diepro01e.docx

the general science journal

The *Euclid*ean universe–An alternative theory of relativity

Dieter Prochnow, Berlin
Mail: du.prochnow@t-online.de

Keywords: four-dimensional *Euclid*ean universe, clock time, *Galilei*-time, space-time-related *Galilei*-transformation.

As an alternative to *Einstein'*s theory of relativity, a four-dimensional *Euclid*ean, hence flat, universe, based on a space-time-related *Galilei* transformation, is founded. As far as possible, Einstein's principles of relativity are also taken into account.
In the *Euclid*ean universe, gravity is to be understood as conservative force that changes the density distribution of the mass-charged particles. The local density distribution generates a potential energy and, with it, a conservative force that induces (without warping space-time) a relative movement of the mass points. As a result, the density distribution is now changed again. In the course of this, the gravity potential depends on Newton's potential. Accelerated particle movements are admitted.
Cause-effect relationships between events presuppose the events to be in order. The order is realized by the time-like (fourth) coordinate of the mass points in space-time. The laws of *Newtonian* physics that apply invariant to form in all systems of the universe have to be related then in their time-dependent formulation to the time-like coordinate. Accordingly, the coordinate time of the time-like coordinate orders the events of a universe in the sequence of their occurrence. In the *Euclid*ean universe, the coordinate time of the time-like coordinate is an invariant of all systems and is therefore designated as *Galilei* time. In general, *Galilei* time durations are directly not measurable.
The measurable clock time duration in the *Euclid*ean universe coincides approximately only at small particle velocities with *Galilei* time duration. In general, clock time does not order events in the sequence of their occurrence, but it constitutes here a measure for the particle path length in the four-dimensional space-time, and therefore, is subject to a dilatation, however only seemingly. As a consequence, the tensor calculus cannot be applied to the alternative theory.
In comparison with Einstein's universe, the *Euclidean* universe has analogous properties caused by common principles as well as also contrary properties which allow to interpret experimental results without contradiction in another way (example: flight duration of muons). At this, the contrary properties mostly concern the relation of absoluteness and relativity of phenomena. Thus, the invariance of the simultaneousness of events is rehabilitated in the *Euclidean* university and there is no *Lorentz*-length contraction. The aging of matter supposed here to proceed at a finite and constant velocity is related to *Galilei* time. Consequently, aging takes place then in the same way in all systems. There is no twin paradox. The speed of light related to clock time is in fact constant and finite, but at the same time infinite with respect to *Galilei* time. Accordingly, we could suppose that in the *Euclid*ean universe, we do not perceive the past (even of remote objects, no matter how far the distance), but the present.

---

1. Introduction

In the 19th century, serious contradictions occurred within *Newtonian* physics in connection with insights into the propagation of light. In particular, the investigations done by *Michelson* and *Morley* [1] showed the constancy and finiteness of the speed of light independent of the reference system. Seemingly, these results were in contradiction with the classical relativity principle of *Newtonian* physics (*Galilei* transformation) and were incompatible with *Maxwell's* equations of electrodynamics.

By the 17th century, *Römer* had already conducted astronomical observations to assess the speed of light, and he used these observations to point to the finiteness of the speed of light [2]. Then, in the early 20th century, *Einstein* discovered the essential foundations for understanding and solving these contradictions, and he explained them in his theories of relativity [3-5]. In the decades that followed, these theories together with their fundamental principles were confirmed both theoretically and experimentally along in many respects (see, in particular [6–12]). But at the same time, also many doupts and reasonable objections have been raised toward Einstein's theories of relativity (see Borderlands of Science).

Minkowski contributed essential parts of the mathematical structure, especially by combination of space and time to a four-dimensional space-time, to the present special relativity theory (SRT) [13,14]. Moreover, he considered inertial systems to be four-dimensional pseudo-*Riemannian* spaces (*Minkowski* spaces) of a flat universe in which the mass points of space-time were described by three space-like coordinates and one time-like coordinate.

We suppose that the time-like coordinate always orders the events of the universe in the sequence of their occurrence and thus also controls the aging of matter.
The laws of *Newtonian* physics that in accordance with the covariance principle always apply invariantly to form in all admissible systems of a universe must consequently be related to the time-like coordinate in their formulation.

Einstein always identified the time measured by clocks as a coordinate time (linear function) of the time-like coordinate, which is the same as the inertial time in SRT. The *Minkowski* signature of spaces can be regarded as a consequence of this identification. Thus, clock time likewise orders events in the *Einstein*ian universe in the sequence of their occurrence and also monitors the course of aging. Below, we will call the validity of this assumption into question.

The linear mapping of a *Minkowski* space onto itself constitutes an automorphism group that is defined by the *Lorentz* transformation if in this context the line world element, determined by the metric of the space, is an invariant of the transformation.

In SRT, utilization of the *Lorentz* transformation [15] in place of the *Galilei* transformation removed the classical relativity principle of *Newtonian* physics and, as a result, made it possible to realize the principle of the constancy and finiteness of the speed of light, as well as the covariance principle of SRT. On the other hand, the application of the *Lorentz* transformation [16,17] went far beyond the framework of *Newton*ian physics (in our opinion, excessively far beyond)—quite apart from promoting subjective approaches in physics (the observer's point of view).

With the application of the *Lorentz* transformation, the *Newton*ian universe characterized by absolute properties became a universe to which essential phenomena are still only valid conditionally and system-dependently. Thus, the simultaneousness of events is no longer system-invariant [12]. The aging of matter happens contradictorily (twin paradox [18]). The inertial time must be amenable to dilatation, and the space-like magnitude of bodies is subject to the *Lorentz* contraction [15]. In particular, the *Lorentz* contraction in systems that are accelerated relative to one another, such as rotating systems, was going beyond the scope of *Euclid*ean geometry and thus beyond the framework of *Minkowski* systems. Therefore, in his general relativity theory (GRT) [5], which now included gravitation and acceleration, *Einstein* described a non-*Euclid*ean universe in which general *Gauss*ian systems of the *Minkowski* signature and nonlinear coordinate transformations are allowed. The gravity theory that was developed in this context constitutes a non-*Euclid*ean geometrization of gravitation by utilizing the properties of space-time curvature.

However, in the last few decades of the 20th century, precision measurements of cosmic background radiation performed by the high-altitude balloons COBE [19,20], BOOMERANG, and MAXIMA [21,22,23] yielded results, in accordance with inflation theory, indicating with a probability close to certainty that our universe is flat, at least on a large scale. There is no excluding that the universe might also be flat on small scales, and hence flat in its entirety.
The flatness of space-time would call into question the utilization of the *Lorentz* transformation, and with it also the relativity of phenomena in the universe.

The theoretical investigations described in this paper address the possibility of a flat universe and thus corroborate the verification of this supposition.
We substantiate a four-dimensional *Euclid*ean universe that is in agreement with the classical relativity principle of *Newton*ian physics, meaning, it admits space-time-related *Galilei* -transformations instead of *Lorentz* – transformations to form systems of the universe, but at the same time conserves the principle of constancy and finiteness of the speed of light and allows for acceleration and gravitation. In the sense of *Newton*, gravitation is to be understood here more general again as a conservative force that raises (without warping space-time) a particle movement and, with it, changes the density distribution of the particle mass.

In this context, contrary to previous assumptions, time measured by clocks does not order events in the sequence of their occurrence (and therefore also not the aging of matter), but merely represents here a measure for the length of paths covered by the particles in space-time.
In accordance with this view, we must distinguish clock time that is system-dependent from coordinate time that is system-independent (*Galilei* time). In the *Euclid*ean universe, only *Galilei* time arranges the sequence of time-dependent events according to their occurrence and aging.
In general, we cannot measure *Galilei* times directly, but we can calculate them with the help of clock-time measurements. Clock time and *Galilei* time hardly differ at low particle velocities. However, the principle of constancy and finiteness of light velocity applies only in relation to the time of clocks. In contrast, light velocity, which is the biggest effective velocity of mass-charged particles in the universe, becomes, related to *Galilei* time, infinitely great. This result has essential impacts on the properties and effects of the *Euclid*ean universe.

2. Structure of the universe

High-precision measurements observed over a wide area by the high-altitude balloon missions BOOMERANG and MAXIMA [23] have shown that at large-scale distances, the universe has no curvature and is therefore flat and infinite. Accordingly, the universe’s present expansion will continue. The universe is expanding and its middle densities of matter are permanently diminishing. Thus, it can be considered to be self-dissolving.

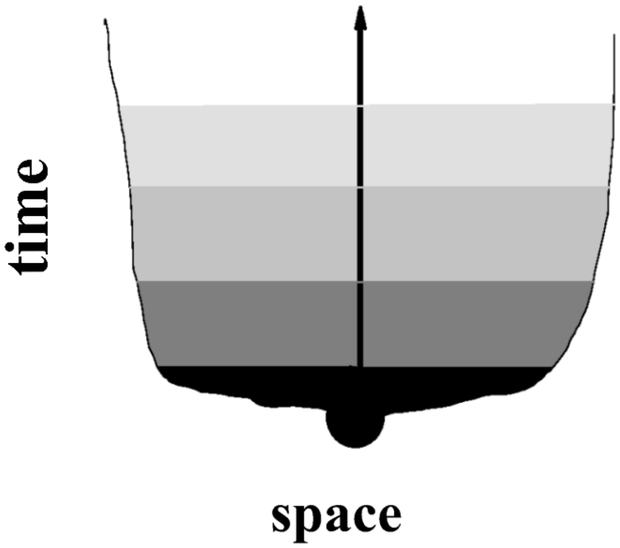

Fig. 1. Self-dissolving universe according to BOOMERANG: at the beginning was the Big Bang and inflation, followed by self-dissolving.

We will show here that a universe corresponding to these experimental findings could also be flat in its entirety.

Our universe consists of matter structured in space and time. In a simplified form, we understand this matter to be a set of *mass-charged particles* located in a four-dimensional continuum; see fig. 1. In short, this is called *space-time*.

Every point **X** of a space-time N_4 is then uniquely determined by four real numbers x^1, x^2, x^3, and x^4, which are the *coordinates* of the point. Moreover, every **X** is assumed here to have a mass density ρ different from zero. Based on this, the elements of space-time are called *mass points.*

Therefore, a space-time can be described in the form

$$N_4 = \left\{ \mathbf{X} = (x^1, x^2, x^3, x^4) \in R^4 \middle| \rho(\mathbf{X}) > 0 \right\} \tag{1}$$

(R is the set of real numbers). With respect to self-dissolving processes in space-time (see fig. 1), we must distinguish between particle and mass point. We assume the following:

- each mass-charged particle k is situated in the universe at least at one mass point **X**;
- there is no more than one mass-charged particle at each mass point **X**: k = P(**X**).

With these assumptions, the set of mass-charged particles can be represented in the form

$$K = \{ k = P(\mathbf{X}) \mid \mathbf{X} \in N_4 \text{ and } P(\mathbf{X}) > 0 \} \tag{2}$$

(P(**X**) = 0 : no mass-charged particle at **X**). Interrelations between particles depend essentially on their distance from each other and on changes in space-time. Space-time related distances ds between the points of N_4 are determined with the help of a so-called *metric fundamental form* [24]

$$ds^2 = g_{i,j} \cdot dx^i \cdot dx^j . \qquad (3)$$

that defines coordinate systems in this manner.[1] The distance *ds* is calculated based on the coordinate differentials dx^1, dx^2, dx^3, and dx^4, and the *metric tensor* G = ($g_{i,j}$). The metric tensor here is actually only a quadratic four-row matrix that can depend on a reference point $\mathbf{X_o}$ (e.g., the point of origin) and thus on a reference particle $k_o = P(\mathbf{X}_o)$ (observer, clock). For the 16 components determining the geometry of the metric tensor,

$$g_{i,j} = g_{j,i} \ , \quad |g_{i,j}| \neq 0 \ , \quad g^{i,\mu} \cdot g_{\mu,j} = \delta^i_j \qquad (4)$$

must apply.
The space-time N_4 of the mass points of the universe, connected with a metrical tensor G, defines a metric space

$$\mathbb{S} = (N_4 , G) \ , \qquad (5)$$

which we call the *system* of the universe.

Systems of the universe constitute the physical basis for the alteration of particles, for interrelations between particles, and for their arrangement in time.

If ds^2 in the metric fundamental form (3) is positively definite, then we have a *Riemann*ian system. Otherwise, if ds^2 is indefinite, then it is a pseudo-*Riemann*ian system. In *Einstein's* relativity theory, the systems of the universe are pseudo-*Riemann*ian spaces.

A system is called flat (uncurved) [24] if g_{ij} has the form

$$g_{ij} = \pm\delta_{ij} \qquad (6)$$

(δ_{ij} is *Kronecker*'s delta). *Minkowski* spaces are flat.

Flat systems are called *Euclid*ean if

$$g_{ij} = \pm\delta_{ij} \qquad (7)$$

applies. Accordingly, *Euclid*ean spaces have Cartesian coordinate systems.

The coordinates of a particle in a system depend on the system's reference parameters, such as at the (local) point of origin. When changing the reference parameters, the coordinates of the points are also changed, and possibly their distances as well. From a system $\mathbb{S}$, there arises a system $\mathbb{S}'$ that can move relative to the system $\mathbb{S}$.

In concrete terms, the forming of universe systems is therefore realized by means of a set $\mathbb{A}$ of coordinate transformations with reversibly unequivocal and differentiable mappings.
Then, for each of the two systems $\mathbb{S}$ and $\mathbb{S}'$ of the universe, there exists a coordinate transformation $A \in \mathbb{A}$ that converts G into G' and performs a mapping of N_4 onto N'_4:

$$X' = \mathbf{X}'(\mathbf{X}) \in N'_4 \ , \ \mathbf{X} \in N_4. \qquad (8)$$

----

[1] The indices i, j, μ, and ν used in the present work always go from 1 to 4. The indices a, b, α, and β vary between 1 and 3. Indices occurring many times must be summarized (*Einstein*ian sum convention).

In this context, the corresponding coordinate differentials are transformed into the form

$$d\mathbf{X}' = A \cdot d\mathbf{X} \quad \text{oder} \quad dx'^{\mu} = A^{\mu}_{\nu} \cdot dx^{\nu} \quad \text{mit} \quad A^{\mu}_{\nu} = \frac{\partial x'^{\mu}}{\partial x^{\nu}} \ . \qquad (9)$$

In addition, the mass-charged particles are invariants of every coordinate transformation:

$$k' = P'(\mathbf{X}') = P(\mathbf{X}) = k$$

If the set A constitutes a group, then all of the arising systems can be regarded as having equal rights. In the following, we assume that $\mathbb{A}$ constitutes a group.

The relationships (8) and (9) describe the interrelation between the particle coordinates of different systems of the universe.

Accordingly, the universe consists of a set of systems that are determined by a space-time N_4, by a metric G, and by a group of coordinate transformations A; in addition, the systems possess all of the characteristic physical properties of the universe.

In SRT, the four-dimensional system of the universe is equipped with the *Minkowski* metric (pseudo-*Euclid*ean spaces). The coordinate transformations form an automorphism group of linear orthogonal mappings of a *Minkowski* space onto itself. An automorphism group can be characterized by equations that conversely mediate a coordinate transformation.

In SRT, these are the equations of the *Lorentz* transformation. *Einstein* performed a generalization of the SRT in his GRT by including inertia and gravity effects based on the equivalence principle of gravity and inertia of masses. On this basis there arose a non-*Euclid*ean universe whose systems are general pseudo-*Riemann*ian spaces [5,25,26].

In the present work, we substantiate a universe that consists of a set of *Euclid*ean systems and can therefore be called a *Euclid*ean universe. Contrary to *Einstein'*s SRT, the systems are formed here by means of a group of space-time-related *Galilei* transformations. In this context, related to clock time, the space-like particle velocities in all systems of the *Euclid*ean universe, just as in the *Minkowski* systems of SRT, are limited by the universal constant c

$$c \approx 3 \cdot 10^5 \text{ km/s} \ , \qquad (10)$$

light is propagated spherically, and the vacuum velocity of light is constantly c.

3. Time and events

The mass points $\mathbf{X} = (x^1,x^2,x^3,x^4) \in N_4$ of a system $\mathbb{S} = (N_4, G)$ of the universe can also be called *elementary events* of $\mathbb{S}$. An *event* E in $\mathbb{S}$ consists of a set of elementary events:

$$E \subseteq N_4. \qquad (11)$$

Cause-effect relationships between events or in the course of events presuppose an arrangement between or within events. The arrangement is guaranteed by the time-like nature of one of the four coordinates x^1, x^2, x^3, x^4. In the present work, we determine the fourth coordinate as time-like and we define the following:

In a system $\mathbb{S}$, an event $\{\mathbf{X}\}$ takes place before an event $\{\mathbf{Y}\}$ if and only if $x^4 < y^4$ applies for any elementary events $\mathbf{X},\mathbf{Y} \in N_4$. Thus, a relation $\leq_S$ is defined that orders any events $\{\mathbf{X}\}$ and $\{\mathbf{Y}\}$ in a system $\mathbb{S}$ of the universe in the sequence of their occurrence,

$$\{\mathbf{X}\} \leq_S \{\mathbf{Y}\} \;\Leftrightarrow\; x^4 \leq y^4 , \tag{12}$$

and thus substantiates the cause-effect relationships between events. Events with the time-like coordinate x^4 can be the cause of events that take place at a coordinate y^4 if $x^4 \leq y^4$. The simultaneousness of events is defined by

$$\{\mathbf{X}\} =_S \{\mathbf{Y}\} \;\Leftrightarrow\; x^4 = y^4. \tag{13}$$

Coordinates that are not time-like are called *space-like*. Hence, the coordinates x^1, x^2, x^3 are space-like. and every mass point of a space-time N_4 has to be described by three space-like coordinates and a time-like coordinate according to (1).
A real parameter τ is called the *coordinate time* of the time-like coordinate of a system $\mathbb{S}$ if x^4 depends in a linear manner on τ

$$dx^4 = c \cdot d\tau \, , \; c = \text{const.} < +\infty, \tag{14}$$

where c is a universal positive constant.

Remarks:
- In relation to the coordinate time τ, here the constant c is the velocity of a particle in the direction of the time-like coordinate x^4.
- For $\mathbf{X}$, $\mathbf{Y} \in N_4$ and $x^4 = c \cdot (\tau_x - \tau_o)$ as well as $y^4 = c \cdot (\tau_y - \tau_o)$, the following holds:

$$\{\mathbf{X}\} \leq_S \{\mathbf{Y}\} \Leftrightarrow \tau_x \leq \tau_y.$$

As *system time*, we designate a real parameter τ_S, which orders the elementary events of a space-time of a system according to any criterion. We designate an event E_T in a system S of the universe as time-*dependent* if the mass points $\mathbf{X}_E \in E_T$ depend functionally on a system time τ_S within a time interval T_{SE}:

$$E_T = \left\{ \mathbf{X}_E(\tau_S) \in N_4 \middle| \; \tau_S \in T_{SE} \right\}. \tag{15}$$

Then the *path* of a mass particle k that is moving in a system represents a time-dependent event

$$E_{T,k} = \left\{ \mathbf{X}_E(\tau_S) \in N_4 \middle| \; k = P(\mathbf{X}_E(\tau_S)) \; , \; \tau_S \in T_{SE} \right\} \tag{16}$$

whose elementary events are all documented by the particle k.

We designate as *space-like* those events that are not time-dependent. In particular, those events that connect the loci of several particles to one body at the same system time are *space-like*. In the next section, time-dependent events are subdivided further into time-like events and light-like events.

The coordinate time of the time-like coordinate of a system arranges the elementary events of space-time according to the sequence of their occurrence, and is therefore a system time that substantiates causalities.

Aging of matter can be thought of as special chain of events in the biochemical decomposition. We assume that the duration of biochemical decomposition procedures is quantified by the coordinate time of the time-like coordinate. Thus, coordinate time, is also controlling the *aging* of matter and the universal constant c, see (14), can be considered as the *aging velocity* of the universe.
Then, by (14), the *principle of constancy and finiteness of the aging velocity* of a universe is underlied.

A coordinate time of the time-like coordinate is designated as *Galilei* time if the coordinate time duration of a time-dependent event is an invariant of all systems of the universe. Therefore, in a universe that is arranged by means of *Galilei* time, both the sequence of events and the course of aging are equal in all systems. In this case, aging of matter proceeds in the same way throughout the entire university.

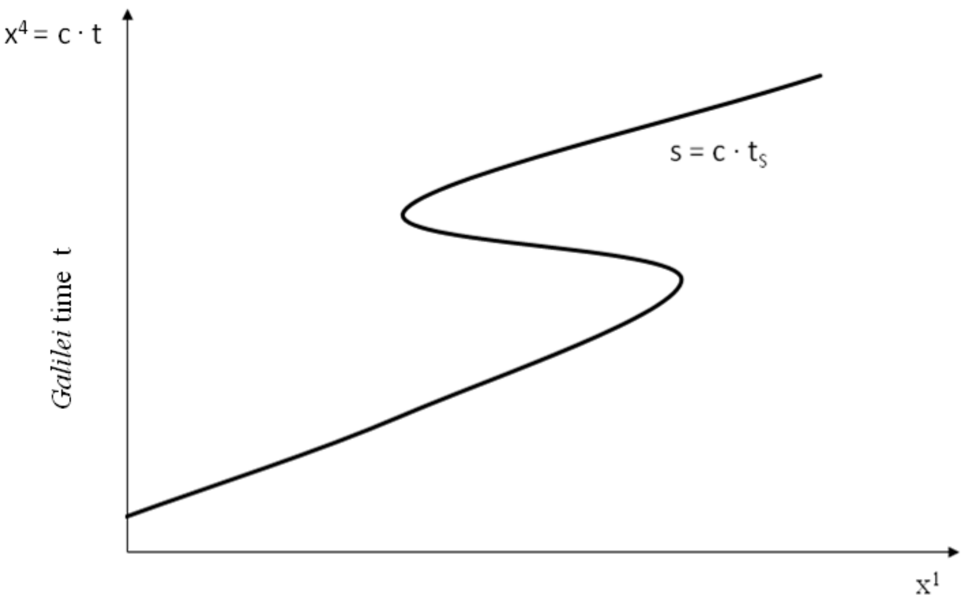

Fig. 2. Particle path in space-time of the *Euclid*ean universe.

Remark:
In general, *Galilei* time is interrelated with all coordinates of space-time. In the case of a universally unilateral dependency of the coordinates on *Galilei* time, one would also be able to speak of 'absolute time' in the context of *Newton*.

4. Metric of the universe

Newton considered the universe to be a fixed absolute three-dimensional space endowed with an absolute time that was proceeding in a uniform manner [16,17]. From a modern viewpoint, *Newton*ian physics was based on empirically established three-dimensional space-like systems

$$\mathbb{S}_N = (N_3 , G_N). \qquad (17)$$

In this context, the mass points of mass-charged particles are determined by three space-like coordinates x^1, x^2, x^3. There is no single time-like coordinate. The metric fundamental form of S_N can be described by

$$ds_N^2 = dx^\alpha \cdot dx^\alpha = |d\mathbf{x}|^2 \;, \;\; \mathbf{x} = (x^1, x^2, x^3) \in N_3 \qquad (18)$$

in Cartesian coordinates [27]. Thus, the systems are *Euclid*ean.

The transition from a system S_N to other systems S'_N was realized by means of *Galilei* transformations. The *classic relativity principle* indicates that the laws of *Newton*ian physics are invariant across all systems in terms of form when *Galilei* transformations are used. Moreover, *Galilei* transformations also transfer inertial systems into *inertial systems*. These are systems in which, in the absence of external forces, mass particles are at rest or are moving in a straight-lined and uniform manner. For inertial systems, the following applies:

$$|\mathbf{u}_\tau| \leq c_\tau \text{ and } A^\mu_\nu = \frac{\partial x'^\mu}{\partial x^\nu} = \text{const},$$

where A^μ_ν is independent of mass points, τ is the system's inertial time, c_τ is the maximal effective speed related to the inertial time, and $\mathbf{u}_\tau = d\mathbf{x}/d\tau$ is the particle's system velocity.

In *Newton*ian physics, the sequence of events - and thus the foundation for causality and aging - is based on an *absolute time* t, which is defined to be independent of all system parameters. In inertial systems, the absolute time is equal to the inertial time: $\tau = t$. In this context, absolute time is considered as a magnitude that can be measured by clocks and is the same in all *Newton*ian systems according to *Galilei* transformations:

$$t' = t. \qquad (19)$$

In relation to the absolute time, one obtains defined space-related particle velocities

$$\mathbf{u} = (u^1, u^2, u^3) \;, \;\; u^\alpha = \frac{dx^\alpha}{dt} \;. \qquad (20)$$

In this context, the maximal effective speed that exists in the *Newton*ian universe is infinitely great:

$$|\mathbf{u}| \leq c_t = +\infty \;. \qquad (21)$$

From (18) and (20),

$$ds_N = |\mathbf{u}| \cdot dt \quad , \quad \mathbf{u}^2 = u^\alpha \cdot u^\alpha. \qquad (22)$$

follows.

In connection with the *Galilei* transformation, three-dimensional *Newton*ian systems are time-dependent in terms of their movement, and therefore they can actually no longer be considered as absolute spaces. However, the spatial measures of a body are equal in all *Newton*ian systems (17), independent of relative system movements. This equality signifies that, at any time t, the distance $| \mathbf{x}_2 - \mathbf{x}_1 |$ of two mass points in a system is the same as in every other system:

$$| \mathbf{x}'_2 - \mathbf{x}'_1 | = | \mathbf{x}_2 - \mathbf{x}_1 | \ , \ \mathbf{x}'_i = \mathbf{x}_i - \mathbf{v} \cdot t \ , \ i = 1,2.$$

There is no contraction of lengths. In this limited meaning, it is still possible to consider the Newtonian systems as *absolute spaces*.

The spatial distance $|d\mathbf{x}|$ of mass points has also proven to be a measurable magnitude, just like absolute time. Accordingly, by extension, in *Newton*ian physics one can also regard the magnitude of a velocity $| \mathbf{u} |$, and consequently the variable s_N, as measurable.

In the 19th century, on the basis of empirical investigations, especially by the experiments of *Michelson* and *Morley* [1], the principle of the constancy and finiteness of the speed of light as well as the principle of the spherical propagation of light were found. These results were not compatible with *Newton*'s relativity principles, particularly with regard to the *Galilei* transformation. Because of these contradictions, a crisis in physics arose.

Only within the framework of *Einstein*'s SRT was it possible in the early 20th century to interpret the results describing the character of the speed of light in a satisfactory manner and to integrate them into a new view of the relativity of space and time. Even without including the effects of gravity, it became necessary to embed *Newton*'s three-dimensional *Euclid*ean systems S_N into flat four-dimensional systems of space-time $S = (N_4, G)$. It was necessary to abandon the absoluteness of space and time due to the now obvious interrelations between space and time.

In *Einstein*'s SRT [14,18], the systems were endowed with the *Minkowski* metric of flat spaces

$$ds^2 = g_{\mu,\nu} \cdot dx^\mu \cdot dx^\nu = dx^\alpha \cdot dx^\alpha - (dx^4)^2 \ , \ G = (g_{\mu,\nu}), \tag{23}$$

in connection with the *Lorentz* coordinate transformations [15,27]. *Einstein* found that the finiteness and constancy of the speed of light in a vacuum in a system are mapped in an invariant manner by the *Lorentz* transformation, and that, as a result, it is possible to guarantee the principle of the spherical propagation of light. Hence, it was suggested to generalize the *Galilei* transformation to the *Lorentz* transformation. Lately, *Newton*'s entire theory was relativized by this work.

In this context, absolute time has been replaced by a measurable system-dependent coordinate time t_S for which

$$dt_S = dx^4 / c \tag{24}$$

applies. From (23) and (24),

$$dt_S^2 = \frac{1}{c^2} \cdot \left(dx^2 - ds^2 \right). \tag{25}$$

is generated. In time-dependent events in *Minkowski* space, therefore, it follows

$$\mathbf{u}_S^2 = \left(\frac{d\mathbf{x}}{dt_S}\right)^2 = c^2 \cdot \frac{d\mathbf{x}^2}{d\mathbf{x}^2 - ds^2} \tag{26}$$

for space-related particle velocities $\mathbf{u}_S = (u_S^1, u_S^2, u_S^3)$.

In *Minkowski* spaces, it is possible to distinguish between space-like and time-dependent events by means of the world line element ds [3,13,27]. In these spaces, an event is space-like if $ds^2 > 0$ applies. Otherwise, when $ds^2 \leq 0$, we designate the event as time-dependent. A time-dependent event can be light-like ($ds^2 = 0$) or time-like ($ds^2 < 0$).

Particle velocities are determined for events that are time-dependent. Therefore, due to (3.10), we obtain

$$|\mathbf{u}_S| \leq c < +\infty \;\text{ and }\; |\mathbf{u}_S| = c \;\Leftrightarrow\; ds^2 = 0 \,. \tag{27}$$

at $ds^2 \leq 0$.

When the *Lorentz* transformation is applied, the validity of (27) is transferred to every inertial system of the universe [12]. Moreover, the *covariance principle* of SRT indicates that the laws of physics are invariant with regard to form in all inertial systems that are at rest with respect to one another, or that are moved uniformly and in a straight line. By means of (27), the principle of constancy and finiteness of the speed of light is realized as the highest effective speed that exists in the universe. Moreover, for $ds^2 = 0$, the spherical propagation of light follows from (27):

$$(dx^1)^2 + (dx^2)^2 + (dx^3)^2 = a^2 \;\;,\;\; a = c \cdot dt_S \,.$$

The covariance principle and the finiteness of the speed of light in vacuum constitute the basis of SRT. Based on the use of the *Lorentz* transformation in SRT, the coordinate time of the *Minkowski* systems is no longer a *Galilei* time, but instead becomes directly measurable. Some properties of the universe that one would not have expected within the framework of the *Newton*ian theory result from this development:

- the relativity of simultaneousness;
- the relativity of the aging of matter;
- the twin paradox;
- the dilatation of time; and
- the *Lorentz* contraction of lengths.

In addition, the *Lorentz* contraction of lengths goes beyond the framework of *Euclid*ean physics. The consequence is a non-*Euclid*ean universe such as that described by *Einstein* in his GRT [5].
With these properties, *Einstein* might have gone farther from the *Newton*ian theory than necessary.
Thus, alternative to *Einstein*'s theory of relativity, especially to his SRT, various four-dimensional *Euclid*ean systems of the universe have been analysed in the preceding decades [28,29,30].

In the present work, we aim to substantiate in agreement with *Newton* a four-dimensional *Euclid*ean universe that also has a general character, but that underlies a space-time-related *Galilei* – transformation instead of the *Lorentz* – transformation.

For this purpose, we also embed *Newton'*s three-dimensional *Euclid*ean systems S_N into flat four-dimensional systems of space-time. With respect to the principle of constancy and finiteness of the aging velocity c, see section 3, we add a time-like coordinate

$$x^4 = c \cdot (t - t_o) \tag{28}$$

to the three space-like coordinates x^1, x^2, x^3 of *Newton'*s system S_N. With it, *Newton'*s absolute time is replaced by the coordinate time t of x^4 that is assumed here to be a system-independent *Galilei* – time.
We assume that the mass points formed in this way establish a four-dimensional space-time in accordance with (1) and (2).
Hence, the universe contains a four-dimensional *Euclid*ean system

$$\mathbb{S} = (N_4 , G) \text{ with } G = (\delta_{\mu,\nu}) \tag{29}$$

equipped with the metric fundamental form

$$ds^2 = \delta_{\mu,\nu} \cdot dx^\mu \cdot dx^\nu = dx^\mu \cdot dx^\mu \ . \tag{30}$$

The transition to other systems of this universe takes place here by means of a space-time-related *Galilei* transformation (see section 6). All systems $\mathbb{S}' = (N'_4 , G')$ received from such a transformation will again equipped with Cartesian coordinates: $G' = G$. Therefore, the tensor calculus that is characteristic for *Einstein*'s theory of relativity cannot be applied here.

On the other side, as we will show, in this manner we obtain a *Euclid*ean universe that as well is in accord with the principle of constancy and finiteness of the speed of light, but nevertheless has none of the mentioned properties that are caused by the *Lorentz* transformation.

Based on the *Galilei* – time t, particle velocities of a space-time are defined by

$$\mathbf{U} = (u^1, u^2, u^3, c), \quad u^\mu = \frac{dx^\mu}{dt}, \ dx^4 = c \cdot dt \ . \tag{31}$$

Due to (30),

$$ds = c \cdot dt \cdot ß, \ ß = \sqrt{1 + \mathbf{u}^2/c^2} \ , \quad \mathbf{u}^2 = u^\alpha \cdot u^\alpha \ . \tag{32}$$

is obtained for time-dependent events.

By

$$dt_S = dt \cdot ß \ , \tag{33}$$

a system time t_S is defined, where $dt_S > 0$ applies as $dt \geq 0$. Then, from (32) and (33), it follows:

$$ds = c \cdot dt_S \tag{34}$$

and we receive the

principle of constancy and finiteness of all particle velocities in space-time:

$$\frac{ds}{dt_S} = |\mathbf{U}_S| = c = \text{const.} < +\infty \,, \tag{35}$$

where $\mathbf{U}_S = (u_S^1, u_S^2, u_S^3, u_S^4)$ and $u_S^\mu = \dfrac{dx^\mu}{dt_S}$.

Moreover, it follows

$$dt_S^2 = \frac{1}{c^2} \cdot (d\mathbf{x}^2 + (dx^4)^2)\,. \tag{36}$$

From this derivation, there follows for space-related velocities $\mathbf{u}_S = (u_S^1, u_S^2, u_S^3)$:

$$\mathbf{u}_S^2 = \left(\frac{d\mathbf{x}}{dt_S}\right)^2 = c^2 \cdot \frac{d\mathbf{x}^2}{d\mathbf{x}^2 + (dx^4)^2} \;\le\; c^2\,. \tag{37}$$

By (37), the amount $|\mathbf{u}_S|$ of a space-related particle velocity in the universe with regard to t_S is never greater than the finite speed c:

$$|\mathbf{u}_S| \le c < +\infty \,. \tag{38}$$

Relation (38) signifies that c is the greatest existing effective space-related velocity also in the *Euclid*ean universe. In this context, the equivalence

$$|\mathbf{u}_S| = c \quad \Leftrightarrow \quad dx^4 = 0 \quad \Leftrightarrow \quad dt = 0\,. \tag{39}$$

holds. Because of this equivalence, we can designate time-dependent events, see (15), here by analogy to *Einstein*'s theory as *light-like* if dt = 0 applies. Time-dependent events that are not light-like are designated as *time-like*. For time-like events, dt > 0 holds.

Measurements of the speed of light conducted in the 19th century [1] showed that, in a vacuum, the speed of a photon whose rest mass is equal to zero in all inertial systems, even in those that are moved toward each other, always has the same finite and constant value,

$$c_{mes} \approx 3 \cdot 10^5 \text{ km/s}$$

Since c_{mes} is the greatest effective velocity of a mass particle that has ever been observed, it was possible to suppose

$$c_{mes} = c\,, \tag{40}$$

see (10). Thus, the principle of constancy and finiteness of all particle velocities in space-time (35) has an experimental confirmation and is, at the same time, a generalization of the principle of constancy and infinity of the speed of light in a vacuum.

Accordingly, we can assume that the system time t_S introduced by (33) is the basis of our (clock) time measurements, and we will therefore designate t_S as *clock time*, also referred to as *measurement time*.

Utilizing (14), the *Galilei* – time t can be determined dependent on the measurement time t_S by using (30), (31) and (35). We obtain

time synchronization

$$dt = dt_S \cdot ß_S \tag{41}$$

where

$$ß_S = \sqrt{1 - \mathbf{u}_S^2/c^2} \tag{42}$$

is the *Lorentz* factor. From (41), it is evident that in general, clock time and Galilei time are not identical in the *Euclid*ean universe. Because of (34), a time duration related to clock time t_S of a time-dependent event is proportional to the length of the path along the event that a particle (at speed c) covers during this event. Hence, when using a clock, we are measuring not the time duration of events *per se*, but rather the lengths of pathways in space-time. Accordingly, clock time does not arrange elementary events in accordance with the chronological order of events. Therefore, clock time controls neither cause-effect relationships of events nor the aging of matter.

As a result of (30),(31) and (34), the interrelation

$$dt_S^2 = |d\mathbf{x}|^2 / c^2 + dt^2 \tag{43}$$

arises between measurement time duration, space-related distance, and *Galilei* time duration. In general, it is impossible to measure the *Galilei* time duration of events, but this duration can be calculated from measured values using (43).

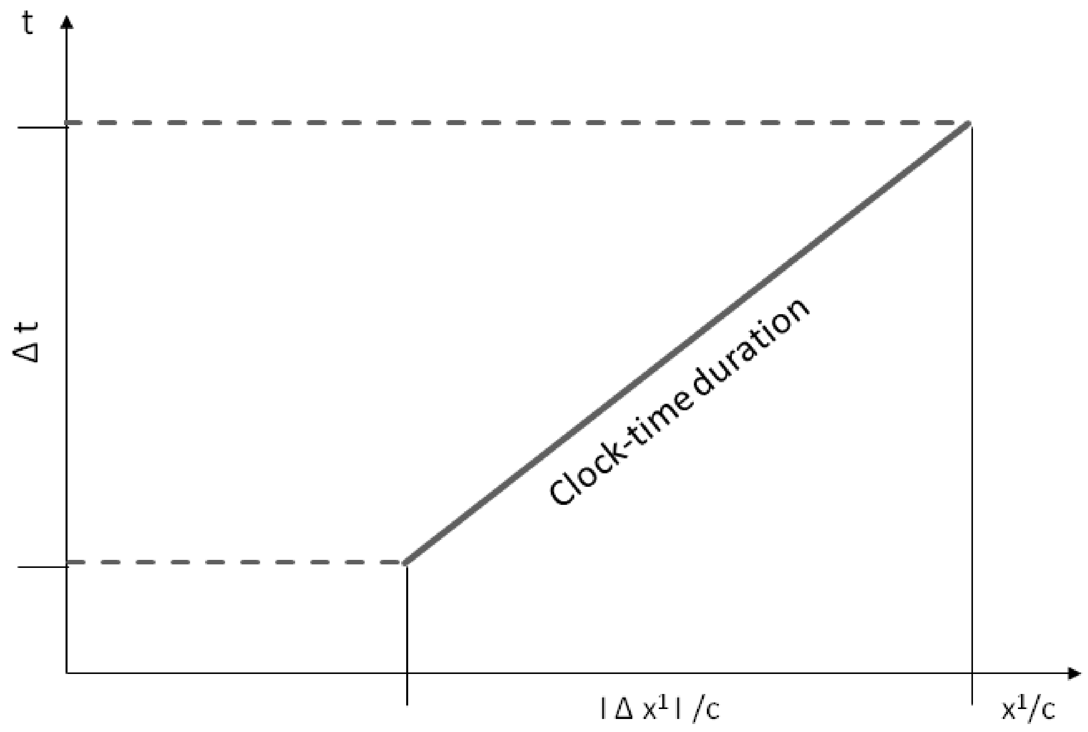

Fig. 3. Clock-time duration as a measure of path lengths in space-time.

However, measurement time and coordinate time are approximately equal if the corresponding particle velocities are small relative to the speed of light c. In these cases, which are at most true to the everyday life of people, a clock will indicate the right chronological order of events and the course of biochemical aging with sufficient precision.

5. Finiteness and infinity of the speed of light

In time-dependent events related to the coordinate time t, every four-dimensional particle velocity in a *Euclid*ean system of the universe has the appearance of (31).

From the metric fundamental form (30), taking into account (28) and (31), it follows

$$\frac{ds}{dt} = |\mathbf{U}| = ß \cdot c \quad \text{und} \quad \frac{dt_S}{dt} = ß \quad , \quad ß = \sqrt{1+\mathbf{u}^2/c^2} \tag{44}$$

and also

$$c = |\mathbf{U}_S| \le |\mathbf{U}| \le \infty \, . \tag{45}$$

In this context, $\mathbf{u} = (u^1, u^2, u^3)$ with $u^\alpha = \dfrac{dx^\alpha}{dt}$ is the space-related particle velocity referred to as time t.

We want to designate the factor ß, which is referred to here as the Galilei - time t, as well as the factor $ß_S$, related to the clock time t_S in (42), as the *Lorentz* factor.

For particles that are moving with light speed (photons), the relation

$$|\mathbf{U}_S| = |\mathbf{u}_S| = c \tag{46}$$

follows from (45) and it arises from (39) that dt = 0 applies. With it, we obtain

$$dt_S^2 = dx^\alpha \cdot dx^\alpha / c^2 \tag{47}$$

from (43).

Analogous relations apply in SRT. However, in SRT, the clock time t_S is also the coordinate time, whereas t has the character of a proper time, see [30] to it.

In *Euclid*ean systems, because of (47) and (48), it is possible to characterize photons as three-dimensional phenomena in the four-dimensional universe that are not subjected to any aging (dt = 0); see Fig. 4.

Because of (33) and (41), between the *Lorentz* factors ß and $ß_S$ there is the following interrelation:

$$ß \cdot ß_S = 1 \quad \text{with} \quad ß_S \le 1 \quad \text{und} \quad ß \ge 1 \, . \tag{48}$$

Compared with the clock time t_S, the *Galilei* time t proceeds slowest:

$$dt_s \ge dt \ge 0. \tag{49}$$

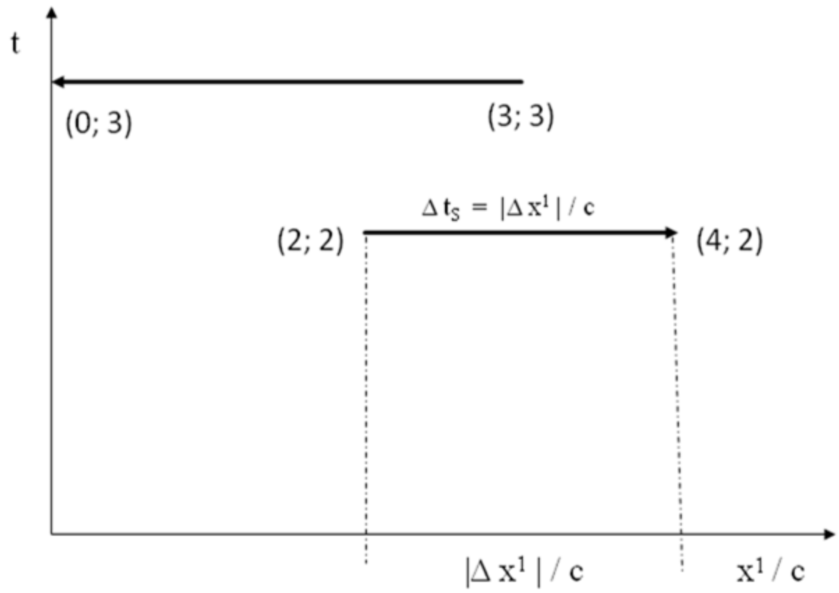

Fig. 4. Particles with light speed in space-time

For the space-related velocity **u**,

$$\mathbf{u} = \frac{d\mathbf{x}}{dt} = \frac{d\mathbf{x}}{dt_s} \cdot \frac{dt_s}{dt} = \mathbf{u}_s \cdot \frac{dt_s}{dt} \qquad (50)$$

or

$$d\mathbf{x} = \mathbf{u} \cdot dt = \mathbf{u}_S \cdot dt_S \,. \qquad (51)$$

applies. The space-related velocities **u** and $\mathbf{u}_S$ are therefore mutually interdependent. We obtain the equations of

velocity synchronization

$$\mathbf{u} = \mathbf{u}_S / ß_S = \frac{\mathbf{u}_s}{\sqrt{1-(\mathbf{u}_s/c)^2}} \quad \text{and} \quad \mathbf{u}_s = \mathbf{u} / ß = \frac{\mathbf{u}}{\sqrt{1+(\mathbf{u}/c)^2}} \,. \qquad (52)$$

see fig. 5.

From $|\mathbf{u}_S| = c$, it follows immediately that $|\mathbf{u}| = \infty$, and if $|\mathbf{u}| \Rightarrow \infty$, then $\mathbf{u}_S \Rightarrow c$. Therefore, with regard to light speed, we obtain the following essential statement:

$$|\mathbf{u}_S| = c \quad \Leftrightarrow \quad |\mathbf{u}| = \infty \,. \qquad (53)$$

Herefore, the speed of light as related to clock time t_S is just finite if the light speed related to time t becomes infinite. Light speed and aging speed both referred to as t are always different. When transmitting information from remote parts of the universe, we have assumed up until now that we were looking into the past. If information items are transmitted at an infinitely great velocity **u** related to *Galilei* time t, see (53), then it might be possible to see the present situation—even of objects that are situated at remote distances.

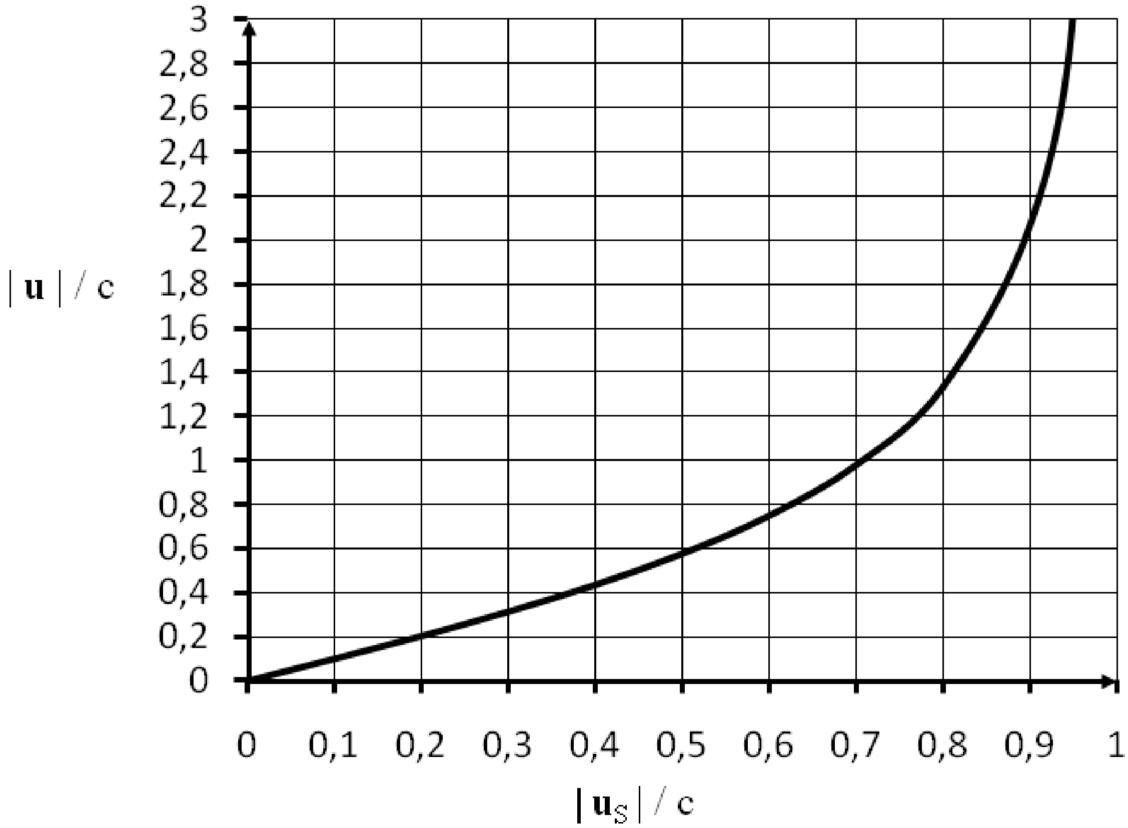

fig. 5. Interdependence of the space-related velocities

6. Space-time-related *Galilei* transformation and *Euclid*ean universe

The transformation of the systems of the *Minkowski* universe is performed in *Einstein'*s SRT by means of the *Lorentz* transformation [15,31]. When using the *Lorentz* transformation, the aging of matter is system-dependent (moved clocks are going slower). In this situation, clock time is also coordinate time, and therefore it is in control of the aging processes. However, this is not the case in the *Euclid*ean universe. Here, the principle of constancy and finiteness of the light speed

$$|\mathbf{u}'_s| = c \quad \Leftrightarrow \quad |\mathbf{u}_s| = c \tag{54}$$

is fulfilled because of (39) only if the coordinate time of the time–like coordinate is a *Galilei* time:

$$dt' = dt \,. \tag{55}$$

In that condition, aging processes occur independently of systems, and half-life periods of biochemical decomposition are invariants of all systems. Therefore, we believe that the coordinate time in the *Euclid*ean universe is *Galilei* time and is transformed accordingly (55).

The transformation of the space-like coordinates of space-time can be discussed in interrelation with particle velocities in *Euclid*ean systems. In space-time, particle velocities during the superposition of events are not additive (at least in the time-like coordinate); see (31). However, in keeping with the *Newton*ian theory, we suppose that, in this context, the space-related particle velocities (in the manner of components) behave additively, and thus we assume the validity of the

Newtonian addition theorem

$$\mathbf{u}' = \mathbf{u} - \mathbf{v} \ \text{ with } \ \mathbf{v}' = -\mathbf{v} \tag{56}$$

for space-related velocities [13,14,27]. Then, the velocity **u** of a particle in a system $\mathbb{S}$ = (N_4, G) is equal to the sum of the space-related system speed **v** of a system $\mathbb{S}'$ = (N'_4, G') in $\mathbb{S}$ and of the space-related speed $\mathbf{u}'$ of the particle in $\mathbb{S}'$. The relative system velocity **v** between $\mathbb{S}$ and $\mathbb{S}'$, both referred to as the measurement time t_S, appears as follows according to (52):

$$\mathbf{v}_S = \frac{\mathbf{v}}{\sqrt{1+(\mathbf{v}/c)^2}} \,.$$

Hence, after substitution of (52), we obtain the

relativistic Newtonian addition theorem:

$$\frac{\mathbf{u}'_s}{\sqrt{1-(\mathbf{u}'_s/c'_0)^2}} = \frac{\mathbf{u}_s}{\sqrt{1-(\mathbf{u}_s/c_0)^2}} - \frac{\mathbf{v}_s}{\sqrt{1-(\mathbf{v}_s/c_0)^2}}\,, \ \ \mathbf{v}'_S = -\mathbf{v}_S \,. \tag{57}$$

We suppose that, in every system of the universe, there are mass points that are charged with a rest mass $m_o > 0$ and hence can also rest in the system. If a particle is at rest in the system $\mathbb{S}'$ ($\mathbf{u}'_S = 0$), then from (57) it follows that $|\mathbf{u}_S| = |\mathbf{v}_S|$.

If the system $\mathbb{S}'$ would move at light speed $|\mathbf{v}_S| = c$ in $\mathbb{S}$, then one would obtain $|\mathbf{u}_S| = c$ and $|\mathbf{u}'_S| = 0$. This result, however, stood in contradiction with the principle of the constancy and finiteness of the light speed, and it signifies that

$$0 \le |\mathbf{v}| < \infty \quad \text{or} \quad 0 \le |\mathbf{v}_S| < c \tag{58}$$

must always apply to space-related relative speed between systems. Systems of the universe *cannot* move relative to one another at light speed.

Corresponding to (9), the equations of a

space-time-related Galilei transformation

$$\begin{aligned} &dx'^{\alpha} = dx^{\alpha} - v^{\alpha}/c \cdot dx^4 \ \text{ with } v'^{\alpha} = -v^{\alpha} \ \text{ for } \alpha = 1, 2, 3 \\ &\text{and} \\ &dx'^4 = dx^4 \,, \ v'^4 = v^4 = c \end{aligned} \tag{59}$$

arise from (55) and (56), with due regard to (20) and (29).
Hence, it follows that the matrix of the space-time-related *Galilei* transformation $d\mathbf{X}' = A(\mathbf{V}') \cdot d\mathbf{X}$ then has the appearance of

$$A(\mathbf{V}') = \begin{pmatrix} 1 & 0 & 0 & v'^1/c \\ 0 & 1 & 0 & v'^2/c \\ 0 & 0 & 1 & v'^3/c \\ 0 & 0 & 0 & v'^4/c \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & -v^1/c \\ 0 & 1 & 0 & -v^2/c \\ 0 & 0 & 1 & -v^3/c \\ 0 & 0 & 0 & 1 \end{pmatrix} = A(\mathbf{v}) , \qquad (60)$$

thus $A^\alpha_\beta = \delta^\alpha_\beta$, $A^\alpha_4 = -v^\alpha / c_0$, $A^4_\mu = \delta^4_\mu$, α = 1,2,3.
In this context, the space-related velocity $\mathbf{v} = (v^1, v^2, v^3)$ of system $\mathbb{S}'$ in $\mathbb{S}$ represents in general a three-dimensional velocity field at space-time N_4 in $\mathbb{S}$:

$$\mathbf{v} = \mathbf{v}(\mathbf{X}) = (v^1(\mathbf{X}), v^2(\mathbf{X}), v^3(\mathbf{X})) \text{ mit } \mathbf{v}'(\mathbf{X}'(\mathbf{X})) = -\mathbf{v}(\mathbf{X}) \text{ for every } X \in \mathbb{S}, \qquad (61)$$

(see also section 7: *Space-like events*).

Especially, if $\mathbf{v}$ = const we obtain from (59) according to (8) except from additive constants

the *Galilei* transformation

$x'^\alpha = x^\alpha - v^\alpha / c \cdot x^4$ with $v'^\alpha = - v^\alpha$ for α = 1, 2, 3
and
$x'^4 = dx^4 = c \cdot t$, $t' = t$, $v'^4 = v^4 = c$

that transfers inertial systems again into inertial systems.

With regard to the concatenation of transformations, set $\mathbb{A}$ of space-time-related *Galilei* transformations (60-61) forms a group (viewed as mappings of R^4 onto itself). This property justifies the supposition that, with a *Euclid*ean system $\mathbb{S} = (N_4, G)$ formed according to (29) and (30), every *Euclid*ean system $\mathbb{S}' = (N'_4, G)$ must also belong to the universe if there exists a space-time-related *Galilei* transformation $A \in \mathbb{A}$ that maps N_4 onto N'_4. Therefore, all systems that belong to the universe in this manner, and only those, can be regarded as having equal rights among one another and are thus *admissible* to forming the universe.
Thus, we receive the

general relativity principle of the Euclidean universe:

The *Euclid*ean universe consists of mass-charged particles, located and structured in admissible four-dimensional *Euclid*ean systems, which have equal rights among one another and can move relative to one another. The admissible systems are formed using the group of space-time-related *Galilei* – transformations. At this, it is required that physical laws are invariant in form towards the application of *Galilei* – transformations (covariance principle) and have to apply to the *Galilei* – time in time–dependent formulations.

Supplementary notes

The four-dimensional space-time of admissible systems is structured according to (1) and (2), where the elementary events of the space time are always determined by three space-like coordinates and one time-like coordinate. Moreover, the elementary events are arranged according to different criteria of the system times:
<u>*Galilei* time</u> t arranges the events of systems according to the sequence of their occurrence and with it according to aging. In this context, the speed of aging

$$c = dx^4 / dt \approx 3 \cdot 10^5 \text{ km/s} \tag{62}$$

is a universal constant that is equally valid in all admissible systems (principle of constancy and finiteness of aging velocity).
Clock time t_S arranges time-like and light-like events within an admissible system according to the length of a corresponding particle path ($ds = c \cdot dt$, see (34)). Because of (34), the principle of the constancy and finiteness of particle speed in space-time, see (35), applies in an invariant manner to all admissible systems of the universe. As the coordinate time of the time-like coordinate is here *Galilei* – time, principle (35) constitutes a generalisation of the principle of constancy and finiteness of the light speed, see (54).

7. Path-time dilatations and length contractions in *Euclid*ean systems

In this section, we consider admissible systems $S = (N_4, G)$ and $S^/ = (N^/_4, G)$ of the *Euclid*ean universe. The systems have then metrical fundamental forms,

$$ds^2 = dx^\alpha \cdot dx^\alpha + c^2 \cdot dt^2 \tag{63}$$

and

$$ds^{/2} = dx^{/\alpha} \cdot dx^{/\alpha} + c^2 \cdot dt^{/2}. \tag{64}$$

We assume that they move relative to one another with a space-related velocity $\mathbf{v} = (v^1, v^2, v^3)$, where $|\mathbf{v}| < \infty$. Due to the space-time-related *Galilei* transformation in this context, there exists the interrelation

$$dx^{/\alpha} = dx^\alpha - v^\alpha \cdot dt, \; \alpha = 1, 2, 3 \text{ and } dt^/ = dt. \tag{65}$$

For events that take place at a fixed point in time t, hence at

$$dt = 0 \text{ or } dx^4 = 0, \tag{66}$$

equations

$$dx^{/\mu} = dx^\mu, \quad \mu = 1, 2, 3, 4, \tag{67}$$

follow and with it

$$ds^/ = ds^2 = ds_N^2 = dx^\alpha \cdot dx^\alpha = |d\mathbf{x}|^2 \tag{68}$$

as well as

$$|d\mathbf{x}^/| = |d\mathbf{x}| \text{ und } |d\mathbf{X}^/| = |d\mathbf{X}| = |d\mathbf{x}|. \tag{69}$$

Thereby, we consider $ds_N = |d\mathbf{x}|$ to be a measurable magnitude (see section 4).

Remark:
Since here the time of happening, i.e., the occurrence of events, is considered, the simultaneousness of the events must relate to the *Galilei* time [see (66)].

Space-like events without the Lorentz contraction

We consider the mass points **X**, **Y** of a continuous body $E_{b,t}$ at the *Galilei* time t. $E_{b,t}$ represents a space-like event in S. The points **X** and **Y** = **X** + d**X** can be connected by a four-dimensional line of the length $ds = |d\mathbf{X}|$. Because of $y^4 = x^4 = c \cdot t$, $dx^4 = c \cdot dt = 0$ follows.

Therefore, the space-like coordinates **x** and **y** = **x** + d**x** are end points of the space-related distance $|d\mathbf{x}|$ at the same time t. Due to (66) and (69), this distance is the same in every system of the universe. Hence, in the *Euclid*ean universe, there is no length contraction.

*Euclid*ean systems differ from *Minkowski* systems in this regard. A space-like line can have different corresponding lengths in different *Minkowski* systems. Here, clock times t_S are at once coordinate times. With respect to the *Lorentz* transformation, events that take place simultaneously ($dt_S = 0$) in a *Minkowski* system can therefore occur successively in another *Minkowski* system. In that case, the relation $dt'_S \neq 0$ applies and the well-known

Lorentz length contraction

$$|dx| = |dx'| \cdot \sqrt{1 - \frac{v_S^2}{c^2}} \tag{70}$$

occurs. The *Lorentz* contraction will extend beyond the framework of *Euclid*ean geometry and thus beyond the framework of *Minkowski* systems, especially when the systems are accelerated to each other. In his GRT, *Einstein* enlarged the metric of the systems and the class of admissible coordination transformations accordingly; see [5].

In the *Euclid*ean universe, the reason for changing the metric disappears together with the *Lorentz* contraction. The limits of *Euclid*ean geometry are not exceeded even if one admits *Galilei* transformations whose relative speeds of systems depend locally on the space-time coordinates $\mathbf{X} = (x^1, x^2, x^3, x^4)$, and hence are not constant; see (61). The space-time-related *Galilei* transformation maps space-like events invariantly according to their distance.

Light-like events

All elementary events of a light-like event take place at the same time t in the *Euclid*ean universe, and depend in this context on clock time t_S. Hence, light-like events are time-dependent.
We consider a particle that is moving with light velocity in S:

$$|\mathbf{u}_S| = \left|\frac{d\mathbf{x}}{dt_S}\right| = c\,,$$

Based on (34) and (63),

$$dt = 0 \text{ in } S$$

arises. As the coordinate time of the time-like coordinate is assumed to be a *Galilei* – time,

$$dt' = 0 \text{ in } S'$$

also has to apply and, with the help of (34) and (64), we obtain

$$|\mathbf{u}'_S| = \left|\frac{d\mathbf{x}'}{dt'_S}\right| = c.$$

Hence, the validity of the principle of the constancy and finiteness of the speed of light in a vacuum (54) applies immediately for all systems of the *Euclid*ean universe.
The validity of principle (54) substantiates the experimental findings of *Michelson* and *Morley* [1] and others - here for the first time also for *Euclid*ean systems.

Moreover, the relations (67-69) apply and

$$dt'_S = dt_S \tag{71}$$

holds. A distance, covered by a photon in the *Euclid*ean university, is an invariant of all admissible systems as well as the clock time duration needed for that reason.

Time-like events

In the Euclidean universe, time-like events describe the path of particles that have a rest mass greater than zero. Hence, they are time-dependent.
The elementary events of a time-like event are dependent here on the *Galilei* - time t, which is increasing strictly in a monotonic manner in the course of the event: dt > 0. In the systems $\mathbb{S}$

$$dt_S = dt/ß_S\,,\quad ß_S = \sqrt{1-u_S^2/c^2}\;\text{ in }\;\mathbb{S}$$

as well as the time duration

$$dt'_S = dt'/ß'_S\,,\quad ß'_S = \sqrt{1-u'^2_S/c^2}\;\text{ in }\;\mathbb{S}'.$$

Owing to $dt' = dt$, we obtain

$$ds' \cdot ß'_S = ds \cdot ß_S \;\text{ and }\; dt'_S \cdot ß'_S = dt_S \cdot ß_S\,. \tag{72}$$

If a particle is at rest in the system S′, then $\mathbf{u}'_S = 0$ applies. Thus, by means of the *Newton*ian addition theorems, (56) and (57), one obtains:

$$|\mathbf{u}| = |\mathbf{v}| \quad \text{or} \quad |\mathbf{u}_S| = |\mathbf{v}_S|.$$

In this case, there results a

dilatation of the path:

$$ds = \frac{ds'}{\sqrt{1-\mathbf{v}_S^2/c^2}}\quad . \tag{73}$$

Here, the dilatation of a particle path cannot be understood in the context of a *Lorentz* length contraction. Rather, here, dilatation signifies that the particle is at space-related rest during a period of time $\Delta t'$ in $\mathbb{S}'$ ($|\Delta\mathbf{x}'| = 0$), but in the course of this time, in the space-time of $\mathbb{S}'$, the particle moves, free of force (according to *Newton* in a straight line and in a uniform manner) on the shortest path $\Delta s' = |\Delta \mathbf{X}'| = c \cdot \Delta t'_S$ parallel to the time-like coordinate $\Delta s' = |\Delta \mathbf{x}'^4|$.

In the system S, also during the time period Δt = Δt′, this same particle takes another necessarily longer path in space-time under the influence of a force that is active there (i.e., a planet's force of gravity); see (73) and (44) at $|\Delta \mathbf{x}|>0$ and $|\Delta x^4| = |\Delta x'^4|$.

In *Euclid*ean systems, path dilatation is transmitted to measured clock-time values [18,32].

In previous physics, clocks have been instruments used to measure the duration of events, and it has been assumed that clock time proceeds in accordance with the chronological sequence of events (at least within a system), and also with the course of the aging of particles [29,33].

In a *Euclid*ean system, clocks are indeed also measuring the time duration that a particle needs to cover a path in a system during an event. However, in this context, we are concerned with a four-dimensional path in space-time. With regard to the clock time, along the path, the particle speed is here always constant c, and the measured time duration is accordingly proportional to the length of the path; see (34):

$$dt_S = 1/c \cdot ds \text{ in } \mathbb{S} \text{ as well as } dt'_S = 1/c \cdot ds' \text{ in } \mathbb{S}'.$$

Due to (73), from these relations, a

dilatation of the clock time

$$dt_S = \frac{dt'_S}{\sqrt{1-\mathbf{v}_S^2/c^2}} \ , \quad dt'_S = dt \tag{74}$$

follows; see [12]. However, this is only a *seeming* dilatation. The considered particle is covering a longer path in the space-time of $\mathbb{S}$ than in that of $\mathbb{S}'$, and accordingly requires more clock time. The aging, however, is equal in both systems: dt = dt′. More precisely, in *Euclid*ean systems we are measuring path lengths in space-time rather than time values, which are controlling the chronological sequence of events and aging.

For the particle velocities $\mathbf{U} = (u^1, u^2, u^3, c)$ in $\mathbb{S}$ and $\mathbf{U}' = (u'^1, u'^2, u'^3, c)$ in $\mathbb{S}'$, which are both referred to as the *Galilei* time t,

$$|\mathbf{U}| = \frac{ds}{dt} \quad \text{and} \quad |\mathbf{U}'| = \frac{ds'}{dt'}$$

apply, see (44), and, due to (55) and (73), we also obtain a

dilatation of particle velocities in space-time:

$$|\mathbf{U}| = |\mathbf{U}'| / \sqrt{1-\mathbf{v}_S^2/c^2} \ . \tag{75}$$

Thereby, $|\mathbf{U}'| = |\mathbf{U}'_S| = c$ applies.

Clocks can be at rest in a system of the universe, but in another admissible system, they can simultaneously be moved. Thus, the clocks (considered as particles) are forming time-dependent events by themselves.

As an *inward clock* of a particle, we designate a clock that is not moving relative to a corresponding particle:

$$\mathbf{u}_E^C = \mathbf{u}_E - \mathbf{u}_C = 0.$$

In the case of $|\mathbf{u}_E^C| > 0$, we speak of an *outward clock* related to the particle.

Remarks:

- A clock can be an inward clock of a particle, but at the same time also an outward clock of another particle.
- Each particle that has a rest mass different from zero ($m_o > 0$) is subjected to aging, which can essentially be identified by biochemical decomposition. In this context, the decomposition rates determine the *Galilei* time duration of decomposition events along the path of a body, especially its lifetime. Thus, these decomposition rates establish the mechanism of an inward clock.
- External clocks of a particle measure the clock-time duration Δt_S, which is necessary for the particle, in order to cover a path $\Delta s = c \cdot \Delta t_S = |\Delta \mathbf{X}|$ in the system space-time. In this context, events are not generally arranged in the sequence of their occurrence.

We designate a system S_C as a *rest system* of a clock C if C is at rest in S_C: $|\mathbf{u}_C| = 0$. If a clock is situated within a system that is moving, then there is a transformation into a rest system of the clock:

$$\mathbf{u} = \mathbf{u}' - \mathbf{v}', \quad \mathbf{v} = -\mathbf{v}', \quad \mathbf{v}' = \mathbf{u}'_C. \tag{76}$$

In such cases, there applies $\mathbf{u}_C = 0$ in S_C.

From (74), it can be seen that the inward clock of a particle goes more slowly than all outward clocks of this particle. If a particle's outward clock is at rest in a system, then, vice versa, the inward clock of the particle is moving in the system. Hence, according to *Einstein'*s SRT, in *Euclid*ean systems, clocks in motion proceed more slowly than clocks at rest.

Remark:

Here, we assume that the frequency of each clock beforehand is tuned and calibrated in its rest system to the radiation frequency of a substance, also resting there, e.g., caesium (1 s corresponds to a duration of 9.192.631.770 periods of caesium 133 radiation). Accordingly, one can calculate the lifetime (or the life expectancy) of particles in the rest system of the clock. If, thereby, a particle is moving, then it is necessary to re-project the calculated clock-time duration afterward to the *Galilei* time by means of synchronization (41) and (52). In the *Euclid*ean universe, the lifetime of particles is related to *Galilei* time, and with it, the lifetime is an invariant of all admissible systems of the universe.

8. Muons

We want to explain the synchronization of times and velocities, as well as the dilatation of paths, clock times, and particle velocities using the behaviour of muons as an example [18,34].

In cosmic radiation processes within the Earth's atmosphere, muons are created at an altitude of about 20 km. Muons move in the direction of the Earth's surface almost at the speed of light. Before they decompose into three leptons, one electron, and two neutrinos, the elementary particles have a life expectancy (half-life period) of 2.2 µs. During this time, muons approach the Earth's surface. However, they ought to cover no more than 660 m if, according to

(38), one considers c to be the universe's maximal effective speed related to clock time. The mean speed $\mathbf{v}_S$ of the muon swarm relative to the Earth's surface could be calculated with $|\mathbf{v}_S|$ = 0.9998 · c [33]. The SRT explains this seeming contradiction with time dilatation: muons in motion simply live longer than muons at rest. In the *Euclid*ean universe, this concept is to be interpreted in another way; see Fig. 6.

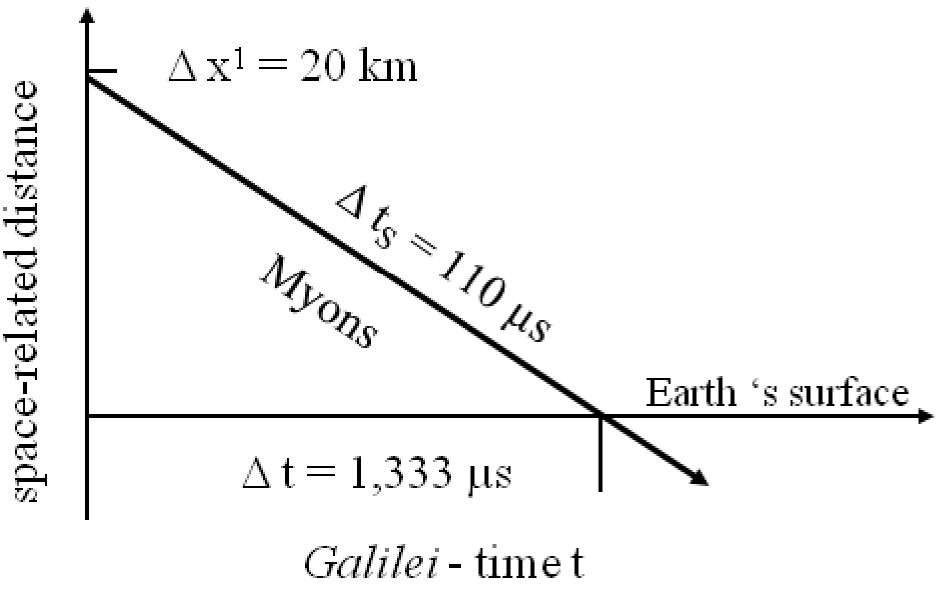

Fig. 6. Lifetime of muons in the *Euclid*ean universe.

The life expectancy here is a *Galilei* time duration and thus system-independent. Hence, muons always live only for 2.2 µs. If one calculates the lifetime of the muons by means of an external clock, then a synchronization of the swarm velocity becomes necessary. We explain this in detail.

We consider the swarm of muons as a system $\mathbb{S}'$ that is moving at the velocity $\mathbf{v}_S$ in the Earth's *Euclid*ean system $\mathbb{S}$. With respect to *Galilei* time, the life expectancy of muons is in S as well as in S':

$$\Delta t' = \Delta t = 2.2\ \mu s.$$

We now neglect the individual movements of muons in the swarm S'. Therefore, we set $\mathbf{u}'_S$ = 0, and with the addition theorems (56) and (57) we obtain

$$|\mathbf{u}_S| = |\mathbf{v}_S| \text{ in } \mathbb{S}.$$

Thereof, the *Lorentz* factors

$$ß_S = \sqrt{1-\mathbf{v}_S^2/c^2} = 0{,}02\ ,\ ß = 1/ß_S = 50 \text{ result in } \mathbb{S},$$

as well as

$$ß'_S = ß' = 1 \text{ in } \mathbb{S}'.$$

and with it, by speed synchronization (52), we receive the space-related and t-referred relative speed

$$|\mathbf{v}| = |\mathbf{v}_S| / ß_S = 49{,}996 \cdot c$$

between the systems.

The space-related path of the muons in the course of their life (apart from obstacles) can then amount to a length of

$$|\Delta\mathbf{x}| = |\mathbf{v}| \cdot \Delta t = 32{,}99\text{km in } \mathbb{S}$$

This length indicates that muons reach the Earth's surface before they disintegrate. On the contrary, in the swarm system $\mathbb{S}'$, the elementary particles are at rest. This signifies

$$|\Delta\mathbf{x}'| = 0 \text{ in } \mathbb{S}'.$$

From this it follows that

$$\Delta t'_S = \Delta t' \text{ and } \Delta s' = \Delta x'^4 = c \cdot \Delta t'_S = 660\text{m in } \mathbb{S}'.$$

Clock time and *Galilei* time are already synchronous in $\mathbb{S}'$. As a result, we obtain the speeds and path lengths of the muons related to *Galilei* time t in the space-time:

$$|\mathbf{U}'| = \Delta s'/\Delta t' = c \text{ and } |\Delta\mathbf{X}'| = |\mathbf{U}'| \cdot \Delta t' = \Delta s' = 660\text{m in } \mathbb{S}'.$$

Thus, before decomposing, the muons cover 660 m (on average) along the time-like coordinate in space-time.
In the system $\mathbb{S}$, the muons partially come also

$$\Delta x^4 = c \cdot \Delta t = 660\text{m}$$

far in the direction of the time-like coordinate, and thus have the same aging.

Now, by means of the dilatation laws (73–75), it is possible to calculate the path lengths and velocities of the muons in space-time in the Earth system $\mathbb{S}$. Because of (73), the mean path length of muons is

$$\Delta s = \Delta s' / ß_S = 33\text{km}.$$

Using an outward clock that is resting in the Earth system $\mathbb{S}$, the muons would need, in accordance with (74), a time duration of

$$\Delta t_S = \Delta t'_S / ß_S = 110\mu\text{s}$$

to reach this path length. Nevertheless, at that rate they are aging, just as in S', only within 2.2 µs. The velocity of muons in the space-time of the Earth system results from (75) to

$$|\mathbf{U}| = ß \cdot |\mathbf{U}'| = 50 \cdot c \text{ at } |\mathbf{u}| = 49{,}996 \cdot c,$$

and we obtain also here the path lengths

$$|\Delta \mathbf{X}| = |\mathbf{U}| \cdot \Delta t = \Delta s = 33\text{km} \text{ as well as } |\Delta \mathbf{x}| = |\mathbf{v}_S| \cdot \Delta t_S = 32{,}99\text{km in } S.$$

According to (45), the particle velocities related to *Galilei* time t are always greater than or equal to c. However, contrary to the *Einstein*ian theory, this finding does not constitute a contradiction in the *Euclid*ean universe. The vacuum light speed is in each case the greatest effective speed that occurs in the universe. On the one hand, related to clock time, it is $c \approx 3 \times 10^5$ km/s, and on the other hand, it is infinitely great related to *Galilei* time. In both cases, the principle of the greatest effective velocity is fulfilled:

$$|\mathbf{u}_S| = 0{,}9998 \cdot c \leq c \text{ und } |\mathbf{u}| = 49{,}996 \cdot c < +\infty.$$

The principle of the constancy and finiteness of the light speed in a vacuum is also guaranteed in the *Euclid*ean universe, but only with reference to clock-time values.

9. The Twin Paradox

In SRT, a twin paradox can generally be understood as a problem of different aging of twins that occurs, for instance, if one of the two twins goes on a voyage in the universe [3,18,35]. Here, we consider the twin paradox in a modified manner: the twins consist here of an observer B who is at rest in the Earth system S, and a muon M that is moving in the swarm $S^{/}$ toward the Earth's surface (apart from the observer's previous life).

In *Einstein*'s SRT, the system-dependent clock time in the context of the *Minkowski* metric determines the course of aging. Accordingly, during the flight of M to the Earth's surface, B, who is at rest in the Earth system, would have to be aging faster than M (clocks in motion proceed more slowly). On the other hand, because of the relativity of movements, B is conversely also moving with the Earth's surface to the resting swarm of muons, and would now, in this context, age slower than M, which is at rest there. In our opinion, this paradox—despite all of the contortions that have been performed for this purpose—is an indication of the fact that system-dependent clock time is unsuitable to describe aging processes.

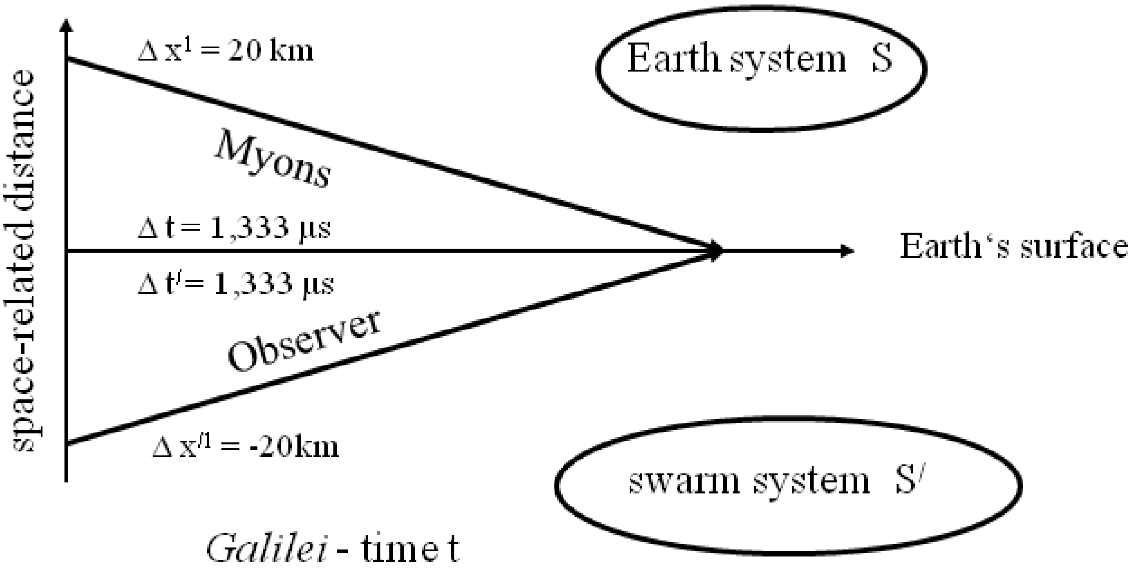

Fig. 7. Twins in *Euclid*ean systems.

Now, we show by this example that, in the *Euclid*ean universe, twins are always aging in the same way independent of systems and of movements (see Fig. 7).

Initially, the swarm of muons is 20 km above the Earth's surface. Accordingly, then, both M in the Earth system S and B in the swarm system S' are covering this distance:

$$|\Delta \mathbf{x}_M| = |\Delta \mathbf{x}'_B| = 20 \text{ km}.$$

Herein, M is at rest in the muon swarm, and B is resting on the Earth's surface:

$$\mathbf{u}_B = 0 \text{ in S and } \mathbf{u}'_M = 0 \text{ in } S'.$$

Moreover, according to the *Newton*ian addition theorem (56), the velocities of B and M coincide with the relative velocity of the systems:

$$\mathbf{u}_M = \mathbf{v} \text{ and } \mathbf{u}'_B = \mathbf{v}' \text{ at } |\mathbf{v}'| = |\mathbf{v}| = 49{,}996 \cdot c\ .$$

Then B requires in S' the same *Galilei* time that M uses in S, in order to cover the distance of 20 km:

$$\Delta t'_B = |\Delta \mathbf{x}'_B| / |\mathbf{v}'| = \Delta t_M = |\Delta \mathbf{x}_M| / |\mathbf{v}| \approx 1{,}333 \mu s.$$

Therefore, the 2.2 μs lifetime of M is sufficient to reach the Earth's surface. Since a *Galilei* time duration is system-independent, we obtain moreover

$$\Delta t'_M = \Delta t_M \text{ and } \Delta t_B = \Delta t'_B\ .$$

Hence, the twins B and M are both aging at the same speed and in a system-independent manner by

$$\Delta t_B = \Delta t_M = \Delta t'_B = \Delta t'_M = 1{,}333 \mu s\ .$$

Thus, we can note that there is no twin paradox in the *Euclid*ean universe.

Remark:
In voyages through the universe at relatively great speeds, as compared to the speed of light, one could get into remote regions of the *Euclid*ean universe. Upon returning, owing to

$$|\Delta \mathbf{x}| = |\mathbf{u}| \cdot \Delta t \quad \text{mit} \quad |\mathbf{u}| < \infty,$$

one would have aged only a little in comparison with life expectancy, (in the limit case, not at all), but always only just as much as all other contemporaries on the Earth.

10. Relativity principles and prospects

In this paper, an alternative to *Einstein*'s relativity theories was presented: a four-dimensional *Euclid*ean and hence flat universe that allows for accelerated particle movements.
The alternative theory is based on three relativity principles:

- the general principle of relativity, see section 6;
  in *Galilei* transformations, invariance with regard to the form of physical laws is required (covariance principle), and this invariance has to be referred to as *Galilei* time in every formulation that is dependent on time;

- the principle of the equivalence of inertial and heavy masses;
  this principle is supposed with regard to the matter distributed in space-time of admissible systems;

- the principle of the constancy and finiteness of the aging velocity in space-time (aging principle), see section 3.

The principle of constancy and finiteness of all particle velocities in space-time is related to clock time and can be derived from the aging principle. The principle can be seen as an accentuation of *Einstein*'s principle of the constancy and finiteness of the vacuum light speed.

Referred to as *Galilei* time, in *Euclid*ean systems the infinity of the vacuum light speed also follows from the aging principle.

If we assume that light speed is likewise an effective speed of information transmission, then, when observing remote objects in accordance with the infinity of the light speed, we do not look at the past, as has been assumed up to now, but rather we see the present.

The *Euclid*ean universe, which is based on these three relativity principles and applies *Galilei* – transformations instead of *Lorentz* – transformations to form systems, shows other properties with respect to the relativity of phenomena in comparison with *Einstein*'s universe:

- The invariance of simultaneousness is recovered.
- Aging of matter takes place equally in all systems of the universe. There is no twin paradox.
- There is no *Lorentz* length contraction.
- The dilatation of clock time occurs only seemingly. *Galilei* time cannot be stretched.

Insights resulting from these properties we have presented exemplarily when interpreting the flight of muons [18,34] and at clarifying the twin paradox [3,18,35].

Moreover, we can show show that the relativity theory of *Euclid*ean systems is also supported by essential experimental findings of the last century, for instance, by measurements of *Doppler* effects [2] and of the diffraction of light under the influence of gravity [8,10] (results in preparation).

*Maxwell'*s field equations of electrodynamics are mapped covariantly by *Galilei* transformations if the speed of wave propagation (*Weber*'s relation [18,36]) is related to the *Galilei* time following the general relativity principle.

Within the framework of a four-dimensional *Newton*ian physics, the mass-energy equivalence, which *Einstein* related to clock time [31], is adaptable in the *Euclid*ean university with regard to *Galilei* time.
In *Einstein*'s theory [4,5], gravity is understood as a fictitious force needed to realize mass attraction. The *Einstein*ian field equations are based on the tensor generalization of *Poisson'*s equation [5], which calculates *Newton*'s potential.

Due to the missing invariance of space-time-related distances, the absent curvature of space-time, and the infinity of light speed (related to *Galilei* time), such a generalization in the *Euclid*ean universe is neither possible nor desirable, and moreover it is not necessary.

In the *Euclid*ean universe, presupposing the equivalence of heavy and inertial mass, gravity is a conservative force, whose potential is formed just by means of *Newton*'s potential as a measure of gravitation intensity, but contrary to *Newton*'s potential, it is related here to *Galilei* time.

Literature

1. Michelson, A.A., Morley, E.W.: On the relative motion of the earth and the luminiferous ether. Am. J. of Science (3.Series) **34**(203), 333-345 (1887)
2. Römer, O.: Eine Demonstration der Bewegung des Lichts (Übersetzung der Originalarbeit von 1676). In: Der Weg der Physik, S. Samburski (ed.), dtv 6093, München 1978
3. Einstein, A.: Zur Elektrodynamik bewegter Körper. Ann. Phys. **17**, 891-1021 (1905)
4. Einstein, A.: Feldgleichungen der Gravitation. Sitzungsberichte der Preußischen Akad. D. Wiss. **47**, 831 (1915)
5. Einstein, A.: Die Grundlagen der allgemeinen Relativitätstheorie. Ann. Phys. **51**, 739-822 (1916)
6. Alley, C.O.: Relativity and clocks. In: Proc. 33. Annual Symp. on Frequency Control (IEEE), Atlantis City, New Jersey, USA, 30 May – 1 June 1979
7. Born, M.: Einstein's Theory of Relativity. Dover Publications, New York 1962
8. Colls, P.: Einstein, Eddington and the 1919 Eclipse. In: Proc. Int. school on the historical Development of modern cosmology, Valencia 2000
9. Kramer, M., et al.: Tests of General Relativity from Timing the Double Pulsar. Science **314**, 97-102 (2006)
10. McEvoy, J.P.: Sonnenfinsternis. Die Geschichte eines Aufsehen erregenden Phänomens. Berlin 2001
11. Mercier, A., Treder, H.-J., Yourgrau, W.: On General Relativity. Akademie-Verlag, Berlin 1979
12. Laue, M.: Die Relativitätstheorie. In: Die Wissenschaft Bd. 38 und 68, Vieweg & Sohn, Braunschweig 1965 (Nachdruck)
13. Minkowski, H.: Raum und Zeit. Phys. Zeitschrift **10**, 104-117 (1909)
14. Minkowski, H.: Das Relativitätsprinzip. Ann. Phys. **352**, 927-938 (1915)
15. Lorentz , H.A., Einstein, A., Minkowski, H.: Das Relativitätsprinzip. Teubner, Leipzig/Berlin 1913
16. Newton, I.: Philosophiae Naturalis Principia Mathematika. In: Reg. Soc., London 1686
17. Newton, I.: Die mathematischen Prinzipien der Physik. V. Schüller und W. De Gruyter (eds.), Berlin/New York 1999
18. Melcher, H.: Relativitätstheorie in elementarer Darstellung mit Aufgaben und Lösungen. Dt. Verlag der Wissenschaften, Berlin 1974
19. Bogess, N.W., et al.: The COBE mission: Its Design and Performance Two Years after the launch. Astrophysical J. **397**, 420 (1992)
20. Odenwald, S., Newmark, J., Smoot, G.: A study of external galaxies detected by the COBE Diffuse Infrared Background Experiment, Astrophysical J. **500** (2), 544-568 (1998)
21. de Bernardis, P., et al.: A flat universe from high-resolution maps of the Cosmic Background. Nature **404**, 955-959 (2000)
22. Lange, A.E., et al.: Cosmological Parameters from the first results of Boomerang. Phys. Rev. **D 63**,1-7 (2001)

23. Netterfield, C.B., et al.: A measurement by BOOMERANG of multiple peaks in the angular power-spectrum oft the cosmic microwave background. Ap. J. **571**, 604-616 (2002)
24. Stephani, H.: Allgemeine Relativitätstheorie. Dt. Verlag der Wissenschaften, Berlin 1977
25. Einstein, A.: Prinzipielles zur Allgemeinen Relativitätstheorie Ann. Phys. **55**, 241-244 (1918)
26. Einstein, A.: Grundzüge der Relativitätstheorie. In: Vier Vorlesungen über Relativitätstheorie, 8. erweiterte Aufl.,Vieweg, 1990
27. Lenk, R., Macheleit, G., Möbius, P.: Statistische Physik, Relativitätstheorie, Elementarteilchen. Studienbücherei, Bd. 12, Dt. Verlag d. Wiss. Berlin 1979
28. Almeida, J.B.: An alternative to Minkowski space-time, arXiv:gr-qc/0104029v2, June 2001.
29. Gersten, A.: Euclidean Special Relativity. Foundation of Physics **33**(8), 1237-1252 (2003)
30. Montanus, J.M.C.: Proper-Time Formulation of Relativistic Dynamics. Foundation of Physics **31**(9), 1357-1400 (2001)
31. Stachel, J.: Einsteins Annus mirabilis . Fünf Schriften, die die Welt der Physik Revolutionierten. Rowohlt, 2. Auflage, Reinbek bei Hamburg 2005
32. Hafele, J.C., Keating, R.E.: Around the world Atomic clocks: Predicted Relativistic Time Gains (Theory and experiment). Science **177** (4044), 166-170 (1972)
33. Bailey, J., et al.: Measurement of relativistic time dilatation for positive and negative muons in a circular orbit. Nature **268**, 301-305 (1977)
34. Bailey, J., et al.: Final report on the CERN muon storage ring including the anomalous magnetic moment and the electric dipole moment of the muon, and a direct test of relativistic time dilation. Nucl. Phys. **B 150**, 1-75 (1979)
35. Skobelzyn, D.W.: Das Zwillingsparadoxon in der Relativitätstheorie. Akademieverlag, Berlin 1972
36. Weber, J.: General Relativity and Gravity waves. Interscience Publ. (Wiley), New York 1961