER does Mother Nature reveal her secrets.

Acknowledgements: I thank Siegfried W. Stein for his contributions to Sect. 5.10 and Figs. 2, 4, 5. After several rejected submissions, he decided to withdraw his co-authorship. I thank Matthias Bartelmann, Walter Dehnen, Cornelis Dullemond, Felix Finster, Xuan Phuc Nguyen, Dirk Rischke, Jürgen Struckmeier, Christopher Tyler, Götz Uhrig, and Andreas Wipf for asking inspiring questions about ER. My special thanks go to all reviewers and editors for investing some of their valuable, *proper* time.

Comments: (1) Further studies on gravity are required, but this is no reason to reject ER. GR seems to explain gravity, but GR is incompatible with QM unless we add quantum gravity. (2) In ES, there are no singularities and thus no black holes. Again, this is no reason to reject ER. Singularities conflict with QM. Projections of highly concentrated energy could possibly be interpreted as “black holes”. (3) It is often a good idea to match the symmetry. The symmetry of nature is SO(4). (4) Absolute time puts an end to all discussions about time travel. Does any other theory explain time’s arrow as clearly as ER? (5) Physics does not ask: Why is my reality a projection? Projections are less speculative than postulating cosmic inflation *plus* expanding space *plus* dark energy *plus* non-locality.

It takes open-minded editors and reviewers to evaluate a new theory that heralds a *paradigm shift*. Taking SR and GR for granted paralyzes progress. I apologize for my 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 valid arguments that would disprove ER. I was advised to consult experts or submit to other journals. Were the editors afraid of publishing against the mainstream? Did they underestimate the benefits of ER? I am told that predicting 12 empirical facts would be too much to be convincing. I disagree. A paradigm shift often leads to many new insights. Even good friends refused to support me. Every setback motivated me to formulate ER even better. Finally, I identified four shortcomings of coordinate time.

A well-known preprint archive suspended my submission privileges. I was penalized because I showed that GR is not as general as it seems. The editor-in-chief of a top journal replied: “Publishing is for experts only.” One editor rejected ER because it would “demand too much” from his reviewers. Several journals rejected ER because it was “neither innovative nor significant”. I like to speak of ER as “holistic physics”, but unfortunately the reviewers did not accept this term. I do not blame anyone. Paradigm shifts are hard to accept. In the long run, ER will prevail because it predicts what we observe. These comments shall encourage young scientists to stand up for good ideas even if it is challenging: “unscholarly research”, “fake science”, “equations from entry-level textbooks”, “too simple to be true”. *Simplicity and truth are not mutually exclusive. Beauty is when they go hand in hand together.*

Author Contributions: The entire manuscript was written by the author.

Data Availability: The data that support the findings of this study are available within this article.

Funding: No funds, grants, or other support was received.

Declarations

Competing Interests: The author declares no competing interests.

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