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Euclidean Relativity Improves Cosmology and Quantum Mechanics

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Special/general relativity (SR/GR) work for all 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 in ES. All action in ES is due to an *absolute,* external parameter θ. Every object experiences two orthogonal projections from ES as space and time: The axis of its current 4D motion is its proper time τ. Three orthogonal axes are its 3D space x_1, x_2, x_3. Observing is synonymous with projecting objects from ES onto an observer's physical reality, which is a 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. ER predicts the same relativistic effects as SR/GR, but gravity is Newtonian. Action at a distance is not an issue: Information is instantaneous in timeless ES. Only in physical realities does the time coordinate cause a delay. Presumably, gravity is carried by gravitons and manifests itself in τ-MS as gravitational waves. ER does not require curved spacetime, cosmic inflation, expanding space, dark energy, and non-locality. Nonetheless, ER predicts time's arrow, galactic motion, the Hubble tension, entanglement, and more. We propose using ER in cosmology and quantum mechanics. Is ER the key to unifying physics?

Keywords: spacetime; special relativity; general relativity; Hubble tension; dark energy; non-locality

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

SR and GR work for all observers. And yet, we show: ER must be applied to (a) the very early universe, (b) very distant objects (high-redshift supernovae), and (c) entangled objects (moving in opposite directions through 4D Euclidean space at the speed of light). In such extreme situations, a 4D Euclidean vector "flow of proper time" must be taken into account. *What is the key message of ER?* There is a mathematical reality beyond all physical realities. *Does ER make any quantitative predictions?* Yes, ER predicts the ten percent discrepancy in the published values of the Hubble constant (see Sect. 5.8).

Request to all readers: Avoid the following six pitfalls. Editors and reviewers of top journals fell into them. (1) *Do not apply the concepts of SR/GR to ER.* The only standards for a theory are its own concepts and measurement data. (2) *Do not play SR/GR off against ER.* ER provides relevant information that is not available in GR. (3) *Do not expect Einstein's field equations in ER.* In ER, gravity is Newtonian. (4) *Do not reject ER because it extends beyond an observer's reality.* ER is a physical theory because it predicts what we observe. (5) *Be curious.* New coordinates can bring us new insights. Coordinates in SR/GR are only labels that can be adjusted to simplify computations. In ER, coordinates are inherent properties of objects that cannot be adjusted (they refer to absolute 4D space). (6) *Be fair.* A paper cannot cover all of physics. Our approach is essentially geometric in nature. Illustrations can be just as rigorous as equations. What's more, they can visualize a 3D hypersurface.

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.

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. Montanus [10] claimed: This constraint is required to avoid "distant collisions" (without a physical contact) and a "character paradox" (confusion of photons, particles, antiparticles). We show that the constraint deprives ER of its most important feature: *full symmetry in all four axes.* There are no distant collisions because only three axes are experienced as spatial. There is no character paradox because an object's character manifests itself only in physical realities. Montanus derived the deflection of starlight and the precession of Mercury's perihelion [10, 11] from a Euclidean metric. He also tried to derive Maxwell's equations in 4D Euclidean space [10], but failed to realize that they are incompatible with the SO(4) symmetry.

Almeida [12] studied geodesics in 4D Euclidean space. Gersten [13] showed 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 rearranged the Minkowski metric of SR to give it a Euclidean appearance. We propose three steps to make ER work: (1) There is a mathematical Master Reality (4D Euclidean space) beyond all physical realities. (2) Every object experiences two projections from the Master Reality as space and time. (3) An observer's physical reality is a Minkowskian reassembly of his space and his time.

To this day, ER is rejected for various reasons: (a) GR has been confirmed very often. (b) There seem to be paradoxes in ER. (c) ER takes a new approach to gravity. Now we are at a turning point: (a) No scientific theory is "set in stone". (b) Projections avoid paradoxes. (c) In GR, gravity cannot be Newtonian because information cannot travel faster than the speed of light c. In ER, action at a distance is not an issue because information is instantaneous in timeless 4D Euclidean space. Only in physical realities does the time coordinate cause a delay in information. Thus, gravity can be Newtonian in ER.

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. In physical realities, the parameter converts to parameter time.

2. Identifying Issues in Special and General Relativity

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 two clocks at the points P and Q. At a 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

$$t_{\mathrm{Q}} - t_{\mathrm{P}} = t^*_{\mathrm{P}} - t_{\mathrm{Q}} \ . \qquad (1)$$

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

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

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

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

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

where $\mathrm{d}\tau$ is an infinitesimal change in the invariant τ, and all $\mathrm{d}x_i$ $(i = 1, 2, 3)$ and $\mathrm{d}t$ 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 is retained as the time coordinate. We identify four issues in SR and GR: (1) SR/GR work for all observers, but they do not provide diagrams of nature that work for all observers. (2) The GR-based Lambda-CDM model fails to predict time's arrow and the Hubble tension. It predicts other empirical facts (see Sect. 5) only by postulating highly speculative concepts (curved spacetime, cosmic inflation, expanding space, dark energy). (3) t-based QM predicts entanglement only by postulating another highly speculative concept (non-locality). (4) GR is probably incompatible with QM.

SR/GR provide a "multi-egocentric description" (definition: nature is described as a relative manifold). Even *coordinate-free* formulations of SR/GR [14–16] lack absolute space and absolute time. ER provides a "universal description" (definition: nature is described as an absolute manifold). Physics has paid a high price for sticking to coordinate time t. ER predicts time's arrow and the Hubble tension. On top, it predicts other empirical facts (see Sect. 5) without postulating highly speculative concepts. Thus, the four issues are real. Michelson and Morley [17] refuted the aether (absolute 3D space), but they did not refute absolute 4D space embedding countless 3D spaces with relative orientations.

The issues in SR/GR are not about wrong predictions, but about fewer predictions and unnecessary concepts. These issues have much in common with the issue in geocentrism, which is the "egocentric view from Earth". In the old days, it was tempting to believe that all celestial bodies would orbit Earth. Astronomers wondered about the retrograde loops of some planets and claimed: Earth orbits the sun! Nowadays, it is tempting to believe that the universe would be expanding. It is our turn to wonder: *What could it expand into?* The standard answer is: The universe creates new space within itself. *How could space be created? Since spacetime is a single entity, shouldn't time expand too?* Physics is at an impasse, but continues to reject ER. The human brain is smart, but susceptible to illusions.

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?*

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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.

Postulates: (1) *All objects move through 4D Euclidean space (ES) at the dimensionless speed* C. There is no time in ES. All motion in ES is due to an absolute, external parameter θ. We call it "evolution parameter". (2) *The laws of physics have the same form in the physical realities of observers who move uniformly through ES.* An observer's physical reality is a Minkowskian reassembly of his 3D space and his proper time (see below). Observing is synonymous with projecting objects from ES onto his physical reality. His 3D space is the same in SR and ER because it is Euclidean in either theory. Our first postulate is stronger than the second SR postulate: C is absolute and universal. Our second postulate refers to physical realities. Variational principles [18] could be another way to derive ER. The metric of ES is

$$C^2\,\mathrm{d}\theta^2 \;=\; \mathrm{d}X_1^2 + \mathrm{d}X_2^2 + \mathrm{d}X_3^2 + \mathrm{d}X_4^2\ , \tag{4}$$

where $\mathrm{d}\theta$ is an infinitesimal change in the invariant θ, and all $\mathrm{d}X_\mu$ $(\mu = 1, 2, 3, 4)$ 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" $\boldsymbol{U}$ in ES. Its four components $U_\mu = \mathrm{d}X_\mu/\mathrm{d}\theta$ 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* (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. Thus, every object experiences two orthogonal projections [19, 20] from ES as space and time: The axis of its *current* 4D motion is its proper time τ. Three orthogonal axes are its 3D space x_1, x_2, x_3. If an object's worldline 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. And then, we *reassemble* the axes x_1, x_2, x_3, x_4 in a Minkowskian way (space and time are assigned opposite signs in the metric) to form τ-based Minkowskian spacetime x_1, x_2, x_3, τ (τ-MS). The adjective "Minkowskian" refers only to the metric. In τ-MS, τ is the time coordinate and θ converts to "parameter time" ϑ. An observer's physical reality is not ES, but τ-MS. The metric of τ-MS is

$$c^2\,\mathrm{d}\vartheta^2 \;=\; c^2\,\mathrm{d}\tau^2 - \mathrm{d}x_1^2 - \mathrm{d}x_2^2 - \mathrm{d}x_3^2\ , \tag{6}$$

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.

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$$\vartheta \;=\; \theta \text{ in seconds (s)}\,, \tag{7a}$$

$$x_i \;=\; X_i \;\; (i = 1, 2, 3) \text{ in light seconds (Ls)}\,, \tag{7b}$$

$$x_4 \;=\; c\tau \;=\; X_4 \text{ in light seconds (Ls)}\,. \tag{7c}$$

Our approach ensures that all equations of SR, and Maxwell's equations in particular, retain their form in ER if we replace t with τ. The SO(4) symmetry of ES is incompatible with waves, but the SO(1,3) symmetry of τ-MS is compatible with waves. There are waves in physical realities only! An object's τ flows in the direction of its 4D motion. Thus, we define a 4D Euclidean vector "flow of proper time" $\boldsymbol{T}$ even if ES itself is timeless.

$$\boldsymbol{T} \;=\; \boldsymbol{U}/C\;. \tag{8}$$

τ-MS is not a construct because τ is a natural concept: τ is inherent in clocks. Internal clocks of all objects, such as biological clocks, measure proper time τ. In SR, the four coordinates are $x_1(\tau), x_2(\tau), x_3(\tau), t(\tau)$, where t is a man-made concept and τ is an internal parameter. In ER, the four coordinates are $x_1(\vartheta), x_2(\vartheta), x_3(\vartheta), \tau(\vartheta)$, where τ is a natural concept and ϑ is an external parameter. Parameter time ϑ increases monotonically while there is action in an observer's "universe" (synonyms: physical reality, τ-MS).

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. Thus, he experiences a projected time: Every clock measures its proper time τ', but this τ' is projected to his time axis. 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 traveled distance.* Since an observer does not move in his x_1, x_2, x_3, his clock displays both τ and ϑ according to Eq. (6). If Eq. (3) is applicable, Eqs. (3) and (6) give us

$$\mathrm{d}\vartheta \;=\; \mathrm{d}t \qquad \text{(for uniformly moving objects).} \tag{9}$$

Remarks: (1) Mathematically, ES is a 4D Euclidean manifold. Physically, three axes of ES are experienced as spatial and one as temporal. This is why we cannot observe all four axes of ES at once. (2) Clocks measure τ by themselves. Thus, there is no need to synchronize clocks in ER. (3) An object's character is not observable in ES. Despite this fact, our ES diagrams show characters ("clock", "rocket") for better readability. (4) Parameter time ϑ is not a fifth dimension. In SR, the parameter τ is not a fifth dimension either. (5) In the standard notation of SR, time is *always* the first (or fourth) coordinate. The same applies to τ-MS, but here *any* axis of ES can be the preimage of the time axis used in τ-MS. (6) Do not confuse ER with a Wick rotation [21], where τ is retained as the parameter.

We consider two identical clocks "r" (red clock) and "b" (blue clock). 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 either clock 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 evolution 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".

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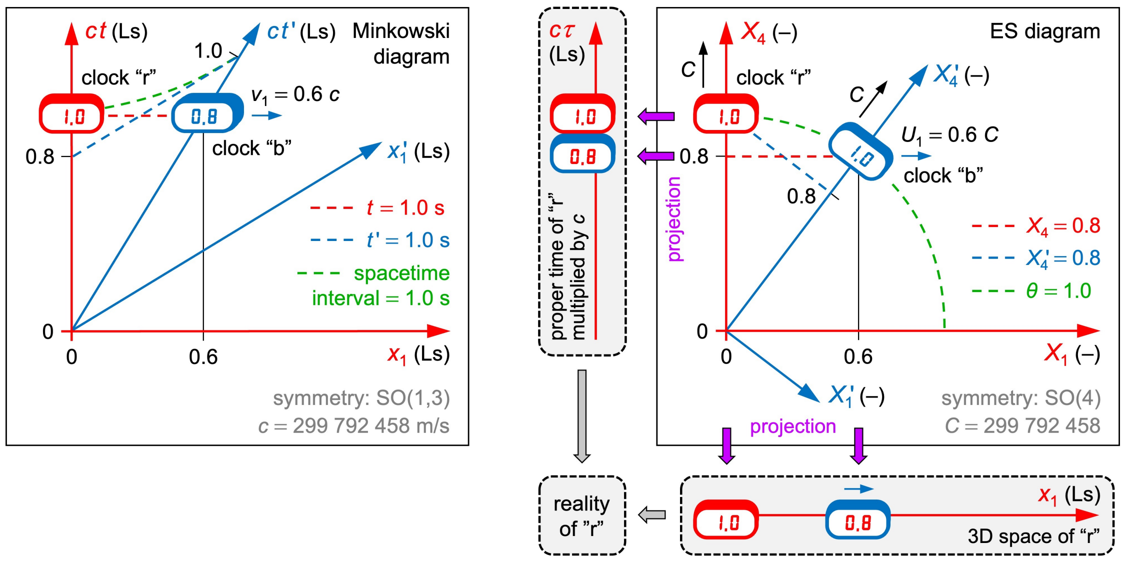

Fig. 1 Minkowski diagram and ES diagram of two uniformly moving clocks. **Left:** "b" is slow with respect to "r" in t'. Coordinate time is relative ("b" is at different positions in t and t'). **Right:** "b" is slow with respect to "r" in X_4. The evolution parameter is absolute (both clocks are at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

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. SR and ER describe time dilation correctly if γ is recovered in ER (see Sect. 4). 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 (see Sect. 4).

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. Geometric Effects in Euclidean Relativity

We consider two identical rockets "r" (red rocket) and "b" (blue rocket). 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).

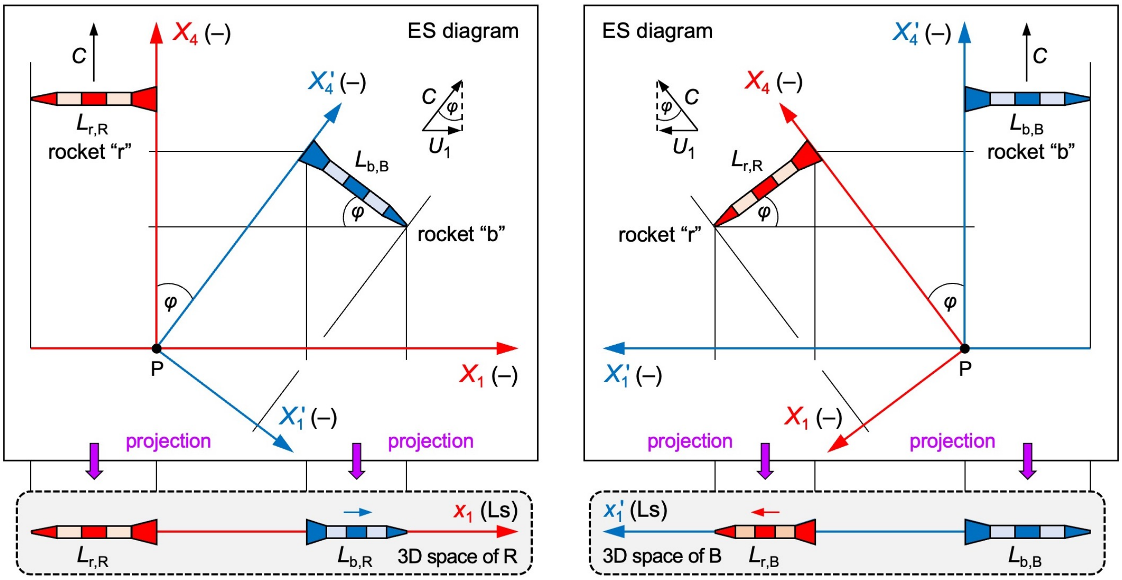

Fig. 2 ES diagrams of two uniformly moving rockets. Observer R (or B) is in the rear end of "r" (or else "b"). **Top left and right:** "r" and "b" move at the speed C, but in different 4D directions. The ES diagrams are identical. **Bottom left:** In the projection onto the 3D space of R, "b" contracts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

$$\sin^2\varphi \;+\; \cos^2\varphi \;=\; (U_1/C)^2 \;+\; (L_{b,R}/L_{b,B})^2 \;=\; 1\;, \tag{10}$$

$$L_{b,R} \;=\; \gamma_{ER}^{-1}\, L_{b,B} \qquad \text{(length contraction)}, \tag{11}$$

where $\gamma_{ER} = (1 - U_1^2/C^2)^{-0.5}$ is equal to $\gamma = (1 - v_1^2/c^2)^{-0.5}$ if $U_1/C = v_1/c$. The numerical values of C and c are equal. Because of $U_1 = \mathrm{d}X_1/\mathrm{d}\theta$, $v_1 = \mathrm{d}x_1/\mathrm{d}t$, and Eqs. (7a–b), $U_1/C = v_1/c$ if $\mathrm{d}\vartheta = \mathrm{d}t$. Eq. (9) tells us that $\mathrm{d}\vartheta = \mathrm{d}t$ for uniformly moving objects. Thus, we conclude: *ER recovers the Lorentz factor.* A 4D rotation followed by an orthogonal projection recovers γ. Orthogonal projections are not injective. Thus, ES is the Master Reality. In a second step, we project B's traveled distance onto the X_4 axis (see Fig. 2 left).

$$\sin^2\varphi \;+\; \cos^2\varphi \;=\; (U_1/C)^2 \;+\; (X_{4,B}/X'_{4,B})^2 \;=\; 1\;, \tag{12}$$

$$X_{4,B} \;=\; \gamma_{ER}^{-1}\, X'_{4,B}\;, \tag{13}$$

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

$$X_{4,R} \;=\; \gamma_{ER}\, X_{4,B} \qquad \text{(time dilation)}, \tag{14}$$

where $X_{4,R}$ is the distance that R traveled in X_4. Eqs. (11) and (14) tell us that ER confirms length contraction and time dilation. Which distances does R observe in X_4? We rotate "b" until it serves as a ruler in X_4. In the 3D space of R, the ruler contracts to zero length. *For R, the X_4 axis disappears because of length contraction at the speed C.* Our rockets are an example. To calculate the lifetime of a muon, we replace rocket "b" with a muon.

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. (15a–b). It is a 4D rotation by the angle φ. Note that 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. Euclidean 4D rotations in ES replace hyperbolic rotations (Lorentz boosts) in Minkowski spacetime.

$$X'_{1,\mathrm{R}}(\theta) \;=\; X_{4,\mathrm{R}}(\theta)\,\sin\varphi \;=\; X_{4,\mathrm{R}}(\theta)\;U_1/C\;, \tag{15a}$$

$$X'_{4,\mathrm{R}}(\theta) \;=\; X_{4,\mathrm{R}}(\theta)\,\cos\varphi \;=\; X_{4,\mathrm{R}}(\theta)\;\gamma_{\mathrm{ER}}^{-1}\;. \tag{15b}$$

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.

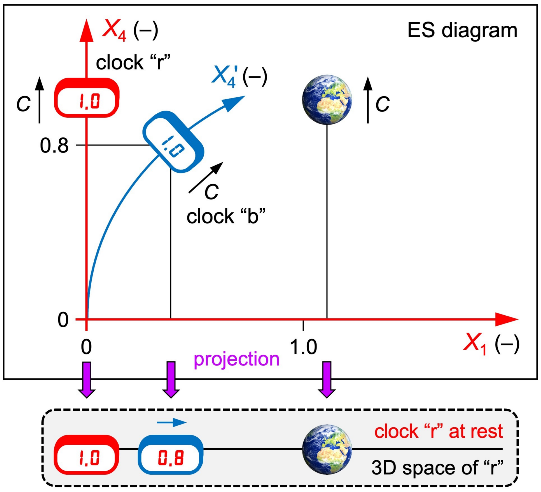

Fig. 3 ES diagram of two clocks and Earth. "b" falls freely toward Earth. It experiences gravity as an acceleration of other objects. Its X_4' axis is curved because X_4' indicates its current 4D motion.

Because of Eq. (5), all accelerations in ES are transversal: The speed $U_{1,\mathrm{b}}$ of clock "b" in the X_1 axis increases at the expense of its speed $U_{4,\mathrm{b}}$ in the X_4 axis. In the specific scenario shown in Fig. 3, "b" will not collide with Earth in ES. This is not an issue because ES diagrams do not show events (see the last paragraph of Sect. 4). The only relevant quantities for a collision are X_1, X_2, X_3, θ. We now claim: In ER, gravity is Newtonian. We provide evidence for this claim by showing that assuming Newton's law of gravitation in ER yields exactly the same gravitational time dilation as GR. We also assume that $U_{1,\mathrm{b}}/C = v_{1,\mathrm{b}}/c$. Under these two assumptions, the kinetic energy of "b" in the X_1 axis is

$$\tfrac{1}{2} m U_{1,\mathrm{b}}^2 \;=\; GMm/R\;, \tag{16}$$

where m is the mass of "b", G is the gravitational constant, M is the mass of Earth, and R is the distance of "b" to the center of Earth in X_1. All quantities are dimensionless. The gravitational potential follows a $1/R$ law because ES is reduced to 3D space: Physically, only three axes of ES are experienced as spatial. Eqs. (5) and (16) give us

$$U_{4,\mathrm{b}}^2 \;=\; C^2 - U_{1,\mathrm{b}}^2 \;=\; C^2 - 2GM/R\;. \tag{17}$$

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With $U_{4,\mathrm{b}} = \mathrm{d}X_{4,\mathrm{b}}/\mathrm{d}\theta$ ("b" moves in the X_4 axis at the speed $U_{4,\mathrm{b}}$) and $C = \mathrm{d}X_{4,\mathrm{r}}/\mathrm{d}\theta$ ("r" moves in the X_4 axis at the speed C), we calculate

$$\mathrm{d}X_{4,\mathrm{b}}^2 = (C^2 - 2GM/R)\,(\mathrm{d}X_{4,\mathrm{r}}/C)^2 \ , \tag{18}$$

$$\mathrm{d}X_{4,\mathrm{r}} = \gamma_{\mathrm{grav}}\,\mathrm{d}X_{4,\mathrm{b}} \qquad \text{(gravitational time dilation)}, \tag{19}$$

where the factor $\gamma_{\mathrm{grav}} = (1 - 2GM/(RC^2))^{-0.5}$ has the same form as in GR. We recall that we assumed $U_{1,\mathrm{b}}/C = v_{1,\mathrm{b}}/c$ in Eq. (16). Thus, the same argument applies as before with the Lorentz factor: $U_{1,\mathrm{b}}/C = v_{1,\mathrm{b}}/c$ if $\mathrm{d}\vartheta = \mathrm{d}t$. Since spacetime in GR is locally Minkowskian, thus locally $\mathrm{d}\vartheta = \mathrm{d}t$ according to Eq. (9), we conclude: *Locally, ER predicts the same gravitational time dilation as GR.* Thus, ER also predicts relativistic effects that are caused by gravitational time dilation. Since ER confirms both factors γ and γ_{grav}, the experiment by Hafele and Keating [22] does not only support SR/GR, but also ER.

In GR, gravity is the result of a curved spacetime. In ER, gravity is Newtonian. Eq. (5) tells us: *If an object accelerates in three axes of ES, it automatically decelerates in the fourth axis.* It is not ES that is curved, but the worldlines in ES can be curved! In ER, action at a distance is not an issue: Information is instantaneous in timeless ES. Only in physical realities does the time coordinate cause a delay in information. Presumably, gravity is carried by gravitons [23, 24] and manifests itself in τ-MS as gravitational waves [25]. ER supports this idea even if gravitons have not yet been experimentally confirmed. Gravitons in ES and gravitational waves in τ-MS could possibly be related to each other in the same way as photons and electromagnetic waves. ***ER does not require curved spacetime.***

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

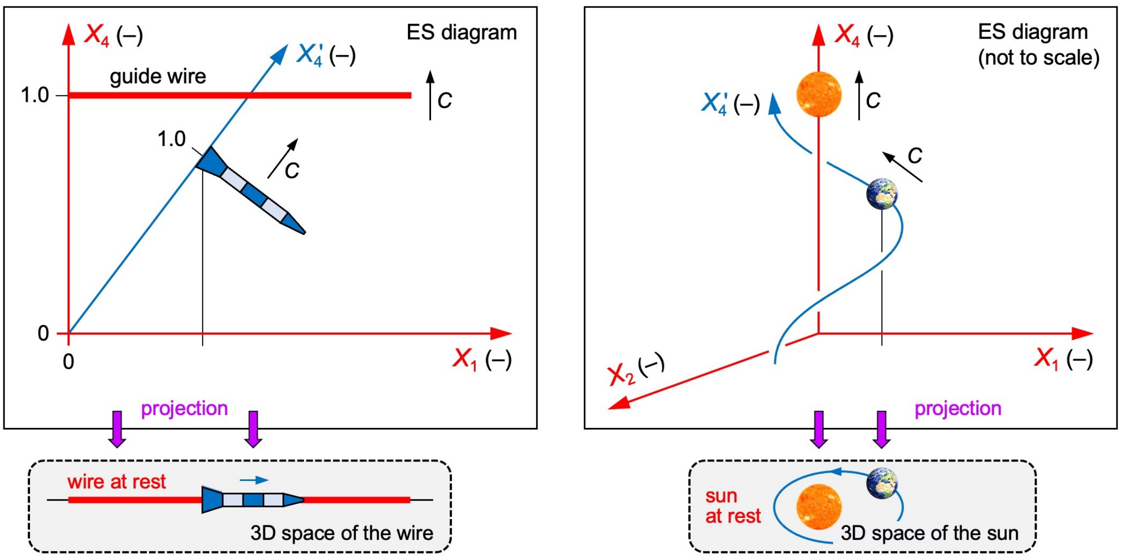

Fig. 4 Two instructive problems. **Bottom left:** In the 3D space of a guide wire, a rocket moves along the wire. **Top left:** In ES, the wire escapes from the rocket. **Bottom right:** In the 3D space of the sun, Earth orbits the sun. **Top right:** In ES, the sun escapes from Earth. Note that this illustration is only an approximation because 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* $\boldsymbol{T}$.

5. Empirical Evidence for Euclidean Relativity

In § 22 of GR [2], Einstein proposes three tests for validating GR: gravitational redshift (see Sect. 5.2), the deflection of starlight, and the precession of Mercury's perihelion. Montanus [10] showed that a Euclidean metric predicts the same deflection by the sun and the same precession as GR. However, he used coordinate time t as a parameter (see page 13 of [10]) and neither the evolution parameter θ nor parameter time ϑ. To a first approximation, the sun, Mercury, and Earth move uniformly through ES (deviations from a uniform motion are negligible because of the very high speed C). Thus, $\mathrm{d}\vartheta \cong \mathrm{d}t$ according to Eq. (9). Only in this case is t as good a parameter as ϑ. Thus, ER passes the latter two tests proposed by Einstein. On top, ER predicts the following ten empirical facts.

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 ES divided by C. Regardless of the direction of an object's 4D motion, "distance traveled" is a monotonically increasing function.

5.2. Gravitational Redshift

Gravitational redshift is the decrease in frequency of radiation emerging from a gravitational well. Frequency is related to time. ER locally predicts the same gravitational time dilation as GR. Thus, ER also locally predicts the same gravitational redshift as GR.

5.3. Cosmic Microwave Background (CMB)

Today's standard model of cosmology, the Lambda-CDM model [26, 27], is based on GR. In this model, the universe inflated from a singularity. The Big Bang occurred "everywhere". In Sects. 5.3 to 5.9, 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 [28].

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. 5.9). (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).

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5.4. 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.

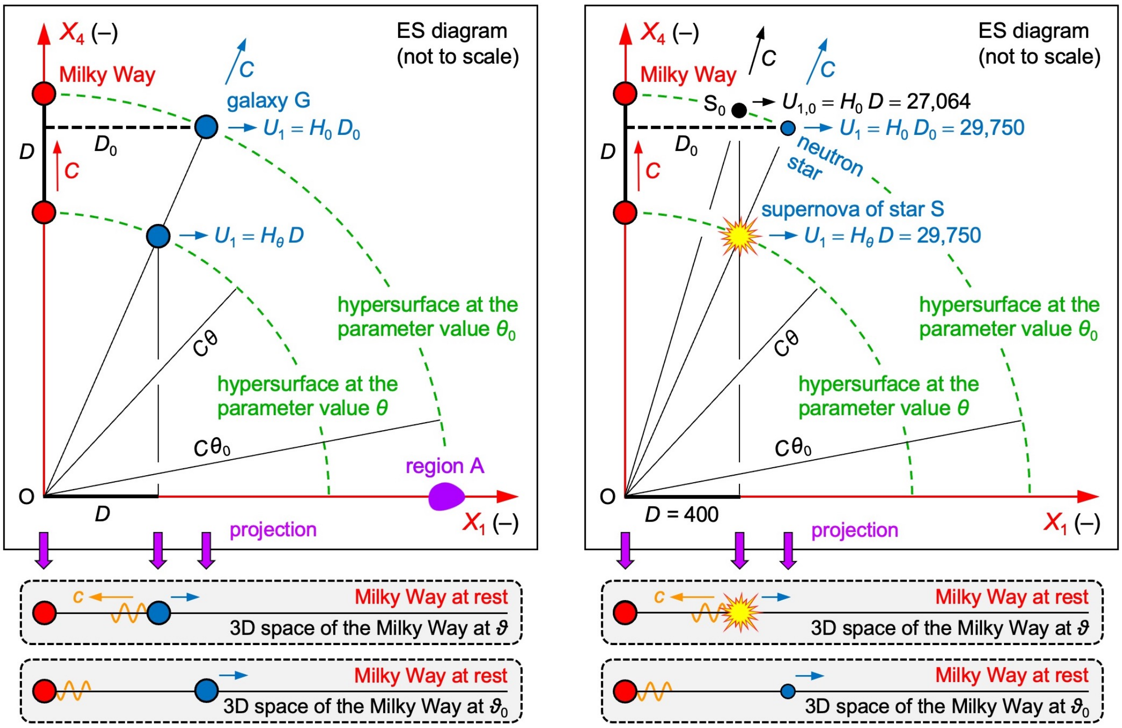

Fig. 5 ER-based model of cosmology. The green arcs show a 3D hypersurface. **Left:** G recedes from O at the speed C and from the X_4 axis at the speed U_1. **Right:** If S_0 happens to be at the same distance D today at which the supernova of S occurred, S_0 recedes more slowly from X_4 than S.

$$U_1 = CD/C\theta = D/\theta = H_\theta\, D\ , \tag{20}$$

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. (20) turns into

$$U_1 = CD_0/C\theta_0 = D_0/\theta_0 = H_0\, D_0\ , \tag{21}$$

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. (21) is an improved Hubble–Lemaître law [29, 30]. 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. (21) 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.

5.5. Flat Universe

An observer experiences neither ES nor the curved 3D hypersurface, but τ-MS. Thus, his physical reality is a "flat universe" (his 3D Euclidean space and his proper time). This statement is true even if his worldline in ES is curved, as for clock "b" in Fig. 3.

5.6. Large-Scale Structures

Most cosmologists [31, 32] 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 does not require cosmic inflation.***

5.7. 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.

5.8. 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 [33]. 73.04 ± 1.04 km/s/Mpc according to team B [34]. 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. (20), 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 $H_0 = 67.66$. This is because H_θ is not a constant. The red points tell us: If we compare the supernovae of two stars S and S', the more distant one recedes faster, but each star maintains its recession speed. Thus, Eq. (9) applies: $\mathrm{d}\vartheta = \mathrm{d}t$ for uniformly moving objects. Thus, U_1/C in our plot is equal to v_1/c, as calculated from the measured redshift. According to Eq. (21), we have to plot U_1 versus D_0 to get a straight line (blue points). Since team B does not take Eq. (21) 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 obvious fact explains the Hubble tension.

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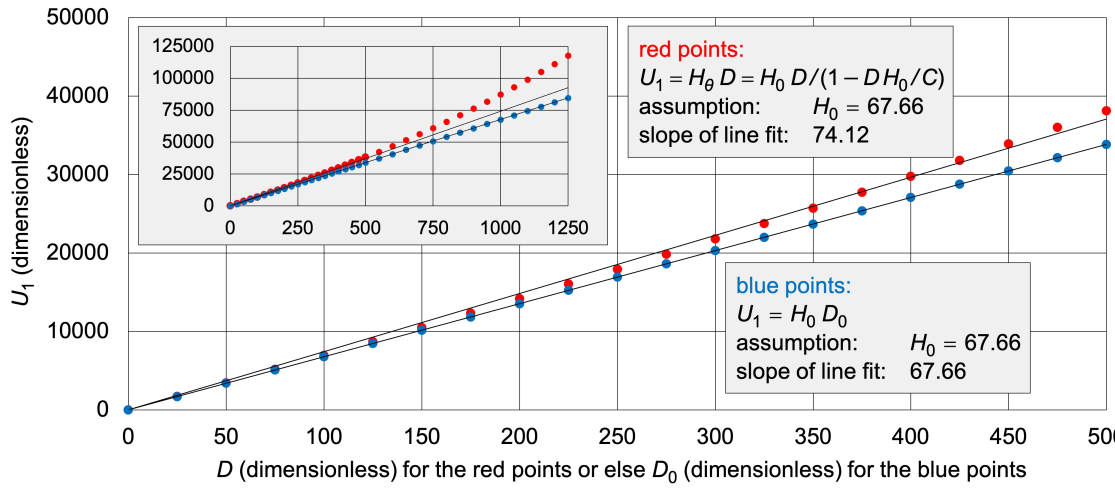

Fig. 6 Hubble diagram of simulated supernovae. The red points, calculated from Eq. (20), do not form a straight line. Because of Eqs. (20) and (23), U_1 is not proportional to D. The blue points, calculated from Eq. (21), do form a straight line because U_1 is proportional to D_0.

Eq. (21) requires the knowledge of D_0, but measurable magnitudes of supernovae are related to D. We solve this technical difficulty by rewriting Eq. (21) as

$$U_{1,0} = H_0\, D \;, \tag{22}$$

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

$$H_\theta = C/C\theta = C/(C\theta_0 - D) = H_0/(1 - DH_0/C) \;. \tag{23}$$

Inserting H_θ from Eq. (20), H_0 from Eq. (22), and $U_1/C = v_1/c$ into Eq. (23) gives us

$$U_{1,0} = U_1/(1 + U_1/C) \;, \tag{24}$$

$$U_{1,0}/C = U_1/(C + U_1) = v_1/(c + v_1) \;. \tag{25}$$

We kindly ask team B to convert v_1 to $U_{1,0}$ according to Eq. (25). Because of Eq. (22), plotting $U_{1,0}$ versus D then 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.

5.9. 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 [35, 36] 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. (25) tells us: S_0 recedes more slowly (speed of 27,064 and shortest arrow in Fig. 5 right) from X_4 than S (speed of 29,750). *It does so because of the 4D Euclidean geometry.* The 4D vector $\boldsymbol{T}'$ of S_0 differs less from $\boldsymbol{T}$ of the Milky Way than $\boldsymbol{T}''$ of S differs from $\boldsymbol{T}$. Physicists "invented" dark energy [37] 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 H_θ and not because of a dark energy.

Cosmological redshift and the Hubble tension have the same physical background: In Eq. (21), we must not confuse D_0 with D. Because of Eqs. (20) and (23), 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 requires neither expanding space nor 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 $\boldsymbol{T}$ in particular. GR works well if $\boldsymbol{T}$ is irrelevant, but $\boldsymbol{T}$ is relevant for high-redshift supernovae: Their $\boldsymbol{T}'$ differs greatly from $\boldsymbol{T}$ 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 does not require curved spacetime, cosmic inflation, expanding space, and dark energy. Thus, ER significantly improves cosmology. ER also improves QM (see Sect. 5.10).

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).
Gravity is the result of a curved spacetime.	Gravity is Newtonian.
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.
This model does not predict the Hubble tension.	This model predicts the Hubble tension.

Table 1 Comparing two models of cosmology.

5.10. Quantum Entanglement

It was Erwin Schrödinger who coined the word "entanglement" in his comment [38] on the Einstein–Podolsky–Rosen paradox [39]. 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 [40] showed that QM is incompatible with local hidden-variable theories. Meanwhile, several experiments [41–43] have confirmed that entanglement violates locality in an observer's *3D space.* Quantum entanglement has been interpreted as a "non-local effect" ever since.

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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. There are 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 the 3D space of R, the first pair is experienced as entangled photons. The second pair is experienced as entangled material objects, such as electrons. R has no idea how entangled objects "communicate" with each other in no time.

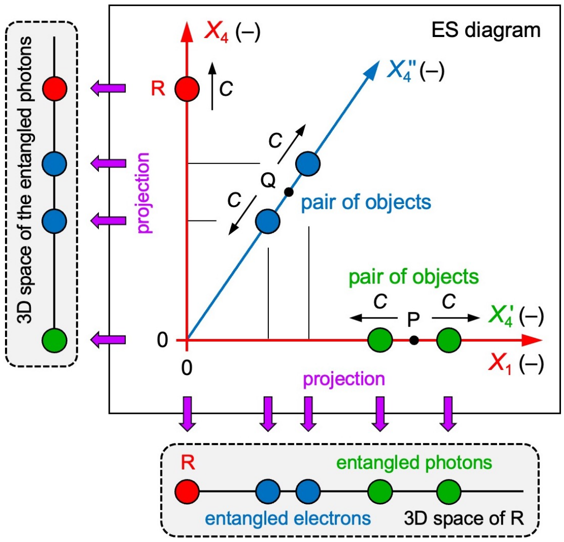

Fig. 7 Entanglement. Observer R moves in X_4. In his 3D space, one pair is experienced as entangled photons. The other pair is experienced as entangled electrons. In the photons' 3D space, the photons stay together spatially. In the electrons' 3D space (not shown), the electrons stay together spatially.

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 $\boldsymbol{T}$ do not affect local communication as long as the twins stay together spatially. *What the time axis is for entangled objects, a space axis—or a mix of space and time—is for the observer.* There is a "spooky action at a distance" (a phrase 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 $\boldsymbol{T}'$ and its 3D space can be rotated with respect to an observer's 4D vector $\boldsymbol{T}$ and his 3D space. This is possible in ES only, where all four axes are fully symmetric. The SO(4) symmetry of ES enables the entanglement of photons and other objects [44]. 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 $\boldsymbol{T}$. The entanglement is destroyed. ***ER does not require non-locality.***

6. Conclusions

Today's physics lacks absolute space, an absolute, external parameter, and a vectorial concept of time. In ER, there is absolute space (ES), an absolute evolution parameter (θ), and a vector "flow of proper time" ($\boldsymbol{T}$). Information hidden in ES, θ, and $\boldsymbol{T}$ is not available in SR/GR. ES is relevant for modeling an observer's universe (a Minkowskian reassembly of two projections from ES). θ is relevant for modeling galactic motion. $\boldsymbol{T}$ is relevant for explaining cosmic homogeneity, cosmological redshift, and entanglement.

ER recovers the Lorentz factor and locally predicts the same gravitational time dilation as GR. Thus, either GR or else ER is an approximation. GR is probably that approximation because ϑ suits QM better than t. For instance, time is not an operator in the Schrödinger equation, but an external parameter. In ER, ϑ is such a parameter. 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. All three adjustments are essential if we want to improve physics. One adjustment is not enough. It is obvious that a paper cannot cover all of physics. It is also obvious that ten predicted empirical facts in *different* areas of physics are most likely not ten coincidences. Some facts can be predicted without ER, but only by postulating curved spacetime, cosmic inflation, expanding space, dark energy, and non-locality. None of these concepts is required in ER. Occam's razor makes no exceptions.

Einstein was awarded the Nobel Prize in Physics 1921 for his theory of the photoelectric effect [45] 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 ever, humanity grasps 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. With that said, conflicts of humanity become all so small.

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 it from ES diagrams, as shown in Eqs. (15b) and (7c). 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 very 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* [46]: 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 to the truth. The pillars of physics are ER and QM. Together, they describe Mother Nature from the very distant to the very small. Everyone is welcome to test ER. Only in natural concepts does Mother Nature reveal her secrets. *Isn't it natural that she rewards an all-natural description of herself?*

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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 often helps 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 curved spacetime *plus* 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 all the benefits of ER? I was told that predicting ten empirical facts all at once would be too much to be convincing. I disagree. Paradigm shifts often lead to many new insights. Even good friends did not support me. Every setback motivated me to formulate ER even better. Finally, I was able to identify four issues in SR and GR.

A well-known preprint archive suspended my submission privileges. I was penalized because I showed that GR is not as general as it seems. I was told that I may submit only those articles that have appeared in a mainstream conventional journal. 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 experts. 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.*

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