Article

Not peer-reviewed version

15 Evidences That the Scope of Special/General Relativity Is Limited

Markolf H. Niemz *

Posted Date: 4 December 2024

doi: 10.20944/preprints202207.0399.v80

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

15 Evidences That the Scope of Special/General Relativity Is Limited

Markolf H. Niemz

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

Today's physics describes nature in "empirical concepts" (concepts that are based on observation), such as spatial/temporal, wave/particle, and force/field. There are coordinate-free formulations of special and general relativity (SR/GR), but there is no absolute time in SR/GR and thus no "holistic view" (view that is universal for all objects at the *same* instant in time). **Here I show:** A holistic view is required to solve the Hubble tension and 14 other mysteries. Euclidean relativity (ER) provides a holistic view by describing nature in "natural concepts" (concepts that are immanent in all objects). "Pure distance" replaces spatial/temporal distance. "Pure energy" replaces wave/particle. I give one example where a "process" replaces force/field. Each object's proper space d_1, d_2, d_3 and its proper time τ span absolute, Euclidean spacetime (ES), where d_1, d_2, d_3 and $d_4 = c\tau$ are pure distances. The new invariant is absolute, cosmic time θ. All energy moves through ES at the speed of light c. An observer's reality is created by orthogonally projecting ES to his proper space and to his proper time. *Information is lost in projections.* Thus, there will always be unsolved mysteries if we ignore ES. ER solves 15 mysteries purely geometrically, that is, without forces and fields. On top, ER declares four concepts obsolete, such as dark energy and non-locality. **I conclude:** (1) ER describes the master reality ES. (2) SR/GR describe all observers' realities. (3) ER neither replaces nor extends SR/GR but holds additional information that is hidden in absolute time and thus not available in SR/GR.

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

There are two legitimate approaches to describing nature: either in "empirical concepts" (concepts that are based on observation) or else in "natural concepts" (concepts that are immanent in all objects). Observation implies that the description may not be complete or that it may require concepts that are obsolete in the second approach. Special and general relativity (SR/GR) take the first approach [1, 2], but there is no absolute time in SR/GR and thus no "holistic view" (view that is universal for all objects at the *same* instant in time). Euclidean relativity (ER) takes the second approach and provides a holistic view. Editors of top journals told me that physical theories must build upon SR/GR. They are mistaken because I show that the scope of SR/GR is limited. My key message: In empirical concepts, spacetime is non-Euclidean. In natural concepts, spacetime is Euclidean.

Ten pieces of advice: (1) *Read carefully.* I disprove neither SR nor GR. I show that the scope of SR/GR is limited. (2) *Be receptive to new concepts in physics.* ER solves 15 mysteries of cosmology and quantum mechanics (QM) purely geometrically, that is, without forces and fields. (3) *Do not expect that there are field equations in ER.* Field is an empirical concept. (4) *Do not evaluate ER with the concepts of SR/GR.* We must not compare the incomparable. (5) *Do not confuse spacetime in ER with spacetime in SR/GR.* A peer reviewer claimed that my Euclidean diagrams are false because spacetime is non-Euclidean in SR/GR. This is as if he claimed that the heliocentric model is false because the sun orbits Earth in the geocentric model. (6) *Do not reject ER unless you can disprove ER.* So far, no one has disproven ER. (7) *Do not be prejudiced against a simple, powerful theory.* Nature often realizes simple truths. (8) *Appreciate illustrations.* As a geometric theory, ER complies with the stringency of math. (9) *Be fair.* One paper cannot cover all of physics. SR/GR have been tested for 100+ years. ER deserves the same chance. (10) *Be objective.* Experts may feel offended.

To sum it up: Predictions made by SR/GR are correct, but cosmology and QM profit a lot from ER. I apologize for my many preprint versions, but I received almost no support. My final version is all that is needed. All earlier versions are documents that illustrate my path. Figuring out that we must not apply empirical concepts in cosmology and QM was the trickiest part. Sect. 2 discloses an issue in SR/GR. Sect. 3 describes ER. Sect. 4 describes geometric effects in ER. In Sect. 5, I outline the solutions to 15 mysteries.

 doi:10.20944/preprints202207.0399.v80

1. Introduction

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

Three postulates of ER: (1) All energy moves through Euclidean spacetime (ES) at the speed of light c. (2) The laws of physics have the same form in each observer's reality. (3) An observer's reality is created by orthogonally projecting ES to his proper space and to his proper time. The two projections are reassembled in SR/GR to form a non-Euclidean spacetime. The reassembly is not (!) a topic of my paper. It is a fact that spacetime in SR/GR is non-Euclidean. *Information is lost in projections.* Thus, there will always be unsolved mysteries if we ignore ES. My first postulate is much stronger than the second SR postulate: c is absolute and universal. My second postulate refers to observers' realities and not to ES. My third postulate is unique. I also make use of natural concepts: "Pure distance" replaces spatial/temporal distance. "Pure energy" replaces wave/particle. To improve readability, all my observers are male. To make up for it, Mother Nature is female.

Since each observer's reality is created by projecting ES, I call ES the "master reality". Fig. 1 left illustrates how to relate an observer's reality to ES. Fig. 1 right illustrates where to apply ER and where to apply SR/GR. ER describes the master reality, which is "beyond" (outside the scope of) an observer's reality, and also how an observer's reality is created. SR/GR describe all observers' realities and also how the realities of two observers relate to each other. Note that ER describes nature but not an observer's reality.

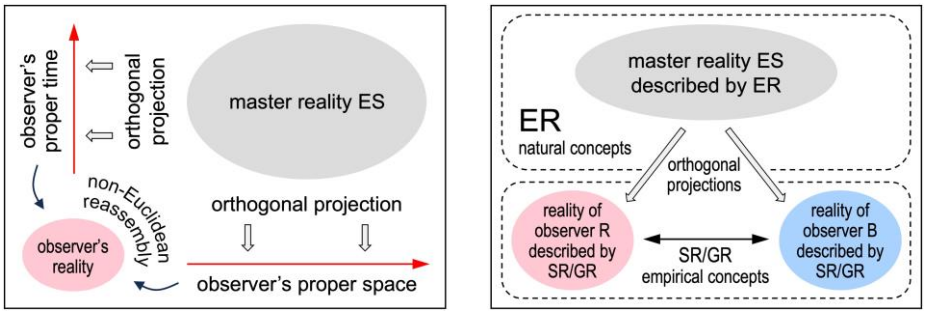

Fig. 1 Observer's reality and master reality ES (for orthogonal projections, see Sect. 4). **Left:** How to relate an observer's reality to ES. **Right:** Where to apply ER and where to apply SR/GR

In 1969, Newburgh and Phipps [8] pioneered ER. Montanus [9] added a constraint: A pure time interval is a pure time interval for all observers. According to Montanus [10], this constraint is required to avoid the twin paradox and a "character paradox" (confusion of photons, particles, antiparticles). I show that the constraint is obsolete. *Whatever is proper time for me, it may be one axis of proper space for you.* There is no twin paradox if we consider cosmic time as the parameter. There is no character paradox if we consider "pure energy". Montanus [11] tried to describe kinematics in ES using the Lagrange formalism. Montanus [10] even tried to formulate Maxwell's equations in ES but wondered about a wrong sign. He overlooked that the SO(4) symmetry of ES is incompatible with waves. Nevertheless, Montanus [10] calculated the precession of Mercury's perihelion in ER. In short, ER makes the same predictions as SR/GR but excludes empirical concepts (waves etc.).

Almeida [12] studied various geodesics in ES. Gersten [13] showed that the Lorentz transformation is an SO(4) rotation (see Sect. 3). van Linden maintains a website about ER (https://euclideanrelativity.com/). Most physicists reject ER because dark energy and nonlocality make cosmology and QM work, ER excludes waves, and paradoxes turn up if ER is believed to describe an observer's reality. This paper marks a turning point: *I disclose an issue in SR/GR. I justify the exclusion of waves. I avoid paradoxes by projecting ES.*

 doi:10.20944/preprints202207.0399.v80

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

2. Disclosing an Issue in Special and General Relativity

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

$$t_Q - t_P = t_P^* - t_Q \ . \tag{1}$$

In § 3 of SR, Einstein derives the Lorentz transformation. The coordinates x_1, x_2, x_3, t of an event in a system K are transformed to the coordinates x_1', x_2', x_3', t' in K′ by

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

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

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

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

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

The analogy of SR/GR to the geocentric model is stunningly close: (1) It holds despite all covariances. After a transformation in SR/GR (or after appointing another planet as the center of the Universe), the view is again egocentric (or else geocentric). (2) ER has much in common with a "heliocentric model 2.0", where the sun is the center of our solar system but not of our galaxy. That particular model provides a more general view from beyond our galaxy. ER provides a holistic view from beyond an observer's reality. (3) Retrograde loops make the geocentric model work, but they are obsolete in the heliocentric model. Dark energy and non-locality make cosmology and QM work, but they are obsolete in ER (see Sect. 5). (4) The heliocentric model was rejected in the old days. ER is rejected today. *Have physicists not learned from history? Does history repeat itself?*

 doi:10.20944/preprints202207.0399.v80

3. The Physics of Euclidean Relativity

The Minkowski metric in SR is often written as

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

where $\mathrm{d}\tau$ is an infinitesimal distance in proper time τ, whereas $\mathrm{d}t$ and $\mathrm{d}x_i$ $(i = 1,2,3)$ are infinitesimal distances in coordinate spacetime x_1, x_2, x_3, t. This spacetime is *empirical* because coordinate space x_1, x_2, x_3 and coordinate time t are empirical concepts: They are not immanent in rulers/clocks but are construed by observers. Rulers measure proper length. Clocks measure proper time. I introduce ER by defining its metric

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

where $\mathrm{d}\theta$ is an infinitesimal distance in cosmic time θ, whereas all $\mathrm{d}d_i$ $(i = 1,2,3)$ and $\mathrm{d}d_4 = c\,\mathrm{d}\tau$ are infinitesimal distances in Euclidean spacetime d_1, d_2, d_3, d_4 (ES). The roles of θ and τ are switched: *The new invariant is absolute, cosmic time θ. The fourth coordinate is an object's proper time τ. The metric tensor is the identity matrix.* I prefer the indices 1–4 to 0–3 to stress the 4D symmetry. I choose the symbol θ because the initial of "theta" is "t". Each object's proper space d_1, d_2, d_3 and its proper time τ span ES, where d_1, d_2, d_3 and $d_4 = c\tau$ are pure distances. This spacetime is *natural* because all d_μ $(\mu = 1,2,3,4)$ are natural concepts: They are measured by and thus immanent in rulers/clocks. Do not confuse Eq. (4) with a Wick rotation [18], where coordinate time is imaginary.

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

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

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

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

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

An observer's reality is created by orthogonally projecting ES to his proper space and to his proper time. Information is lost in projections. Thus, there is no continuous transition from SR to ER. An observer's reality can be construed from ES but not vice versa. This is not an issue because SR describes nature in empirical concepts $x_1(\tau), x_2(\tau), x_3(\tau), t(\tau)$, where τ is the parameter and t is coordinate time. On the contrary, ER describes nature in natural concepts $d_1(\theta), d_2(\theta), d_3(\theta), d_4(\theta)$, where θ is the parameter and d_4 relates to τ. Only in proper coordinates can we access ES, but the proper coordinates of other objects cannot be measured. This is not an issue either as I explain in my Conclusions.

It is instructive to contrast the three concepts of time. Coordinate time t is a subjective measure of time: An observer uses his clock as the master clock. Proper time τ is an objective measure of time: Clocks measure τ independently of observers. Cosmic time θ is the total distance covered in ES (length of a worldline) divided by c. By taking θ as the parameter, all observers will agree on what is past and what is future. Since cosmic time is absolute, there is no twin paradox in ER. *Twins are the same age in cosmic time.*

 doi:10.20944/preprints202207.0399.v80

Let us compare SR with ER. We consider two identical clocks "r" (red clock) and "b" (blue clock). In SR, "r" moves in the ct axis. Clock "b" starts at $x_1 = 0$ and moves in the x_1 axis at a constant speed of $v_{3D} = 0.6\,c$. Fig. 2 left shows the instant when either clock moved 1.0 s in ct. Clock "b" moved 0.6 Ls (light seconds) in x_1 and 0.8 Ls in ct'. It displays "0.8". In ER, Fig. 2 right shows the instant when either clock moved 1.0 s in its proper time. Both clocks display "1.0". Clock "b" moved 0.6 Ls in d_1 and 0.8 Ls in d_4.

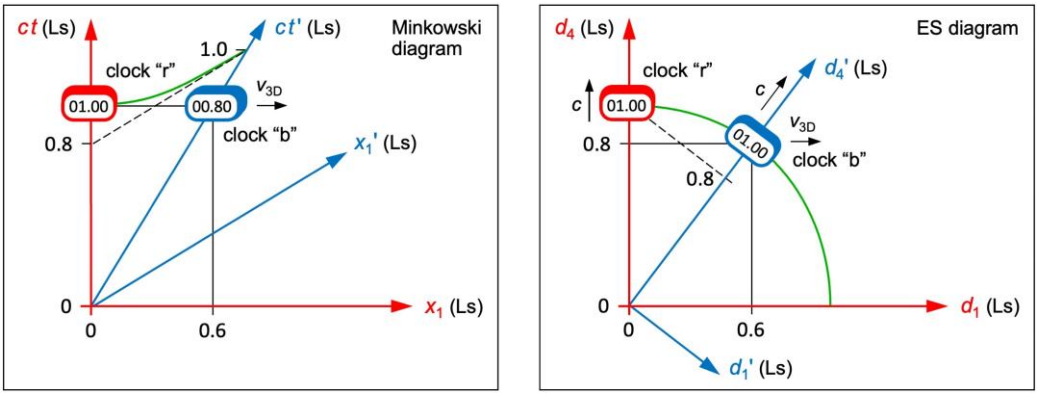

Fig. 2 Minkowski diagram and ES diagram of two identical clocks "r" (red) and "b" (blue). **Left (SR):** "b" is slow with respect to "r" in t'. Coordinate time is relative ("b" is not at the same positions in ct and ct'). **Right (ER):** "b" is slow with respect to "r" in d_4. Cosmic time is absolute ("r" is in d_4 at the same position as "b" in d_4'). Only the ES diagram is rotationally symmetric

We now assume that an observer R (or B) is moving with the clock "r" (or else "b"). In SR and only from R's perspective, clock "b" is at $ct' = 0.8$ Ls when "r" is at $ct = 1.0$ Ls (see Fig. 2 left). Thus, "b" is slow with respect to "r" in t' (of B). In ER and independently of observers, clock "b" is at $d_4 = 0.8$ Ls when "r" is at $d_4 = 1.0$ Ls (see Fig. 2 right). Thus, "b" is slow with respect to "r" in d_4 (of R). *In SR and ER, "b" is slow with respect to "r", but time dilation occurs in different axes.* Experiments do not disclose the axis in which a clock is slow. Thus, SR and ER may claim that they describe time dilation correctly.

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

Gersten [13] showed that the Lorentz transformation is an SO(4) rotation in a "mixed space" x_1, x_2, x_3, ct', where only ct' is primed. The four mixed coordinates x_1, x_2, x_3, ct' rotate to x_1', x_2', x_3', ct. I will not repeat the derivation. I consider it my task to turn ER into an accepted theory by revealing its power. However, a mixed space is physically pointless. In ER, unmixed d_1', d_2', d_3', d_4' rotate with respect to d_1, d_2, d_3, d_4 (see Sect. 4).

There is also a big difference in the synchronization of clocks: In SR, each observer is able to synchronize a uniformly moving clock to his clock (same value of ct in Fig. 2 left). If he does, these clocks are not synchronized from the perspective of the moving clock. In ER, clocks with the same 4D vector $\boldsymbol{\tau}$ are always synchronized, whereas clocks with different $\boldsymbol{\tau}$ and $\boldsymbol{\tau}'$ are never synchronized (different values of d_4 in Fig. 2 right).

4. Geometric Effects in Euclidean Relativity

We consider two identical rockets "r" (red rocket) and "b" (blue rocket). Let observer R (or B) be in the rear end of "r" (or else "b"). The 3D space of R (or B) is spanned by d_1, d_2, d_3 (or else d_1', d_2', d_3'). We use "3D space" as a synonym of "proper space". The proper time of R (or B) relates to d_4 (or else d_4') according to Eq. (5). Both rockets start at the point P and move relative to each other at the constant speed v_{3D}. R and B are free to label the

 doi:10.20944/preprints202207.0399.v80

axis of relative motion in 3D space. R (or B) labels it as d_1 (or else d_1'). The ES diagrams in Fig. 3 must fulfill my three postulates and the initial condition (same starting point P). This is achieved by rotating the red and the blue frame with respect to each other. Do not confuse the ES diagrams with Minkowski diagrams. *In ES diagrams, objects maintain proper length and clocks display proper time.* To improve readability, these diagrams show a rocket's width in d_4 (or d_4'). Fig. 3 bottom shows the projection to the 3D space of R (or B).

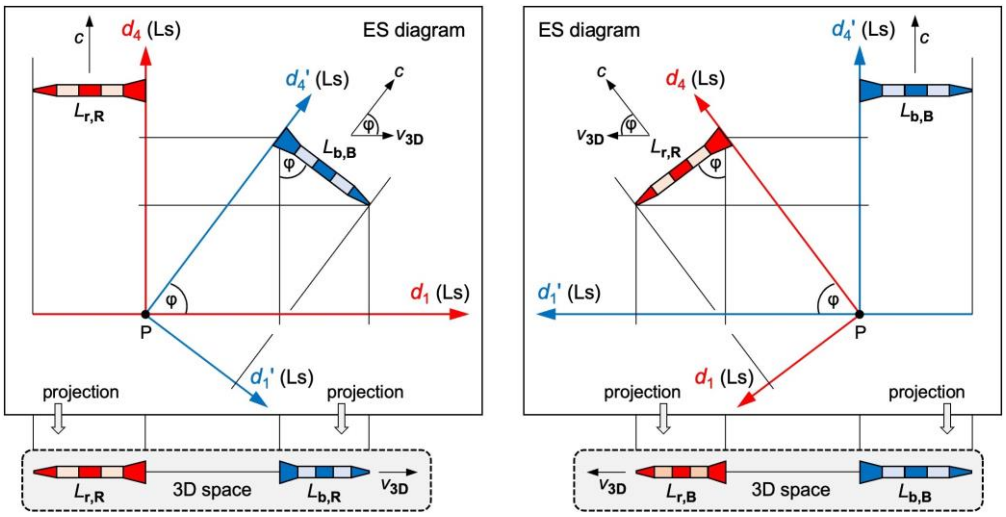

Fig. 3 ES diagrams and 3D projections of two rockets "r" (red) and "b" (blue). **Top:** Both rockets move in different 4D directions at the speed c. **Bottom left:** Projection to the 3D space of R. Rocket "b" contracts to $L_{\mathrm{b,R}}$. **Bottom right:** Projection to the 3D space of B. Rocket "r" contracts to $L_{\mathrm{r,B}}$

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

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

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

where $\gamma = (1 - v_{3\mathrm{D}}^2/c^2)^{-0.5}$ is the same Lorentz factor as in SR. For R, rocket "b" contracts to $L_{\mathrm{b,R}}$. We now ask: Which distances will R observe in d_4? We continue the rotation of rocket "b" until $\varphi = 0$, that is, until "b" serves as a ruler for R in d_4. In his 3D space, this ruler contracts to a point: *The d_4 axis disappears for R because of length contraction at the speed c.* In a second step, we project the blue rocket in Fig. 3 top left to the d_4 axis.

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

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

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

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

where $d_{4,\mathrm{R}}$ is the distance that R moved in d_4. Eqs. (9) and (12) tell us: γ is recovered in ER if we project ES to the axes d_1 and d_4 of an observer. The rockets serve as an example. All other objects are projected the same way to an observer's reality. For an overview of orthogonal projections, the reader is referred to geometry textbooks [19, 20].

 doi:10.20944/preprints202207.0399.v80

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

$$d_{1,\mathrm{R}}(\theta) = d_{1,\mathrm{R}}(\theta_0) \ , \tag{13a}$$

$$d_{2,\mathrm{R}}(\theta) = d_{2,\mathrm{R}}(\theta_0) \ , \qquad d_{3,\mathrm{R}}(\theta) = d_{3,\mathrm{R}}(\theta_0) \ , \tag{13b}$$

$$d_{4,\mathrm{R}}(\theta) = d_{4,\mathrm{R}}(\theta_0) + c\,(\theta - \theta_0) \ . \tag{13c}$$

$$d'_{1,\mathrm{B}}(\theta) = d'_{1,\mathrm{B}}(\theta_0) \ , \tag{14a}$$

$$d'_{2,\mathrm{B}}(\theta) = d'_{2,\mathrm{B}}(\theta_0) \ , \qquad d'_{3,\mathrm{B}}(\theta) = d'_{3,\mathrm{B}}(\theta_0) \ , \tag{14b}$$

$$d'_{4,\mathrm{B}}(\theta) = d'_{4,\mathrm{B}}(\theta_0) + c\,(\theta - \theta_0) \ . \tag{14c}$$

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

$$d'_{1,\mathrm{R}}(\theta) = d_{4,\mathrm{R}}(\theta)\,\cos\varphi = d_{4,\mathrm{R}}(\theta)\,v_{3\mathrm{D}}/c \ , \tag{15a}$$

$$d'_{2,\mathrm{R}}(\theta) = d_{2,\mathrm{R}}(\theta) \ , \qquad d'_{3,\mathrm{R}}(\theta) = d_{3,\mathrm{R}}(\theta) \ , \tag{15b}$$

$$d'_{4,\mathrm{R}}(\theta) = d_{4,\mathrm{R}}(\theta)\,\sin\varphi = d_{4,\mathrm{R}}(\theta)\,\gamma^{-1} \ . \tag{15c}$$

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

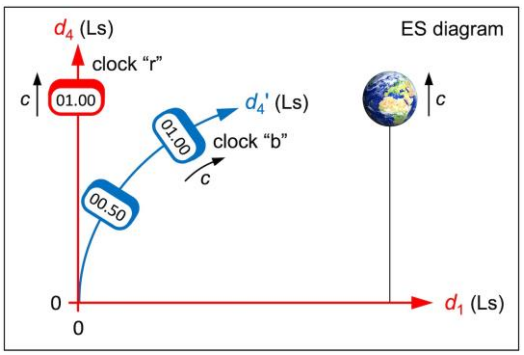

Fig. 4 ES diagram of two identical clocks "r" (red) and "b" (blue). Clock "r" and Earth move in the d_4 axis of "r" at the speed c. Clock "b" accelerates in the d_1 axis of "r" toward Earth

Gravitational waves [21] support the idea of GR that gravity is a feature of spacetime. In ER, the SO(4) symmetry of ES is incompatible with waves. This is fine because wave is an empirical concept and thus described by SR/GR. However, a natural concept of force and field has yet to be defined, which manifests itself as a force or a field in an observer's reality. "Process" is a promising natural concept of force and field. A typical process is the transfer of energy or momentum [22]. As an example, we now recover gravitational time dilation in ER. Let us consider the process "transfer of potential energy to kinetic energy". Initially, our clocks "r" and "b" are very far away from Earth. Eventually, "b" falls freely toward Earth (see Fig. 4). The kinetic energy of "b" in d_1 is

 doi:10.20944/preprints202207.0399.v80

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

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 Earth's center. By applying Eq. (7), we obtain

$$u_{4,\mathrm{b}}^2 = c^2 - u_{1,\mathrm{b}}^2 = c^2 - 2GM/R \ . \tag{17}$$

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

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

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

where $\gamma_{\mathrm{gr}} = (1 - 2GM/(Rc^2))^{-0.5}$ is the same dilation factor as in GR. Eq. (19) tells us: γ_{gr} is recovered in ER if we project ES to the d_4 axis of an observer. *I derived* γ_{gr} *from a process.* More studies are required to confirm that process is the natural concept of force and field. Since field is an empirical concept, there are no field equations in ER.

Summary of time dilation: In SR, a uniformly moving clock "b" is slow with respect to "r" in the time dimension of "b". In GR, an accelerating clock "b" or a clock "b" in a stronger gravitational field is slow with respect to "r" in the time dimension of "b". In ER, a clock "b" is slow with respect to "r" in the time dimension of "r" (!) if the 4D vectors $\boldsymbol{\tau}$ of "r" and $\boldsymbol{\tau}'$ of "b" are not the same. Since both dilation factors γ and γ_{gr} are recovered in ER, the results of the Hafele–Keating experiment [23] do not only support SR/GR but also ER. Thus, GPS satellites work in ER as well as in SR/GR.

Three instructive problems teach us how to read ES diagrams correctly (see Fig. 5). Problem 1: In billiards, the blue ball is approaching the red ball. In ES, both balls move at the speed c. Let the red ball move in its d_4 axis. As the blue ball covers distance in d_1, its speed in d_4 must be less than c. *How can the balls ever collide if their* d_4 *values do not match?* Problem 2: A rocket moves along a guide wire. In ES, both objects move at the speed c. Let the wire move in its d_4 axis. As the rocket covers distance in d_1, its speed in d_4 must be less than c. *Doesn't the wire escape from the rocket?* Problem 3: Earth orbits the sun. In ES, both objects move at the speed c. Let the sun move in its d_4 axis. As Earth covers distance in d_1, d_2, its speed in d_4 must be less than c. *Doesn't the sun escape from Earth?*

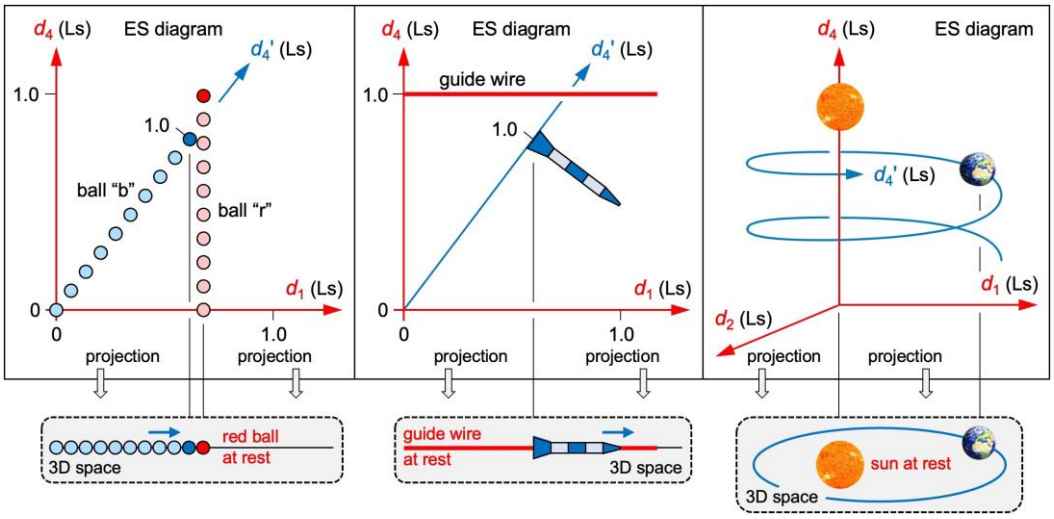

Fig. 5 Solving three instructive problems in ER. Each snapshot shows one instant in cosmic time. **Left:** The blue ball "b" is approaching the red ball "r". In the 3D space of "r", the balls collide. **Center:** A rocket moves along a wire. In the 3D space of the wire, the wire does not escape from the rocket. **Right:** Earth orbits the sun. In the 3D space of the sun, the sun does not escape from Earth

 doi:10.20944/preprints202207.0399.v80

The questions in the last paragraph seem to disclose paradoxes in ER. The fallacy lies in the assumption that all four dimensions of ES would be spatial. We solve all problems by projecting ES to the 3D space of the object that moves in d_4 at the speed c. In its 3D space, it is at rest. We see the solutions in the ES diagrams, too, if we read them correctly: In Fig. 5 left, "r" and "b" collide if $d_{i,\mathrm{r}} = d_{i,\mathrm{b}}$ $(i = 1, 2, 3)$ and if the same proper time has elapsed for both balls ($d_{4,\mathrm{r}} = d'_{4,\mathrm{b}}$). *Thus, a collision in 3D space does not show up as a collision in ES.* This is reasonable because only three axes of ES are experienced as spatial. For the same reason, the wire (or the sun) does not spatially escape from the rocket (or else Earth). ES is not (!) a 4D space as often claimed. Objects moving in 4D space at the speed c would be causally disconnected. ES diagrams are *flow diagrams* showing the flow of proper time. Spacetime diagrams in SR/GR are *event diagrams* showing events (collisions etc.).

5. Outlining the Solutions to 15 Fundamental Mysteries

We recall: (1) An observer's reality is a projection from ES. (2) Cosmic time θ is the correct parameter for a holistic view. In Sects. 5.1 through 5.15, I outline the solutions to 15 fundamental mysteries and declare four concepts of today's physics obsolete.

5.1. The Mystery of Time

Proper time τ is what a clock measures. Cosmic time θ is the total distance covered in ES divided by c. An observer's clock always displays both quantities: his τ and θ. An observer's 4D vector $\boldsymbol{\tau}$ may differ from an observed clock's 4D vector $\boldsymbol{\tau}'$.

5.2. The Mystery of Time's Arrow

Time's arrow is a synonym for "time moving only forward". The arrow emerges from the fact that covered distance (d_4 or total distance) cannot decrease but only increase.

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

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

$$E = \gamma mc^2 = E_{\mathrm{kin,3D}} + mc^2 \,, \tag{20}$$

where $E_{\mathrm{kin,3D}}$ is its kinetic energy in an observer's 3D space and mc^2 is called its "energy at rest". SR does not tell us why there is a factor c^2 in the energy of objects that in SR do not move at the speed c. ER gives us the missing clue: The object is never at rest but moves in its d'_4 axis. From the object's perspective, $E_{\mathrm{kin,3D}}$ is zero and mc^2 is its kinetic energy in d'_4. The factor c^2 is a hint that it moves through ES at the speed c. In SR, there is

$$E^2 = p^2\,c^2 = p_{\mathrm{3D}}^2\,c^2 + m^2\,c^4 \,, \tag{21}$$

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

5.4. The Mystery of Length Contraction and Time Dilation

In SR, length contraction and time dilation can be traced back to Einstein's instruction for synchronizing clocks, but this is just a measurement instruction. ER discloses that they stem from projecting absolute ES to the axes d_1 and d_4 of an observer.

5.5. The Mystery of Gravitational Time Dilation

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

 doi:10.20944/preprints202207.0399.v80

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

In Sects. 5.6 through 5.12, I outline an ER-based model of cosmology. As a mathematical manifold, ES is timeless like numbers. In particular, ES is not inflating/expanding. For some reason, there was a Big Bang. In the inflationary Lambda-CDM model, the Big Bang occurred "everywhere" (space inflated from a singularity). In the ER-based model, the Big Bang is locatable: A huge amount of energy was injected into ES at an "origin O". Cosmic time θ is the total time that has elapsed since the Big Bang. At $\theta = 0$, all available energy started moving radially away from O. *The Big Bang was a singularity in providing energy and radial momentum.* Shortly after $\theta = 0$, energy was highly concentrated. While this energy was moving away from O, plasma particles were created in the projection to any 3D space. Recombination radiation was emitted that we still observe as CMB today [24].

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

5.7. The Mystery of the Hubble–Lemaître Law

In Fig. 6 left, Earth and a galaxy G recede from the origin O of ES. In Earth's 3D space, G recedes from Earth at the 3D speed v_{3D}. According to my first postulate, v_{3D} relates to the 3D distance D of G to Earth as c relates to the radius r of a 4D hypersphere.

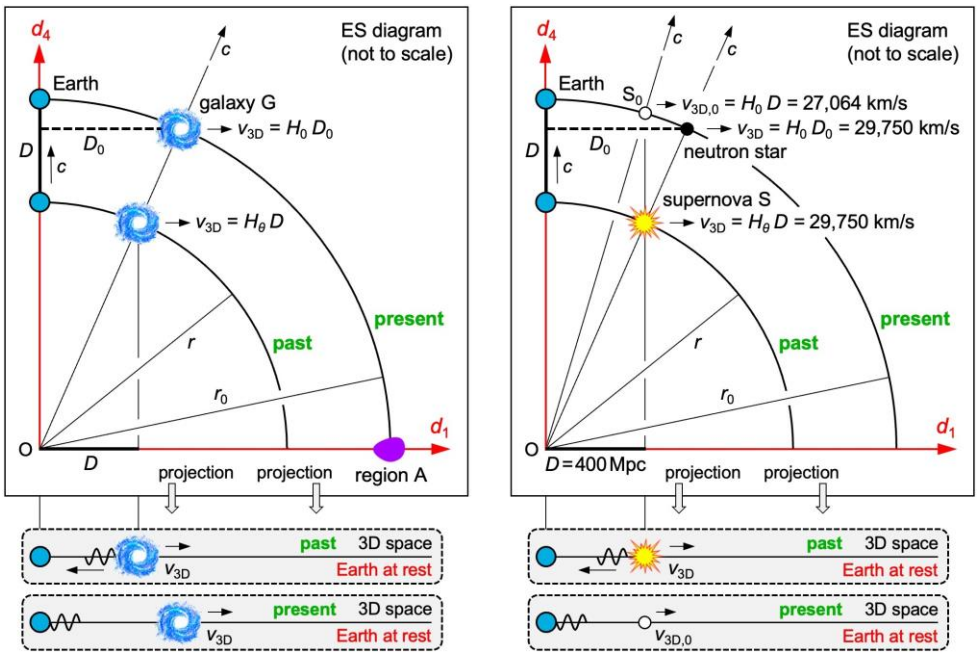

Fig. 6 ER-based model of cosmology. The circular arcs are part of an expanding 3D hypersurface. **Left:** Galaxy G recedes from the origin O of ES (location of the Big Bang) at the speed c, and from the d_4 axis in particular at the 3D speed v_{3D}. **Right:** If star S_0 happens to be at the same distance D today at which the supernova of star S occurred, S_0 recedes more slowly from Earth than S

$$v_{3D} = D\,c/r = H_\theta\,D\ , \tag{22}$$

where $H_\theta = c/r = 1/\theta$ is the Hubble parameter. If we observe G today at the cosmic time θ_0, the recession speed v_{3D} and c remain unchanged. Thus, Eq. (22) turns into

$$v_{3D} = D_0\,c/r_0 = H_0\,D_0\ , \tag{23}$$

 doi:10.20944/preprints202207.0399.v80

where $H_0 = c/r_0 = 1/\theta_0$ is the Hubble constant, $D_0 = D\, r_0/r$ is today's 3D distance of G to Earth, and r_0 is today's radius of the 4D hypersphere. Eq. (23) is the correct Hubble–Lemaître law [25, 26]. Cosmologists are aware of the Hubble parameter and of the quantity "cosmic time". They are not yet aware that the 4D geometry is Euclidean, that v_{3D} is equal to $H_0\, D_0$ rather than to $H_0\, D$, and that there is no acceleration. Out of any two galaxies, the one farther away recedes faster, but each galaxy maintains its 3D speed v_{3D}.

5.8. The Mystery of the Flat Universe

For each observer, ES is orthogonally projected to his proper space and to his proper time. Thus, he experiences two seemingly discrete structures: flat 3D space and time.

5.9. The Mystery of Cosmic Inflation

Most cosmologists [27, 28] believe that an inflation of space shortly after the Big Bang explains the isotropic CMB, the flat universe, and large-scale structures. The latter inflated from quantum fluctuations. I just showed that ER explains the first two effects. ER even explains large-scale structures if the impacts of quantum fluctuations have been expanding like the 4D hypersphere. ***In ER, cosmic inflation is an obsolete concept.***

5.10. The Mystery of Cosmic Homogeneity (Horizon Problem)

How can the universe be so homogeneous if there are causally disconnected regions of space? In the Lambda-CDM model, a region A at $x_1 = +r_0$ and a region B at $x_1 = -r_0$ are causally disconnected unless we postulate a cosmic inflation. Without it, information could not have covered $2r_0$ since the Big Bang. ER solves the problem without a cosmic inflation: In Fig. 6 left, A is at $d_1 = +r_0$ and B is at $d_1 = -r_0$ (not shown). From A's or B's perspective, their d_4' axis (equal to Earth's d_1 axis) disappears because of length contraction at the speed c. *A and B are causally connected because they overlap spatially in either reality.* Their opposite 4D vectors $+\boldsymbol{\tau}'$ and $-\boldsymbol{\tau}'$ do not affect causal connectivity.

5.11. The Mystery of the Hubble Tension

Up next, I explain why the published values of the Hubble constant H_0 do not match each other (also known as the "Hubble tension"). I compare CMB measurements (Planck space telescope) with calibrated distance ladder measurements (Hubble space telescope). According to team A [29], there is $H_0 = 67.66 \pm 0.42$ km/s/Mpc. According to team B [30], there is $H_0 = 73.04 \pm 1.04$ km/s/Mpc. Team B made efforts to minimize the error margins in the distance measurements. However, there is a systematic error in team B's calculation of H_0, which arises from assuming a wrong cause of the redshifts.

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

$$1/H_\theta \;=\; r/c \;=\; (r_0 - D)/c \;=\; 1/H_0 \;-\; D/c\ . \qquad (24)$$

For a very short distance of $D = 400$ kpc, Eq. (24) tells us that H_θ deviates from H_0 by only 0.009 percent. When plotting v_{3D} versus D for distances from 0 Mpc to 500 Mpc in steps of 25 Mpc (red points in Fig. 7), the slope of a straight-line fit through the origin is roughly 10 percent greater than H_0. Since team B calculates H_0 from relating z to magnitude, which is like plotting v_{3D} versus D, its value of H_0 is roughly 10 percent too high. *This solves the Hubble tension.* Team B's value is not correct because, according to Eq. (23), we must plot v_{3D} versus D_0 (!) to get a straight line (blue points in Fig. 7).

 doi:10.20944/preprints202207.0399.v80

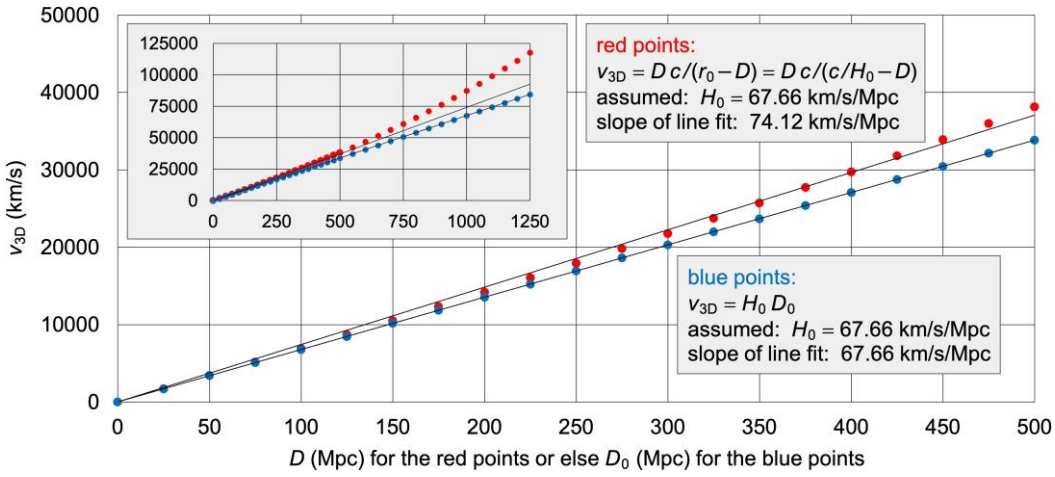

Fig. 7 Hubble diagram of simulated supernovae at distances up to 1250 Mpc. The horizontal axis is D for the red points or else D_0 for the blue points. The red points were calculated from Eq. (22). They do not yield a straight line because H_θ is not a constant. The blue points were calculated from Eq. (23). They yield a straight line if we do not confuse D_0 with D

Since we cannot measure D_0 (observable magnitudes relate to D and not to D_0), the easiest way to fix the calculation of team B is to rewrite Eq. (23) as

$$v_{3D,0} = D\,c/r_0 = H_0\,D\ , \tag{25}$$

where $v_{3D,0}$ is today's 3D speed of another star S_0 (see Fig. 6 right) that happens to be at the same distance D today at which the supernova of star S occurred. I kindly ask team B to recalculate H_0 after converting all v_{3D} to $v_{3D,0}$. To perform this conversion, we only have to combine Eq. (24) with Eq. (25) and then with Eq. (22). This gives us

$$H_\theta = H_0\,c/(c - H_0\,D) = H_0/(1 - v_{3D,0}/c)\ , \tag{26}$$

$$v_{3D,0} = v_{3D}/(1 + v_{3D}/c)\ . \tag{27}$$

By applying Eq. (27) and plotting $v_{3D,0}$ versus D, all red points in Fig. 7 drop down to the blue points. However, Fig. 7 does not only solve the Hubble tension. The figure also tells us: The more high-redshift data are included in team B's calculation, the more data deviate from the straight line with the slope H_0, and the more the H_0 tension increases. The moment of the supernova is irrelevant to team B's calculation of H_0. All that counts in the Lambda-CDM model is the duration of the light's journey to Earth. The parameter z continuously increases during the journey. In the ER-based model, all that counts is the moment of the supernova. Each wavelength is initially redshifted by the Doppler effect. The parameter z remains constant during the journey. It was specified at the moment of the supernova. Space is not expanding. Rather, energy is receding from the origin O of ES (location of the Big Bang). ***In ER, expanding space is an obsolete concept.***

5.12. The Mystery of Dark Energy

Team B can fix the systematic error in its calculation of H_0 by converting all v_{3D} to $v_{3D,0}$ according to Eq. (27). I now reveal another systematic error, but it is inherent in the Lambda-CDM model. It stems from assuming an accelerating expansion of space and can be fixed only by replacing this model with the ER-based model unless we postulate a dark energy. Most cosmologists [31, 32] believe in an accelerating expansion because the calculated recession speeds v_{3D} deviate from a straight line in the Hubble diagram (if v_{3D} is plotted versus D) and because the deviations increase with D. An accelerating expansion would indeed stretch each wavelength even further and explain the deviations.

 doi:10.20944/preprints202207.0399.v80

In ER, the explanation of the deviations is less speculative: The older the redshift data are, the more H_θ deviates from H_0, and the more v_{3D} deviates from $v_{3D,0}$. If another star S_0 (see Fig. 6 right) happens to be at the same distance of $D = 400$ Mpc today at which the supernova of star S occurred, Eq. (27) tells us: S_0 recedes more slowly (27,064 km/s) from Earth than S (29,750 km/s). *It does so because of the geometry.* As long as cosmologists are not aware that the 4D geometry is Euclidean, they hold dark energy [33] responsible for an accelerating expansion of space. Dark energy has not been confirmed. It is a stopgap for an effect that the Lambda-CDM model cannot explain. Older supernovae recede faster not because of an accelerating expansion but because of a larger H_θ in Eq. (22).

The Hubble tension and dark energy are solved exactly the same way: *In Eq. (23), we must not confuse D_0 with D.* Because of Eq. (22) and because of $H_\theta = c/(r_0 - D)$, the recession speed v_{3D} is not proportional to D but to $D/(r_0 - D)$. This is why the red points in Fig. 7 run away from a straight line. Any expansion of space (uniform or accelerating) is only virtual. There is no accelerating expansion of space even if the Nobel Prize in Physics 2011 was given "for the discovery of the accelerating expansion of the Universe through observations of distant supernovae". This particular prize was given for something that does not really exist. In the Lambda-CDM model, the word "Universe" implies space, but space is not expanding. Most galaxies do recede from Earth, yet they do so uniformly in a non-expanding ES. ***In ER, dark energy is an obsolete concept.***

This casts doubt on the Lambda-CDM model but not on GR. Galaxies are driven by their momentum. Shortly after $\theta = 0$, all energy moved radially away from the origin O. Because of physical interactions, some energy accelerated transversally while maintaining the speed c. This is why some galaxies move toward Earth today. In Table 1, two models of cosmology are compared. Note that "Universe" and "universe" are not the same thing. Observers may experience different universes. In Sects. 5.6 through 5.12, natural concepts prove useful in cosmology. In Sect. 5.13 and 5.14, they also prove useful in QM.

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

Table 1 Comparing two different models of cosmology

5.13. The Mystery of the Wave–Particle Duality

The wave–particle duality was first discussed by Niels Bohr and Werner Heisenberg [34] and has bothered physicists ever since. Electromagnetic waves are oscillations of an electromagnetic field, which propagate through an observer's 3D space at the speed c. In some experiments, objects behave like waves. In other experiments, the very same objects behave like particles (also known as the "wave–particle duality"). In today's physics, one object cannot be wave and particle at once because the energy of a wave is distributed in space, whereas the energy of a particle is always localized in space.

In order to solve the duality, we make use of two natural concepts: "Pure distance" replaces spatial/temporal distance. "Pure energy" replaces wave/particle. My neologism "wavematter" visualizes pure energy (see Fig. 8). In an observer's reality (external view), a wavematter appears as a wave packet or as a particle. As a wave, it propagates in his x_1 axis at the speed c and it oscillates in his axes x_2 and x_3 (electromagnetic field). Since

 doi:10.20944/preprints202207.0399.v80

here we talk about an observer's reality, the wave propagates and oscillates as a function of coordinate time. In its own reality (internal view), the axis of the wavematter's 4D motion disappears because of length contraction at the speed c. It deems itself particle at rest. "Wavematter" is not a substitute word for the duality. Rather, it visualizes a natural concept of energy that takes the internal view of photons into account.

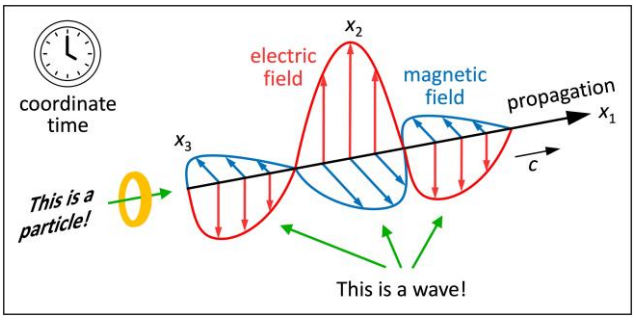

Fig. 8 Illustration of a wavematter. In an observer's reality (external view), a wavematter appears as a wave packet or as a particle. As a wave (shown here), it propagates and oscillates as a function of coordinate time. In its own reality (internal view), the axis of the wavematter's 4D motion disappears because of length contraction at the speed c. It deems itself particle at rest

Wave and particle are empirical concepts, just like spatial and temporal distance, and they are relative too: *What I deem wave, deems itself particle at rest.* For each wavematter, its pure energy "condenses" (concentrates) to what we call "mass". Albert Einstein taught us that energy and mass are equivalent [35]. Likewise, a wave's polarization and a particle's spin are equivalent. My neologism "wavematter" phrases this equivalence.

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

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

5.14. The Mystery of Quantum Entanglement

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

Up next, I show that there is no violation in four dimensions. All we need to untangle entanglement is ER: Non-locality becomes obsolete because all four d_μ $(\mu = 1, 2, 3, 4)$ are interchangeable. Fig. 9 illustrates two wavematters that were created at once at a point P. They move away from each other in opposite 4D directions $\pm d_4'$ at the speed c. It turns out that they are automatically entangled. For an observer moving in any direction other than $\pm d_4'$ (external view), the two wavematters are *spatially* separated. The observer has no idea how they are able to "communicate" with each other in no time.

 doi:10.20944/preprints202207.0399.v80

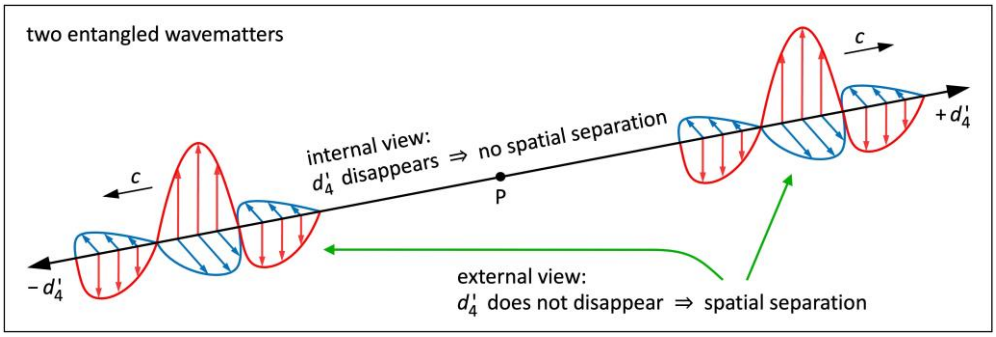

Fig. 9 Two wavematters moving in $\pm d_4'$ at the speed c are spatially separated for an observer moving in any direction other than $\pm d_4'$ (external view). For each wavematter (internal view), the d_4' axis disappears. From the internal view, the twins have never been spatially separated

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

This time, the horizon problem and entanglement are solved exactly the same way: *An observer's 4D vector* $\boldsymbol{\tau}$ *and his 3D space may differ from an observed region's (or object's) 4D vector* $\boldsymbol{\tau}'$ *and its 3D space.* This is possible only if all four d_μ ($\mu = 1, 2, 3, 4$) are interchangeable. ER also explains the entanglement of matter, such as electrons [43]. In an observer's 3D space, electrons move at a speed $v_{3D} < c$. In their $\pm d_4'$ axis, electrons always move at the speed c. Any measurement tilts the axis of 4D motion of one twin and thus destroys the entanglement. ***In ER, non-locality is an obsolete concept.***

5.15. The Mystery of the Baryon Asymmetry

In the Lambda-CDM model, almost all matter was created shortly after the Big Bang. Only then was the temperature high enough to enable pair production. But pair production creates equal amounts of baryons and antibaryons. So, why do we observe more baryons than antibaryons today (also known as the "baryon asymmetry")? ER scores again: Energy manifests itself as wavematters, and each wavematter deems itself particle at rest. I solve this mystery at the end because it requires my concept of wavematter.

But why do wavematters not deem themselves antiparticles at rest? Well, antiparticles are not the opposite of particles but particles with the opposite electric charge. They are created in pair production only. Being an antiparticle is relative: *What I deem antiparticle, deems itself particle.* Thus, the "character paradox" [10] is reasonable. We may conclude: The baryon asymmetry is only virtual. The asymmetry disappears as soon as we describe nature in natural concepts. ER also explains why it seems that time flows backward for an antiparticle. Proper time flows in opposite 4D directions for any two wavematters created in pair production. According to Sect. 5.14, these two wavematters should be entangled. This gives us a chance to falsify ER. Scientific theories must be falsifiable [44].

6. Conclusions

ER solves many unsolved mysteries (time's arrow, Hubble tension, wave–particle duality, baryon asymmetry) and other mysteries that have already been solved but only by adding obsolete concepts (cosmic inflation, expanding space, dark energy, non-locality). This is a perfect example of where to apply Occam's razor. It shaves off all these obsolete concepts. Period. I conclude: (1) ER describes the master reality ES. (2) SR/GR describe all observers' realities. (3) ER neither replaces nor extends SR/GR but holds additional information that is hidden in absolute time and thus not available in SR/GR.

 doi:10.20944/preprints202207.0399.v80

SR/GR are considered two of the greatest achievements of physics because they have been confirmed over and over. I showed that SR/GR do not provide a holistic view. Physics got stuck in its own concepts. The stagnation in physics is of its own making. ER solves 15 mysteries of cosmology and QM purely geometrically, that is, without forces and fields. It is very unlikely that 15 solutions in different areas of physics are 15 coincidences. *Only in natural concepts does Mother Nature disclose her secrets.* If we think of an observer's reality as an oversized stage, the key to understanding nature is beyond all stages.

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

Is ER a physical or a metaphysical theory? This is a very good question because only in proper coordinates can we access ES, but the proper coordinates of other objects cannot be measured. I now explain why this is not an issue: We can always calculate these proper coordinates from ES diagrams as I showed in Eqs. (13a–15c). Measuring is an observer's source of knowledge, but ER tells us not to interpret too much into whatever we measure. Measurements are wedded to observers, whose concepts may be obsolete. Unfortunately, physics has applied empirical concepts—which work well in our everyday world—to the very large and to the very small. This is why cosmology and QM profit the most from ER. *ER is a physical theory because it solves fundamental mysteries of physics.*

Final remarks: (1) I only touched on gravity. We must not reject ER because gravity is still an issue. GR seems to solve gravity, but GR is incompatible with QM unless we add another speculative concept (quantum gravity). More studies are required to understand gravitational effects in ER. (2) I only touched on processes. I gave one example in Sect. 4. More studies are required to confirm that process is the natural concept of force and field. (3) Mysteries often disappear if we match the symmetry. SO(4) is the symmetry group in cosmology and QM. (4) The invariant θ puts an end to all speculations about time travel. Does any other theory solve the mystery of time's arrow as beautifully as ER? (5) Physics does not ask: Why is my reality a projection? Nor does it ask: Why is it a wave function? Projections are far less speculative than postulating cosmic inflation and expanding space and dark energy and non-locality. (6) It looks like Plato's *Allegory of the Cave* [46] is correct: Mankind experiences projections that are blurred—because of QM.

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

Acknowledgements: I thank Siegfried W. Stein for his contributions to Sect. 5.11 and for the Figs. 3, 5 center, and 6 (partly). After several unsuccessful submissions, he eventually decided to withdraw his co-authorship. I also thank Matthias Bartelmann, Dirk Rischke, Jürgen Struckmeier, and Andreas Wipf for asking questions and commenting. In particular, I thank all peer reviewers and editors for the precious time that they spent on grappling with my manuscript.

Comments: It takes open-minded, courageous editors and peer reviewers to evaluate a theory that heralds a paradigm shift. Whoever adheres to established concepts paralyzes the scientific progress. I did not surrender when top journals rejected my theory. Interestingly, I was never given any solid arguments that would disprove my theory. Rather, I was asked to try a different journal. Were the

 doi:10.20944/preprints202207.0399.v80

editors dazzled by the success of SR/GR? Did they underestimate the benefits of ER? It seems to me that most editors were afraid of considering a new theory that opposes the mainstream. Even friends refused to support me. Anyway, each setback inspired me to work out the benefits of ER even better. Finally, I succeeded in disclosing a physical issue in SR/GR and also in formulating a holistic theory of spacetime, which is even more general than Albert Einstein's "general" relativity.

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

Conflict of interest: The author has no conflicts to disclose.

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

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

References

1. Einstein, A.: Zur Elektrodynamik bewegter Körper. Ann. Phys. **322,** 891–921 (1905)
2. Einstein, A.: Die Grundlage der allgemeinen Relativitätstheorie. Ann. Phys. **354,** 769–822 (1916)
3. Minkowski, H.: Die Grundgleichungen für die elektromagnetischen Vorgänge in bewegten Körpern. Math. Ann. **68,** 472–525 (1910)
4. Rossi, B., Hall, D.B.: Variation of the rate of decay of mesotrons with momentum. Phys. Rev. **59,** 223–228 (1941)
5. Dyson, F.W., Eddington, A.S., Davidson, C.: A determination of the deflection of light by the sun's gravitational field, from observations made at the total eclipse of May 29, 1919. Phil. Trans. R. Soc. A **220,** 291–333 (1920)
6. Ashby, N.: Relativity in the global positioning system. Living Rev. Relativ. **6,** 1–42 (2003)
7. Ryder, L.H.: Quantum Field Theory. Cambridge University Press, Cambridge (1985)
8. Newburgh, R.G., Phipps Jr., T.E.: Physical Sciences Research Papers no. 401. United States Air Force (1969)
9. Montanus, H.: Special relativity in an absolute Euclidean space-time. Phys. Essays **4,** 350–356 (1991)
10. Montanus, H.: Proper Time as Fourth Coordinate (ISBN 978-90-829889-4-9, 2023). https://greenbluemath.nl/proper-time-as-fourth-coordinate/. Accessed 26 November 2024
11. Montanus, J.M.C.: Proper-time formulation of relativistic dynamics. Found. Phys. **31,** 1357–1400 (2001)
12. Almeida, J.B.: An alternative to Minkowski space-time. arXiv:gr-qc/0104029
13. Gersten, A.: Euclidean special relativity. Found. Phys. **33,** 1237–1251 (2003)
14. Newton, I.: Philosophiae Naturalis Principia Mathematica. Joseph Streater, London (1687)
15. Kant, I.: Kritik der reinen Vernunft. Hartknoch, Riga (1781)
16. Hudgin, R.H.: Coordinate-free relativity. Synthese **24,** 281–297 (1972)
17. Misner, C.W., Thorne, K.S., Wheeler, A.: Gravitation. W.H. Freeman and Company, San Francisco (1973)
18. Wick, G.C.: Properties of Bethe-Salpeter wave functions. Phys. Rev. **96,** 1124–1134 (1954)
19. Church, A.E., Bartlett, G.M.: Elements of Descriptive Geometry. Part I. Orthographic Projections. American Book Company, New York (1911)
20. Nowinski, J.L.: Applications of Functional Analysis in Engineering. Plenum Press, New York (1981)
21. Abbott, B.P. et al.: Observation of gravitational waves from a binary black hole merger. Phys. Rev. Lett. **116,** 061102 (2016)
22. Kalies, G., Do, D.D.: Momentum work and the energetic foundations of physics. I. Newton's laws of motion tailored to processes. AIP Adv. **13,** 065121 (2023)
23. Hafele, J.C., Keating, R.E.: Around-the-world atomic clocks: Predicted relativistic time gains. Science **177,** 166–168 (1972)
24. Penzias, A.A., Wilson R.W.: A measurement of excess antenna temperature at 4080 Mc/s. Astrophys. J. **142,** 419–421 (1965)
25. Hubble, E.: A relation between distance and radial velocity among extra-galactic nebulae. Proc. Natl. Acad. Sci. U.S.A. **15,** 168–173 (1929)
26. Lemaître, G.: Un univers homogène de masse constante et de rayon croissant, rendant compte de la vitesse radiale des nébuleuses extra-galactiques. Ann. Soc. Sci. Bruxelles A **47,** 49–59 (1927)
27. Linde, A.: Inflation and Quantum Cosmology. Academic Press, Boston (1990)
28. Guth, A.H.: The Inflationary Universe. Perseus Books, New York (1997)

29. Aghanim, N. et al.: Planck 2018 results. VI. Cosmological parameters. Astron. Astrophys. **641,** A6 (2020)
30. Riess, A.G. et al.: A comprehensive measurement of the local value of the Hubble constant with 1 km s^{-1} Mpc^{-1} uncertainty from the Hubble Space Telescope and the SH0ES team. Astrophys. J. Lett. **934,** L7 (2022)
31. Perlmutter, S. et al.: Measurements of Ω and Λ from 42 high-redshift supernovae. Astrophys. J. **517,** 565–586 (1999)
32. Riess, A.G. et al.: Observational evidence from supernovae for an accelerating universe and a cosmological constant. Astron. J. **116,** 1009–1038 (1998)
33. Turner, M.S.: Dark matter and dark energy in the universe. arXiv:astro-ph/9811454
34. Heisenberg, W.: Der Teil und das Ganze. Piper, Munich (1969)
35. Einstein, A.: Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig? Ann. Phys. **323,** 639–641 (1905)
36. Jönsson, C.: Elektroneninterferenzen an mehreren künstlich hergestellten Feinspalten. Z. Phys. **161,** 454–474 (1961)
37. Schrödinger, E.: Die gegenwärtige Situation in der Quantenmechanik. Naturwissenschaften **23,** 807–812 (1935)
38. Einstein, A., Podolsky, B., Rosen, N.: Can quantum-mechanical description of physical reality be considered complete? Phys. Rev. **47,** 777–780 (1935)
39. Bell, J.S.: On the Einstein Podolsky Rosen paradox. Physics **1,** 195 (1964)
40. Freedman, S.J., Clauser, J.F.: Experimental test of local hidden-variable theories. Phys. Rev. Lett. **28,** 938–941 (1972)
41. Aspect, A., Dalibard, J., Roger, G.: Experimental test of Bell's inequalities using time-varying analyzers. Phys. Rev. Lett. **49,** 1804–1807 (1982)
42. Bouwmeester, D., Pan, J.-W., Mattle, K., Eibl, M., Weinfurter,H., Zeilinger, A.: Experimental quantum teleportation. Nature **390,** 575–579 (1997)
43. Hensen, B. et al.: Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres. Nature **526,** 682–686 (2015)
44. Popper, K.: Logik der Forschung. Julius Springer, Vienna (1935)
45. Einstein, A.: Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. Ann. Phys. **322,** 132–148 (1905)
46. Plato: Politeia, 514a