# Review of Minkowski space and Lorentz transformation: A new theory of relativity based on universal quantum

**Chol Jong，  Un Chol Han**

Kim Chaek University of Technology, Pyongyang, Democratic People's Republic of Korea

Email: jch59611@star-co.net.kp (C. Jong); huch8272@163.com, huch8272@star-co.net.kp (U.C. Han)

## Abstract

The theory of relativity is an important pillar supporting modern physics along with quantum theory, but the open questions present in this theory require revolutionizing the perspective on relativity and mathematical foundations of relativity. We present a generalized theory of relativity, which becomes a consequence of a unified mechanics based on the universal quantum postulated as a primitive elementary particle constituting physical vacuum and matter. Our theory does not require the fundamental postulates of the theory of relativity, such as the principle of relativity, the principle of the constancy of the speed of light, and the principle of equivalence, and needs only the universal quantum to formulate a new theory of relativity, but explains relativistic effects successfully. Our work shows that the idea for the unified space-time which gives the Lorentz transformation is not mathematically and physically justified. We first analyze from a new angle the concepts, principles and results of the special theory of relativity and prove that it is impossible to construct a theory of relativity using geometry in the Minkowski space. We introduce the concept of the universal quantum concretizing the concept of the ether and construct a consistent theory of relativity based on the concept of the density of universal quanta and of effective time of interaction, without recourse of Einstein's relativity theory. We construct new relativistic dynamics and electrodynamics based on the effective time of interaction. We formulate a new theory of gravity able to explain relativistic effects, based on the concept of the universal quantum without using the concept of space-time. Thus, our work achieves the aim of constructing a consistent theory of relativity by means of a single mechanism based on the concept of the universal quantum in a unified way to include inertial frames and noninertial frames altogether.

**Keywords：** Principle of constancy of speed of light, Principle of relativity, Lorentz transformation, Minkowski space, Ether

# Contents

# 1. Introduction

The special theory of relativity (STR) emerged in attempts to establish a universal principle of relativity in all fields of mechanics, including not only mechanics but also electrodynamics [1,2]. Einstein's theory of relativity, which adopted as universal bases of physics the principle of relativity and of the constancy of the speed of light, completely overturned Newton's notion of absolute space and time. By applying this theory to mechanics and electrodynamics, the important results were obtained.

The theory of relativity was mainly built by Lorentz, Poincaré and Einstein. Originally, Lorentz and Poincaré proposed the Lorentz transformation that assumed the existence of the ether and accounted for the relativistic effects of the time delay and the length contraction in inertial frames moving in an ether medium. This relativistic transformation was first presented by Lorentz, and then was completed by Poincaré in the present form. In essence, this theory, called Lorentz's theory of relativity, is an ether-based theory of relativity [3,4]. After the advent of this theory, Einstein proposed the principle of the constancy of the speed of light and built STR, based on assuming the Lorentz transformation to be a transformation that holds for any two inertial reference systems. STR built by Einstein was successful in constructing electrodynamics that satisfies the covariance in all inertial frames [5]. As a result, the ether theory had been finally rejected and it was generally accepted that the principle of relativity holds also in the domain of electromagnetic phenomena. The current general evaluation is that the theory of relativity has been successfully applied to mechanics, electrodynamics, and quantum mechanics, and has achieved big successes, and has become the theoretical basis of modern physics including cosmology [6].

Despite the successes, the theory of relativity cannot be assessed as a perfect theory even today due to open problems concerning experimental confirmations and mathematical and physical interpretation [7-12]. It is a recognized fact that there remain some open questions in the theory of relativity in the aspects of logic, mathematics, and physics. Debates still remain due to the conflict of different views regarding the interpretation of various paradoxes that are theoretically unsolvable and the results of various experimental studies to verify the two postulates of STR [5,7,9,13,14]. For the theory of relativity to maintain the present theoretical status, to survive, and to further develop, it must explain all the experimental results in a unified way, and provide perfect solutions to the paradoxes and open problems that exist in the theory of relativity. The anti-relativistic arguments showed that the concepts of relativity and of the unification of space and time were ambiguous, and that the principle of the constancy of the speed of light also was not satisfactorily verified [10,12-16].

The validity of the theory of relativity can be examined in three aspects. They cover the logical aspect, the physical aspect and the mathematical aspect. Originally, Einstein was not inspired with experiments on light velocity, including the Michelson-Morley experiment, and rather was propelled by the purpose for establishing the covariant theory of electrodynamics in inertial systems, so he developed STR in a deductive way. Of course, the question of whether the laws of electrodynamics have to be of covariance for all inertial systems is not self-evident, as in mechanics, and in fact it is no more than a subjective assumption, so the argument about this problem continues up to today [10,17- 20].

One core of these debates is the second postulate of STR, i.e., the principle of the constancy of the speed of light. Einstein's postulation that the speed of light is independent of the motion of a light source or an observer contradicts the concept of time as a universal variable independent of spatial coordinates. This is an idea that is not easily accessible to ordinary physical intuition and logic, so through the whole history of the development of the theory of relativity, many physicists have tried to explain the observed facts without this postulate, and the challenge continues up to date [10,13, 21-24]. The problem of covariance of electrodynamics is directly related to the principle of the constancy of the speed of light. In this sense, the two postulates of STR are not independent. If the speed of light is not constant, the present electrodynamics is a theory that holds for a preferred inertial frame, and the requirement for relativistic covariance is not necessary.

Thus, from this point of view, attempts have been made to modify electrodynamics. One of most notable and lively examples was Ritz's view of electrodynamics. Ritz left the two homogeneous Maxwell equations as they were, and built up electrodynamic equations involving a light source so that the velocity of light is equal to $c$ only when it is observed with respect to the light source. Ritz's theory explained well the observations of the aberrations of positions of stars, Fizeau's experiment, and the early Michelson-Morley experiments with cosmic light sources. However, the results of the measurements of the speed of light from double stars showed that the second postulate of STR or the assumption of the ether was correct, whereas Ritz's theory was not.

On the other hand, it was argued that most experimental data were certainly unreliable because light interacts with matter through an optical instrument before it is observed. In other words, experiments with light coming from cosmic space do not deal with the original velocity of the measured light, since the interaction of light and matter in optical instruments is unavoidable. In fact, if light passes through an optical instrument, it is completely different from the speed of the light before the incidence because it becomes the re-radiant light emitted by the matter interacting with the incident light.

However, many of the later experiments refuted the criticism of the above-mentioned arguments. In 1964, experiments at CERN were most crucial to the withdrawal of Ritz's theory. The experiments were carried out to in the way to measure the time of flight through 80 m path of a photon with the energy of 6 GeV, generated by the decay of a neutral pion of very high energy. In that experiment, where the velocity of light was measured in a direct way without the interaction between light and observational instruments, it was perfectly confirmed that the velocity of light emitted by that source, which had a velocity of 0.99975 $c$ coincided with the universal constant c in the experimental error limit. Thus, it had been revealed that Ritz's theory that the speed of light is determined by adding the speed of a light source to the universal speed of light $c$ was not correct.

Experiments at CERN had shown that the second postulate of STR was certainly true in relation to the motion of light sources. Other experiments with charged particles and neutrinos also showed such results independently. However, since the experimental data clearly did not show that the velocity of light is independent of the observer's motion, these experiments cannot be considered to have fully elucidated the two aspects of the principle of the constancy of the speed of light. The fact that the speed of light does not depend on the motion of the light source also can be reasonably explained based on the ether theory, in which the ether is considered as the medium of light propagation.

As a whole, the experiments conducted so far in relation of the speed of light do not provide a complete answer to the two aspects of the speed of light. There are clear experimental evidences that provide the necessity of examining the principle of the constancy of the speed of light. Evidence was given by an experiment that measured the velocity of light using light beams or electromagnetic waves propagating in opposite directions on a rotating disk or a rotating earth. The experiments were carried out by Sagnac, Michelson and Saburi [5,8]. These experiments clearly showed with sufficient accuracy that the Galilean rule of velocity addition for the velocity of the light source and the speed of light in a rotating system was satisfied. In this connection, some argue that systems where the experiments were carried out are not inertial frames, and thus the principle of the constancy of the speed of light in inertial systems cannot apply. But they cannot logically explain why the laws of inertial and noninertial systems with respect to light must be so different. The papers that reproduce or reinterpret the results of the Michelson-Morley experiment to confirm the validity of the second postulate of STR have attracted attention [25-34]. The new results of the research suggest that the Michelson-Morley experiment rather proves the existence of the ether and absolute motions. While the relativistic effects were well confirmed in part experimentally, numerous experiments which reproduced the Michelson-Morley experiment have shown that there is a detectable, local, preferred reference frame.

From the logical point of view, it is worth noting that philosophers including Herbert Dingle, a philosopher in the 1950s and 1960s, criticized the contradictions in the theory of relativity [7]. They criticized the logic of relativity theory which gives asymmetrical aging in equivalent two inertial systems by dealing with the twin paradox problem. A theory must not involve even a shadow of unexplainable or contradictory results in order to be a perfect theory, so that it should be considered that their criticism, even if it has a purely philosophical logical character, is reasonable. Indeed, the laws of logic are generalized by the principles and laws of nature, so there cannot be any law of nature that violates the laws of logic.

The theory of relativity has been criticized by many researchers trying to explain the mathematical aspects of this theory. A main point here is whether the transformation using one-way light velocity-dependence is of generality [7,35]. Having a negative view of this problem, some researchers proposed a new relativistic transformation considering the two-way light velocity. It is noteworthy here that considering the two-way velocity, the time-coordinate dependence in the relativistic transformation disappears [7,35]. Moreover, it is noteworthy that based on this transformation, both the time delay and the length contraction can be explained. Einstein's clock synchronization is based on the postulate of the constancy of the unidirectional velocity of light. Some researchers argue that the unidirectional velocity of light is not a law of nature and that the relativistic invariance of the interval of events is no more than a subjective hypothesis, and therefore is not a real property of the physical world [7,35]. Thus, the study of a general transformation not depending on unidirectional velocity, though accounting for relativistic effects, such as the time delay and the length contraction, continues [15,35,36]. Thus various types of relativistic transformation distinguished from the Lorentz transformation have been investigated. This situation shows the exploration of relativistic transformations that is distinct from the Lorentz transformation but can explain relativistic effects and can avoid paradoxes, which indicate that Lorentz transformation are not the only choice [15, 35].

From the physical point of view, the theory of relativity has several paradoxes that are difficult to be explained. They are problems of the time delay, simultaneity, and the length contraction (so-called Lorentz- Fitzgerald contraction) [12,16,23,24,37-39]. The twin paradox related to the delay of time remains a crucial clue showing the inner contradiction of the theory, for antirelativists, while it challenges as a great paradox that is not resolved, for relativists. Those who try to solve the problem while maintaining the theory of relativity claim that speed is the cause of the time delay and that it actually delays even biological processes. But motion and rest are purely of a relative character, so it is not possible to give a reasonable answer to how this fact is related to the physical nature of the time delay. Others regard the acceleration experienced by the traveler as the cause of the time delay, since one twin returning from the trip necessarily undergoes acceleration. However, experiments conducted at CERN have shown that speed, not acceleration, is the cause of the time delay [7]. Thus, the time delay is a core result of STR, but at the same time becomes a contradiction.

The same is true for the length contraction problem. If there is the length contraction, it contradicts the principle of relativity, since it outcomes to a denial of the equivalent qualification of any inertial frame. In this case, the nature of space-time in inertial systems is different, but the reason why the physical law must remain unchanged cannot be explained. If there is a physical effect that the different natures of space-time of two inertial frames due to relative motion bring about, it may be possible only in the case of the existence of an absolute rest frame that is distinguished from two inertial frames. However, in the condition that the principle of relativity holds, the physical phenomena occurring in the two inertial frames must be perfectly equivalent, and the equivalence of the metric, and the homogeneity and isotropy of the space on which they are based must be guaranteed. The problem of contraction of lengths of bodies moving with relativistic velocities is still an open problem and requires more sophisticated investigation [40,41]. In this regard, it must be taken into account that the length contraction has not been fully verified experimentally and is, in all respects, a result which the assumption about the unified space-time produces. There is no absolute reason to accept the concept of relativistic length. As a whole, the results of the relativistic transformation show that the postulates of STR are incompatible with each other.

It should be noted that in the context of the discussion concerning the validity of the underlying postulates of the theory of relativity, there have been attempts to fundamentally change the theory of relativity. First, it should be noted that there are attempts to argue the validity of Lorentz's theory of relativity in the consistent interpretation of experimental results and to resurrect this theory [10,42-44]. Ives in the 1930s, Builder in the 1950s, Ruderfer in the 1960s, Prokhovnik, Mansouri and Sexl developed a theory of relativity equivalent to STR based on the ether. In the 1990s, the works of Cavalleri, Selleri, and others based on the ether was of interest.

In connection with this new research trend, we need to consider the historical change in the understanding of the ether theory. Einstein, coming up with STR in 1905, denied the existence of the ether as a medium of light propagation, and by the Michelson-Morley experiment, the ether theory was finally declared inappropriate. Einstein was therefore recognized as a destroyer of the ether concept. On the other hand, in 1909 Lorentz postulated the existence of the ether in the paper "The Theory of Electrons" and established a theory of relativity equivalent to Einstein's theory, in which both the time delay and the length contraction are explained. Interestingly, we should note that Einstein abandoned his negative attitude towards the ether and developed his vision of the ether from the 1920s to 1955 until his last. This is because his general theory of relativity (GTR) required a preferred reference system. In his opinion, the ether is an entity that permeates the whole space, and both the electromagnetic field and gravitational field represent its states. According to his book "Mein Weilbild" published in 1934, Einstein wrote the term "total field" instead of the ether, explaining the concepts of space, ether, and field. Anyhow, this fact suggests that Einstein accepted the concept of the ether [45].

The recent researches provide a broad view of Lorentz and Poincaré invariance by proposing other formulations of relativity theories which can explain the four-dimensional symmetry, although they do not postulate the universal constancy of the speed of light. These non-Einsteinian relativity theories lead to a new understanding of the true nature of the postulate regarding the one-way speed of light. Furthermore, such theories show how the essential components of relativity should be considered from a new angle. In view of these trends suggestive of a new possibility of the future relativity theory, it is worthwhile to review new formulations of relativity theory both theoretically and experimentally [46-48].

These historical facts emphasize that the ether-based theory of relativity is not insignificant and that it is reviving in a new manner today when the fallacies of STR are being discussed [49,50]. In fact, the accepted notion of physical vacuum in terms of quantum field theory and quantum gravity gives a convincing explanation. The existence of the ether, whatever concrete forms may be, is confirmed to be not groundless, in that there are recent observations of the Webb redshift and the ultra high energy cosmic rays, and the modified relativity models that were presented to justify them [49,50]. However, STR, which contradicts the ether theory, still remains unchanged.

STR underlies particle physics, but researches in the recent years provide a strong motivation to explore new departures of the Lorentz invariance both from the theoretical and the phenomenological sides. In the theoretical aspect, the idea that Lorentz invariance might be only an approximate in the case of low-energy symmetry of nature among many other symmetries suggests the necessity for the corrections related to a certain high-energy scale to the standard relativistic dynamics [16,50]. Since Lorentz symmetry is one of the most fundamental symmetries of nature, the possibility of its violation was a serious theme of intense investigation in the recent years [50-53].

Einstein asserted the constancy of the speed of light in vacuum for any observer, which amounts to concluding the absence of any preferred reference frame. But GTR needs a preferred reference frame. This shows that GTR is not commensurable with STR. Meanwhile, GTR inherits the idea for the unified space-time of STR. The postulates of STR are based on the concept of a flat space-time ontology, while GTR for gravity is established in curved space-time [54]. If STR is invalidated, GTR naturally is nullified, because GTR was established with the help of an deductive method based on the idea for the unified space-time of STR. GTR uses classical potentials as the potential involved in the time component of space-time. It is not reasonable that classical potential is required to obtain relativistic results. In particular, the fact that here the absolute magnitude of potential rather than the relative magnitude of one is required implies an ambiguous aspect of GTR.

Thus, the theory of relativity has some problems to be solved from logical, mathematical, and physical points of view. They are the principle of relativity, the principle of the constancy of the speed of light, the generality of the Lorentz transformation, and the physical paradoxes that theory cannot neglect. Moreover, STR cannot be considered to have completely solved problems in relativistic electrodynamics. The physical interpretation of relativistic mass is still a matter of debate. Also, some researchers are discussing the question of whether the principle of relativity in electrodynamics is necessary and can be applicable.

On the other hand, there has been a growing interest in the research to elucidate the connection between the two important fields of modern physics, i.e., the theory of relativity and quantum mechanics, or to unify both sciences [55-59]. Some researchers have shown that the concept of ether could play a key role in the unification of the theory of relativity theory and quantum mechanics [53.60.61]. Meanwhile, the attempts to find the essence of relativity in the nature of interactions, not in the unification of space and time, have also attracted attention [62-64].

In our opinion, the study of the theory of relativity should address the following questions. First, the validity of the fundamental postulates of STR, second, the generality and accuracy of the Lorentz transformation, and third, the possibility of constructing the relativity theory based on physical causality. Based on the consideration of such problems, we aim to propose an alternative theory of relativity based on the interaction of field quanta. The field quanta we talk about are the virtual material entities that form a preferred inertial system where the velocity of propagation of interaction is constant, and that mediate all physical interactions. If relativistic phenomena are completely explained without paradox, based on the concept of it, then we must believe in the existence of the very entity which serves as the medium of light propagation. Experimental and theoretical studies to confirm the existence of the ether and the preferred inertial systems associated with it are being more activated recently [26,34,65-69]. The motivation for such studies is not accidental, and the results of the studies provide evidence in support of the ether theory. Our study is concentrated on showing that it is possible to construct a new theory of relativity that can explain the essence of relativity based on ontologies, not on geometry of space-time, and that our perspective has a realistic value.

The remaining paper is organized as follows. In Sect. 2, we analyze the Minkowski space and the Lorentz transformation. In Sect. 3, we review physical consequences of STR. In Sect. 4, we describe the theory of relativity based on the universal quantum. In sect. 5, we explain experiments on the speed of light, based on a preferred reference frame. In Sect. 6, we describe relativistic electrodynamics, based on a preferred reference frame. In Sect. 7, discussion is given. Finally, in Sect. 8 conclusions are drawn.

## 2. Mathematical analysis of special theory of relativity

### 2.1 Minkowski space

We shall revisit the Minkowski space and the Lorentz transformation to review the mathematical foundations of STR. To begin with, let us consider whether the Minkowski space is a real vector space. In STR, the relativistic invariant is the interval between events. An event is represented by a vector component $(x, y, z, ict)$ in a four-dimensional Minkowski space consisting of time and space. In the theory of relativity, the interval between events is defined as the length of a four-dimensional vector. Then, the four-dimensional vector must be represented by four basis vectors orthogonal to one another. According to the postulate of the constancy of the speed of light, the relativistic invariance describing the propagation of a light wave in two inertial frames can be expressed as

$$x^2 + y^2 + z^2 - c^2t^2 = dX^2 + dY^2 + dZ^2 - c^2T^2 = 0. \quad (2.1)$$

The above equation is a mathematical expression for the postulate of the constancy of the speed of light that the speed of light is the same in any two inertial frames in spite of their relative motion. Of course, for the Lorentz transformation, this relativistic invariance is satisfied, so that the idea for the unification of space and time was introduced.

Let us analyze the geometric relationship between two four-dimensional space-time vectors. The interval between two events expressed by time and spatial variables is represented as

$$s_{12} = \left[c^2(t_2 - t_1)^2 - (x_2 - x_1)^2 - (y_2 - y_1)^2 - (z_2 - z_1)^2\right]^{1/2}. \quad (2.2)$$

Since we consider the interval between events as the length of a space-time vector, the space-time vector in the complex space can be defined as

$$x = (ct, ix, iy, iz,). \quad (2.3)$$

The interval between events amounts to the length of the difference between two four-dimensional space-time vectors, so is represented by the self-scalar product as

$$s_{12} = \sqrt{((\boldsymbol{x}_2 - \boldsymbol{x}_1)\cdot(\boldsymbol{x}_2 - \boldsymbol{x}_1))}.$$

This coincides with Eq. (2.2), so the definition of space-time vector, Eq. (2.3) is correct.

Another definition of space-time vector $\boldsymbol{x} = (ict, x, y, z)$ does not essentially alter the content of the former definition, as shown by Eq. (2.3). Therefore, we shall use the latter notation, $\boldsymbol{x} = (ict, x, y, z)$, in the conventional way in future descriptions. A four-dimensional vector should be represented by four basis vectors orthogonal to one another and Eq. (2.1) should be invariant for the rotation transformation of these orthogonal bases. Let us analyze the geometric relationship between $\boldsymbol{x} = (x, y, z, ict)$ and $\boldsymbol{X} = (X, Y, Z, icT)$ underlying the Lorentz transformation. For the two vectors, the relation

$$(\boldsymbol{x}\cdot\boldsymbol{x}) = (\boldsymbol{X}\cdot\boldsymbol{X}) \quad (2.4)$$

should hold. Then for the four-dimensional vectors $\boldsymbol{x}$ and $\boldsymbol{X}$, the following linear transformation should hold:

$$\boldsymbol{X} = \mathsf{A}\ \boldsymbol{x}. \quad (2.5)$$

First, let us consider whether the four-dimensional space-time is a space represented by orthogonal basis vectors. For a coordinate system $K$ at rest, the unit vectors is expressed as

$$\boldsymbol{E} = (e_x, e_y, e_y, e_t) \quad (2.6)$$

and the unit vectors in the moving coordinate system $K'$,

$$\boldsymbol{E}' = (e'_x, e'_y, e'_y, e'_t). \quad (2.7)$$

Denoting the matrix of the linear transformation $\mathsf{A}$ of the basis vectors by $A$, the transformation relation between the basis vectors becomes

$$\boldsymbol{E}' = \mathsf{A}\ \boldsymbol{E}, \quad (2.8)$$

$$(e'_x, e'_y, e'_y, e'_t) = (\mathsf{A}\ e_x, \mathsf{A}\ e_y, \mathsf{A}\ e_y, \mathsf{A}\ e_t) = (e_x, e_y, e_y, e_t)A. \quad (2.9)$$

Now, let us consider the basis vectors of four-dimensional space-time based on the Lorentz transformation. According to the Lorentz transformation, we have the following relation.

$$e_x \,//\, e'_x,\ \ e_y \,//\, e'_y,\ \ e_z \,//\, e'_z. \quad (2.10)$$

This means that the basis vectors representing the spatial components of the two space-time vectors are not rotated. Eventually, since the spatial coordinate axes do not rotate, it turns out that the basis vector of the time component does not rotate. Thus, we confirm that $e_t$ is parallel to $e'_t$.

But in fact the unit vector of time is inconceivable and the rotation of the time coordinate axis does not make sense. This means that the Lorentz transformation does not describe the rotation of two space-time vectors. It is also clear from the definition of vector that the four-dimensional vector $\boldsymbol{x}=(x, y, z, ict)$ is not a true vector. The space-time vector is represented by use of the basis vectors as

$$\boldsymbol{x} = xe_x + ye_y + ze_z + icte_t = (x, y, z, ict). \tag{2.11}$$

Thus, the Minkowski space is a linear space defined in complex space.

For three vectors $\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{z}$ in this space, the scalar product must satisfy the following axioms of vector:

$$\begin{aligned} &1^\circ\ (\boldsymbol{x},\boldsymbol{y}) = \overline{(\boldsymbol{y},\boldsymbol{x})} \\ &2^\circ\ (\lambda\boldsymbol{x},\boldsymbol{y}) = \lambda(\boldsymbol{x},\boldsymbol{y}) \\ &3^\circ\ (\boldsymbol{x}+\boldsymbol{y},\boldsymbol{z}) = (\boldsymbol{x},\boldsymbol{z}) + (\boldsymbol{y},\boldsymbol{z}) \\ &4^\circ\ (\boldsymbol{x},\boldsymbol{x}):\ \text{zero or positive real number,} \end{aligned} \tag{2.12}$$

where $\lambda$ is a complex number, and the bar notation indicates a complex conjugate number. Defining the axiom $1^\circ$ as $(\boldsymbol{x}, \boldsymbol{y}) = (\boldsymbol{y}, \boldsymbol{x})$ leads to the direct contradiction to the other axioms.

If the axioms of the scalar product $2^\circ$ and $4^\circ$ hold, then for any complex number $\lambda$, it follows that $(\lambda\boldsymbol{x}, \lambda\boldsymbol{x}) = \lambda^2(\boldsymbol{x}, \boldsymbol{x})$, and setting $\lambda = i$ results in $(\lambda\boldsymbol{x}, \lambda\boldsymbol{x}) = -(\boldsymbol{x}, \boldsymbol{x})$. This violates the axiom $4^\circ$ as the norm axiom.

The square of the interval between events $(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_2 - t_1)^2$, which is regarded as the square of the length of a vector, corresponds to the case where axiom $1^\circ$ is defined as

$$(\boldsymbol{x}, \boldsymbol{y}) = x_1y_1 + x_2y_2 + x_3y_3 + \cdots + x_ny_n = (\boldsymbol{y}, \boldsymbol{x}).$$

In this case, it is clear that the interval between events does not satisfy the norm axiom. However, if we define the scalar product as

$$(\boldsymbol{x}, \boldsymbol{y}) = \bar{x}_1y_1 + \bar{x}_2y_2 + \bar{x}_3y_3 + \cdots + \bar{x}_ny_n = \overline{(\boldsymbol{y}, \boldsymbol{x})},$$

the norm axiom is satisfied. In fact, in this case the square of the interval between events is given as

$$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 + c^2(t_2 - t_1)^2$$

in terms of $|\boldsymbol{x}|^2 = (\boldsymbol{x}, \boldsymbol{x})$, so that the norm axiom is satisfied. But this is inconsistent with the mathematical expression for the principle of relativity, i.e., the expression for the interval between events

$$(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_2 - t_1)^2 .$$

Thus, the interval between events cannot be regarded as the length of a vector, and thus we can see that the geometry of the four-dimensional space-time based the interval between events is not correct from its starting point.

## 2.2 Derivation of Lorentz transformation in terms of symmetric matrix

Unlike the previous methods, we will derive the Lorentz transformation from the mathematical point of view. This derivation is helpful to understand the mathematical starting point of the Lorentz transformation.

Suppose that one inertial frame $K$ is at rest and that another one $K'$ moves at speed $V$ in the direction of $x$-axis. As usual, the coordinate systems of the two inertial frames are set such that one axis coincides with the corresponding axis and the other two axes are parallel to the corresponding axes. The space and time coordinates in the stationary coordinate system are $x, y, z, t$, and the space and time coordinates in the moving coordinate system are $X, Y, Z, T$. The $y$-axis and $Y$-axis, and $z$-axis and $Z$-axis are parallel, respectively, so that for the motion in the direction of $x$-axis, we can set

$$y = Y,\ z = Z.$$

Let us assume that for both inertial frames, the following relation of linear transformation holds.

$$\left.\begin{aligned} x &= aX + bcT \\ ct &= bX + acT \end{aligned}\right\}, \tag{2.13}$$

where the second expression of Eq. (2.13), which describes the time-coordinate dependence, is by no means natural and is essentially an important assumption. This assumption leads to the notion of relativity of the simultaneity. The linear transformation relation (2.13) can be expressed in the matrix form as follows.

$$\begin{pmatrix} x \\ ct \end{pmatrix} = \begin{pmatrix} a & b \\ b & a \end{pmatrix} \begin{pmatrix} X \\ cT \end{pmatrix}. \tag{2.14}$$

As shown above, the linear transformation matrix is put in the form of a symmetric matrix. In fact, to be a linear transformation preserving the length of vectors, the transformation matrix must be unitary, and if the unitary matrix is real, its inverse matrix must be the transposed matrix. By Eq. (2.13), for the origin of the moving inertial frame the following relation holds. That is,

$$\frac{x}{ct} = \frac{b}{a} = \frac{V}{c}. \tag{2.15}$$

Let us determine the coefficients $a, b$. According to the postulate of the constancy of the speed of light, we can determine these coefficients. By Eq. (2.13), the differentials of time and coordinate are expressed as

$$\left.\begin{aligned} dx &= adX + bcdT \\ cdt &= bdX + acdT \end{aligned}\right\}. \tag{2.16}$$

This relation is rewritten as

$$\left.\begin{aligned} dx &= adX + bd(cT) \\ d(ct) &= bdX + ad(cT) \end{aligned}\right\}.$$

The above expression is expressed in the form of matrix as

$$\begin{pmatrix} dx \\ d(ct) \end{pmatrix} = \begin{pmatrix} a & b \\ b & a \end{pmatrix} \begin{pmatrix} dX \\ d(cT) \end{pmatrix}. \tag{2.17}$$

Calculating the squares of the differentials, respectively yields

$$\left.\begin{aligned} dx^2 &= a^2dX^2 + 2abcdXdT + b^2c^2dT^2 \\ c^2dt^2 &= b^2dX^2 + 2abcdXdT + a^2c^2dT^2 \end{aligned}\right\}. \tag{2.18}$$

The postulate of the constancy of the speed of light in vacuum leads to the following result.

$$\left.\begin{aligned} &\frac{dx^2}{c^2dt^2} = \frac{a^2dX^2 + 2abcdXdT + b^2c^2dT^2}{b^2dX^2 + 2abcdXdT + a^2c^2dT^2} = 1 \\ &\frac{dX^2}{c^2dT^2} = 1 \end{aligned}\right\}. \tag{2.19}$$

We modify Eq. (2.19) as

$$\left.\begin{aligned} &\left(a^2 - b^2\right)dX^2 + \left(b^2c^2 - a^2c^2\right)dT^2 = 0 \\ &dX^2 - c^2dT^2 = 0 \end{aligned}\right\}. \tag{2.20}$$

Combining these two equations, we get

$$a^2 - b^2 = 1. \tag{2.21}$$

Expressing Eq. (2.21) in the form of

$$1-\frac{b^2}{a^2}=\frac{1}{a^2} \tag{2.22}$$

and taking into consideration Eq. (2.15), we obtain

$$a=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}, \tag{2.23}$$

$$b=\frac{\frac{V}{c}}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{2.24}$$

As a result, the transformation relation between the systems $K$ and $K'$ can be expressed in the form of matrix as

$$\begin{pmatrix} x \\ y \\ z \\ ct \end{pmatrix}=\begin{pmatrix} \beta & 0 & 0 & \beta\frac{V}{c} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \beta\frac{V}{c} & 0 & 0 & \beta \end{pmatrix}\begin{pmatrix} X \\ Y \\ Z \\ cT \end{pmatrix}, \tag{2.25}$$

where, $\beta=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$. Expressing Eq. (2.25) in the form of an algebraic expression, we have

$$\left.\begin{aligned} x&=\frac{X+VT}{\sqrt{1-\frac{V^2}{c^2}}} \\ y&=Y \\ z&=Z \\ t&=\frac{T+\frac{V}{c^2}X}{\sqrt{1-\frac{V^2}{c^2}}} \end{aligned}\right\}. \tag{2.26}$$

The inverse transformation is

$$\begin{pmatrix} X \\ Y \\ Z \\ cT \end{pmatrix}=\begin{pmatrix} \beta & 0 & 0 & -\beta\frac{V}{c} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\beta\frac{V}{c} & 0 & 0 & \beta \end{pmatrix}\begin{pmatrix} x \\ y \\ z \\ ct \end{pmatrix}.$$

The algebraic expression for this is

$$\left.\begin{aligned} X &= \frac{x - Vt}{\sqrt{1 - \dfrac{V^2}{c^2}}} \\ Y &= y \\ Z &= z \\ T &= \frac{t - \dfrac{V}{c^2}x}{\sqrt{1 - \dfrac{V^2}{c^2}}} \end{aligned}\right\}. \tag{2.27}$$

Eqs. (2.26) and (2.27) are nothing but the Lorentz transformation. Thus, we can see that if the transformation matrix is supposed to be a symmetric matrix, the Lorentz transformation is obtained. Whether the Lorentz transformation is consistent can be evaluated by considering the relation with the Galilean transformation.

If the Lorentz transformation is an exact general space-time transformation, it should include the Galilean transformation as its special case which corresponds to the nonrelativistic case. In the nonrelativistic case of $c \gg V$, the Lorentz transformation is expressed as

$$\left.\begin{aligned} X &= x - Vt \\ Y &= y \\ Z &= z \\ T &= t - \frac{V}{c^2}x \end{aligned}\right\}.$$

In the fourth expression of the above equations, the term $\frac{V}{c^2}x$ cannot be ignored, since $x$ can have any size [70]. Therefore, we confirm that $T \neq t$. Obviously, the Lorentz transformation does not include the Galilean transformation as its special case. This disproves the correctness of the Lorentz transformation, as it does not satisfy the general relation between the physical theories that a new physical theory must include the corresponding old physical theory supported by experimental evidence as its special case. Every new physical theory is justified only when it has passed this test, called the correspondence principle, but STR is not watertight in this respect.

## 2.3 Unitarity of Lorentz transformation

Let us consider whether the Lorentz transformation is a unitary transformation. For the interval between events to be invariant, Eq. (2.3) for the scalar product of the space-time vector in both inertial frames should hold. By Eq. (2.4), Eq. (2.3) becomes

$$(\boldsymbol{X}, \boldsymbol{X}) = (A\boldsymbol{x}, A\boldsymbol{x}) = \left(\boldsymbol{x}, \left(A^*\right)^T A\boldsymbol{x}\right). \tag{2.28}$$

Hence, the linear transformation *A* must be unitary. For this relation to hold, the unit vectors of space-time must be represented by orthogonal bases. Equation (2.28) shows that the transformation from one inertial frame to another corresponds to the orthogonal transformation of the space-time coordinate system. Thus, if the Lorentz transformation is a unitary transformation, then the Minkowski space is meaningful, but if not, the Minkowski space is meaningless. The Lorentz transformation

$$\left.\begin{aligned} X &= \frac{x - Vt}{\sqrt{1 - \frac{V^2}{c^2}}} \\ Y &= y \\ Z &= z \\ T &= \frac{t - \frac{V}{c^2}x}{\sqrt{1 - \frac{V^2}{c^2}}} \end{aligned}\right\}$$

can be expressed in matrix form as

$$\begin{pmatrix} X \\ Y \\ Z \\ cT \end{pmatrix} = \begin{pmatrix} \beta & 0 & 0 & -\beta\frac{V}{c} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\beta\frac{V}{c} & 0 & 0 & \beta \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ ct \end{pmatrix}. \tag{2.29}$$

Or, in complex representation, we have

$$.\begin{pmatrix} X \\ Y \\ Z \\ icT \end{pmatrix} = \begin{pmatrix} \beta & 0 & 0 & i\beta\frac{V}{c} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -i\beta\frac{V}{c} & 0 & 0 & \beta \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ ict \end{pmatrix}, \tag{2.30}$$

where $\beta = 1\Big/\sqrt{1 - \frac{V^2}{c^2}}$. If the Lorentz transformation is an orthogonal transformation, the inverse of the transformation matrix

$$A = \begin{pmatrix} \beta & 0 & 0 & -\beta\frac{V}{c} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\beta\frac{V}{c} & 0 & 0 & \beta \end{pmatrix}$$

should be the transposed matrix. That is,

$$A^{-1} = A^T = \begin{pmatrix} \beta & 0 & 0 & -\beta\frac{V}{c} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\beta\frac{V}{c} & 0 & 0 & \beta \end{pmatrix}.$$

Thus, the following relation must hold.

$$AA^T = A^T A = I.$$

Meanwhile, according to the transformation relation (2.29), we immediately identify

$$AA^{-1} = AA^T \neq I.$$

Also, according to the transformation relation (2.30), the following result

$$AA^{-1} = A\left(A^*\right)^T \neq I.$$

is also obvious. Here $I$ is the identity matrix. Thus, the Lorentz transformation does not satisfy the requirement for orthogonal transformation. Thus, we conclude that the Lorentz transformation matrix is not unitary. This shows that the invariance of space-time length as the mathematical expression for the postulate of the principle of relativity does not make sense.

This fact may be explained briefly as follows. By Eq. (2.17), the matrix of the Lorentz transformation is expressed as

$$A = \begin{pmatrix} a & b \\ b & a \end{pmatrix}.$$

For this transformation to be a unitary transformation, the following relation should be satisfied.

$$A(A^T)^* = \begin{pmatrix} a & b \\ b & a \end{pmatrix}\begin{pmatrix} a & b \\ b & a \end{pmatrix} = I.$$

To do so, the following relations must hold

$$\left.\begin{aligned} a^2 + b^2 &= 1 \\ ab &= 0 \end{aligned}\right\}. \tag{2.31}$$

The solution of Eq. (2.31) is $a = 0,\ b = \pm 1$ or $a = \pm 1,\ b = 0$. This corresponds to the following matrices.

$$A = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},\ A = \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix},\ A = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix},\ A = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}.$$

These matrices indicate the independence of space and time, not the unification of space and time. This fact shows that we cannot obtain Lorentz transformation if we require unitary properties for the transformation matrix.

## 2.4 Interval between events and geometry of relativity

Let us consider what the invariance of the interval between events as the starting point of the theory of relativity means. The interval between events in a moving inertial frame and the interval between events in an inertial frame at rest are respectively expressed as

$$\left.\begin{aligned} s_{12}^2 &= c^2(t_2 - t_1)^2 - (x_2 - x_1)^2 - (y_2 - y_1)^2 - (z_2 - z_1)^2 \\ S_{12}^2 &= c^2(T_2 - T_1)^2 - (X_2 - X_1)^2 - (Y_2 - Y_1)^2 - (Z_2 - Z_1)^2 \end{aligned}\right\}. \tag{2.32}$$

According to the geometry of relativity, the intervals between events in the two inertial frames are the same. That is,

$$s_{12}^2 = S_{12}^2.$$

Of course, if time and space are absolute, the intervals between events defined above are the same.

Now, let us consider whether a transformation of space-time such that the interval between events is invariant is possible. The space interval in a stationary system can be expressed using the time taken for the interaction to propagate as

$$c^2(t_2' - t_1)^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2, \tag{2.33}$$

where $t_2'$ is the time when the interaction which started to propagate from $x_1, y_1, z_1$ in space at time $t_1$ is supposed to have reached $x_2, y_2, z_2$ in space.

Likewise, the space in a moving inertial frame can be represented expressed by use of the time of propagation of the interaction as

$$c^2(T_2' - T_1)^2 = (X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2. \tag{2.34}$$

Here, $T_2'$.is the time when the interaction which started to propagate from $X_1, Y_1, Z_1$ in space at time

$T_1$ is supposed to have reached $X_2, Y_2, Z_2$ in space. $t_2'$ and $T_2'$ were used to denote the length in space by use of the length of time. Equations (2.33) and (2.34) are mathematical expressions for the postulate of the constancy of the speed of light.

Combining Eqs. (2.33) and (2.34), we obtain

$$(t_2 - t_1)^2 - (t_2' - t_1)^2 = (T_2 - T_1)^2 - (T_2' - T_1)^2. \tag{2.35}$$

In view of the homogeneity of time, the interval between events should not depend on how the initial time of time is chosen. Thus, without loss of generality we can take the initial times in both reference frames as the same. That is,

$$t_1 = T_1. \tag{2.36}$$

Then Eq. (2.35) becomes

$$(t_2 - t_1)^2 - (t_2' - t_1)^2 = (T_2 - t_1)^2 - (T_2' - t_1)^2. \tag{2.37}$$

Eq. (2.37) is expanded as

$$t_2^2 - t_2'^2 - 2t_2 t_1 + 2t_2' t_1 = T_2^2 - T_2'^2 - 2T_2 t_1 + 2T' t_1. \tag{2.38}$$

Eq. (2.38) is rewritten as

$$t_2^2 - t_2'^2 + 2(t_2' - t_2)t_1 = T_2^2 - T_2'^2 + 2(T_2' - T_2)t_1. \tag{2.39}$$

By arbitrariness of $t_1$ selection, the zero-order and first-order coefficients with respect to $t_1$ must be zero, respectively, for the above equation to be an identity. Thus, the following relations are obtained.

$$\left.\begin{aligned} t_2^2 - t_2'^2 &= T_2^2 - T_2'^2 \\ t_2' - t_2 &= T_2' - T_2 \end{aligned}\right\}. \tag{2.40}$$

From the above relations, we obtain

$$t_2' + t_2 = T_2' + T_2, \tag{2.41}$$

and, finally, combining the two relations:

$$\left.\begin{aligned} t_2' - t_2 &= T_2' - T_2 \\ t_2' + t_2 &= T_2' + T_2 \end{aligned}\right\}, \tag{2.42}$$

we get

$$\left.\begin{aligned} t_2' &= T_2' \\ t_2 &= T_2 \end{aligned}\right\}. \tag{2.43}$$

Thus, we arrive at

$$t_2 - t_1 = T_2 - T_1. \tag{2.44}$$

To obtain this result, we took into consideration the fact that we can take arbitrarily the initial times in two reference systems according to the homogeneity of time, and used the proposition of the theory of relativity that the velocity of light and the interval between events in the two inertial frames should be equal. By the way, it follows that for the intervals between events in two inertial frames to be equal, time intervals in two inertial systems must be the same, and thus time is absolute. From this, we draw the natural conclusion that in order for the intervals between events to be equal, the intervals in space must be the same. That is

$$(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2. \tag{2.45}$$

This means that for any two reference frames, the spatial length of the event is the same.

If Eqs. (2.44) and (2.45) hold, then it follows that for both reference frames the relativity of time and space is meaningless, and therefore the space and time are absolute. This shows that intervals between events are the same only if intervals of time and space in two inertial frames are equal, respectively. Eventually, it should be concluded that it is meaningless to find the relativistic transformation of space-time from the requirement that the space-time interval should be invariant for any two inertial reference frames.

## 2.5 Existence of generalized relativistic transformation of space-time

It can be shown by general mathematical considerations that the postulate of the constancy of the speed of light and the principle of relativity are not compatible. STR requires that the coordinate systems of two inertial frames are set in a specific way. Thus, the two axes of coordinates must coincide, and the *x*-axis must be taken in the direction of motion. In fact, this particular approach has been a critical issue for many researchers due to the lack of generality. We can introduce coordinate systems in any way for two inertial systems to study the laws of physics. There is no physical condition for the axes of any two coordinate systems to be necessarily coincident or parallel. For a coordinate system that is set in an arbitrary way, a universal law must be established. From this point of view, if the theory of special relativity is correct, relativistic transformation relations and reasonable results should be obtained for the two coordinate systems set in an arbitrary way. It is important to consider whether we can obtain a general Lorentz transformation for two coordinate systems set in a general way. If not, STR does not have generality.

Now, based on the idea for the unification of space and time, we shall consider the linear transformation of two inertial systems in a general way. Assuming the homogeneity and isotropy of space and time, the transformation relation between the two coordinate systems must be the following linear transformation relation.

$$\left.\begin{aligned} x &= a_{11}X + a_{12}Y + a_{13}Z + a_{14}cT \\ y &= a_{21}X + a_{22}Y + a_{23}Z + a_{24}cT \\ z &= a_{31}X + a_{32}Y + a_{33}Z + a_{34}cT \\ ct &= a_{41}X + a_{42}Y + a_{43}Z + a_{44}cT \end{aligned}\right\}. \tag{2.46}$$

Here, we do not present the specific requirement of setting the coordinate axes of the two inertial frames, and take the coordinate system in a general way and assume the form of the general transformation relation. It should be noted that if we adopt the same method for setting coordinate systems as do when deriving the Lorentz transformation and assume the one-way velocity dependence of space-time, the transformation matrix becomes the Lorentz transformation. The space-time transformation relation of the form of Eq. (2.46) is a generalization of the Lorentz transformation.

Since the velocity of the origin of the moving coordinate system is $\boldsymbol{V}$, from Eq. (2.46) the following relations must hold.

$$\frac{x}{ct} = \frac{a_{14}}{a_{44}} = \frac{V_x}{c}, \tag{2.47}$$

$$\frac{y}{ct} = \frac{a_{24}}{a_{44}} = \frac{V_y}{c}, \tag{2.48}$$

$$\frac{z}{ct} = \frac{a_{34}}{a_{44}} = \frac{V_z}{c}. \tag{2.49}$$

The linear transformation relation between two inertial systems can be represented in the form of matrix as

$$\begin{pmatrix} x \\ y \\ z \\ ct \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ cT \end{pmatrix}. \tag{2.50}$$

We denote the matrix of the linear transformation in Eq. (2.50) by

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix}$$

and introduce the following matrix representation:

$$\boldsymbol{x} = A\boldsymbol{X}.$$

First, we denote the velocity of light in two inertial frames to determine the matrix elements of the linear transformation *A*. By Eq. (2.46), the relation for the square of the differentials of the space-time coordinates can be written as

$$\begin{aligned} \mathrm{d}x^2 &= (a_{11}\mathrm{d}X + a_{12}\mathrm{d}Y + a_{13}\mathrm{d}Z + a_{14}c\mathrm{d}T)^2 \\ \mathrm{d}y^2 &= (a_{21}\mathrm{d}X + a_{22}\mathrm{d}Y + a_{23}\mathrm{d}Z + a_{24}c\mathrm{d}T)^2 \\ \mathrm{d}z^2 &= (a_{31}\mathrm{d}X + a_{32}\mathrm{d}Y + a_{33}\mathrm{d}Z + a_{34}c\mathrm{d}T)^2 \\ c^2\mathrm{d}t^2 &= (a_{41}\mathrm{d}X + a_{42}\mathrm{d}Y + a_{43}\mathrm{d}Z + a_{44}c\mathrm{d}T)^2 \end{aligned}. \tag{2.51}$$

The expansions of Eq. (2.51) are given by

$$\begin{aligned} \mathrm{d}x^2 &= a_{11}^2\mathrm{d}X^2 + a_{12}^2\mathrm{d}Y^2 + a_{13}^2\mathrm{d}Z^2 + a_{14}^2c^2\mathrm{d}T^2 + \\ &+ 2a_{11}a_{12}\mathrm{d}X\mathrm{d}Y + 2a_{11}a_{13}\mathrm{d}X\mathrm{d}Z + 2a_{11}a_{14}c\mathrm{d}X\mathrm{d}T + 2a_{12}a_{13}\mathrm{d}Y\mathrm{d}Z \\ &+ 2a_{12}a_{14}c\mathrm{d}Y\mathrm{d}T + 2a_{13}a_{14}c\mathrm{d}Z\mathrm{d}T, \end{aligned} \tag{2.52}$$

$$\begin{aligned} \mathrm{d}y^2 &= a_{21}^2\mathrm{d}X^2 + a_{22}^2\mathrm{d}Y^2 + a_{23}^2\mathrm{d}Z^2 + a_{24}^2\mathrm{d}T^2 + \\ &+ 2a_{21}a_{22}\mathrm{d}X\mathrm{d}Y + 2a_{21}a_{23}\mathrm{d}X\mathrm{d}Z + 2a_{21}a_{24}\mathrm{d}X\mathrm{d}T + 2a_{22}a_{23}\mathrm{d}Y\mathrm{d}Z \\ &+ 2a_{22}a_{24}\mathrm{d}Y\mathrm{d}T + 2a_{23}a_{24}\mathrm{d}Z\mathrm{d}T, \end{aligned} \tag{2.53}$$

$$\begin{aligned} \mathrm{d}z^2 &= a_{31}^2\mathrm{d}X^2 + a_{32}^2\mathrm{d}Y^2 + a_{33}^2\mathrm{d}Z^2 + a_{34}^2c^2\mathrm{d}T^2 + \\ &+ 2a_{31}a_{32}\mathrm{d}X\mathrm{d}Y + 2a_{31}a_{33}\mathrm{d}X\mathrm{d}Z + 2a_{31}a_{34}c\mathrm{d}X\mathrm{d}T + 2a_{32}a_{33}\mathrm{d}Y\mathrm{d}Z \\ &+ 2a_{32}a_{34}c\mathrm{d}Y\mathrm{d}T + 2a_{33}a_{34}c\mathrm{d}Z\mathrm{d}T, \end{aligned} \tag{2.54}$$

$$\begin{aligned} c^2\mathrm{d}t^2 &= a_{41}^2\mathrm{d}X^2 + a_{42}^2\mathrm{d}Y^2 + a_{43}^2\mathrm{d}Z^2 + a_{44}^2c^2\mathrm{d}T^2 + \\ &+ 2a_{41}a_{42}\mathrm{d}X\mathrm{d}Y + 2a_{41}a_{43}\mathrm{d}X\mathrm{d}Z + 2a_{41}a_{44}c\mathrm{d}X\mathrm{d}T + 2a_{42}a_{43}\mathrm{d}Y\mathrm{d}Z \\ &+ 2a_{42}a_{44}c\mathrm{d}Y\mathrm{d}T + 2a_{43}a_{44}c\mathrm{d}Z\mathrm{d}T. \end{aligned} \tag{2.55}$$

Since the velocity of the origin $(X = 0,\ Y = 0,\ Z = 0)$ of the moving inertial system is $\boldsymbol{V}$, we obtain

$$\left.\begin{aligned} x &= a_{14}cT \\ y &= a_{24}cT \\ z &= a_{34}cT \\ ct &= a_{44}cT \end{aligned}\right\} \tag{2.56}$$

and

$$V^2 = \frac{\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2}{\mathrm{d}t^2} = \frac{a_{14}^2 + a_{24}^2 + a_{34}^2}{a_{44}^2}. \tag{2.57}$$

Now, we use the postulate of the constancy of the speed of light to determine the elements of the linear transformation matrix. By the postulate of the constancy of the speed of light, the light velocity for any direction must satisfy the following relations

$$\frac{dx^2+dy^2+dz^2}{c^2dt^2}$$
$$=\frac{A_{XX}dX^2+A_{YY}dY^2+A_{ZZ}dZ^2+A_{TT}dT^2+A_{XY}dXdY+A_{XZ}dXdZ+A_{XT}dXdT+A_{YZ}dYdZ+}{B_{XX}dX^2+B_{YY}dY^2+B_{ZZ}dZ^2+B_{TT}dT^2+B_{XY}dXdY+B_{XZ}dXdZ+B_{XT}dXdT+B_{YZ}dYdZ+}\cdots$$
$$\frac{+A_{YT}dYdT+A_{ZT}dZdT}{+B_{YT}dYdT+B_{ZT}dZdT}. \tag{2.58}$$

$$\frac{dX^2+dY^2+dZ^3}{c^2dT^2}=1, \tag{2.59}$$

where the coefficients of the differential terms $A_{XX}, A_{YY}, A_{ZZ}, A_{TT}, A_{XY}, \cdots, B_{XX}, B_{YY}, B_{ZZ}, B_{TT}, B_{XY}\cdots$ are represented by the elements of the transformation matrix.

Combining Eqs. (2.56) and (2.57) yields the following equations for the coefficients of the differential terms.

$$\left.\begin{aligned}
&dX^2: a_{11}^2+a_{21}^2+a_{31}^2-a_{41}^2=1\\
&dY^2: a_{12}^2+a_{22}^2+a_{32}^2-a_{42}^2=1\\
&dZ^2: a_{13}^2+a_{23}^2+a_{33}^2-a_{43}^2=1\\
&dT^2: a_{14}^2+a_{24}^2+a_{34}^2-a_{44}^2=-1\\
&dXdY: \quad a_{11}a_{12}+a_{21}a_{22}+a_{31}a_{32}-a_{41}a_{42}=0\\
&dXdZ: \quad a_{11}a_{13}+a_{21}a_{23}+a_{31}a_{33}-a_{41}a_{43}=0\\
&dXdT: \quad a_{11}a_{14}+a_{21}a_{24}+a_{31}a_{34}-a_{41}a_{44}=0\\
&dYdZ: \quad a_{12}a_{13}+a_{22}a_{23}+a_{32}a_{33}-a_{42}a_{43}=0\\
&dYdT: \quad a_{12}a_{14}+a_{22}a_{24}+a_{32}a_{34}-a_{42}a_{44}=0\\
&dZdT: \quad a_{13}a_{14}+a_{23}a_{24}+a_{33}a_{34}-a_{43}a_{44}=0
\end{aligned}\right\}. \tag{2.60}$$

Thus, ten equations for matrix elements are given. On the other hand, given that the linear transformation matrix must be unitary, the transformation relation (2.50) must be symmetric as follows.

$$\begin{pmatrix} x\\ y\\ z\\ t \end{pmatrix}=\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14}\\ a_{12} & a_{22} & a_{23} & a_{24}\\ a_{13} & a_{23} & a_{33} & a_{34}\\ a_{14} & a_{24} & a_{34} & a_{44} \end{pmatrix}\begin{pmatrix} X\\ Y\\ Z\\ cT \end{pmatrix}. \tag{2.61}$$

The number of independent matrix elements in Eq. (2.61) is 10. On the other hand, the following ten equations are given by the requirement that the linear transformation matrix should be unitary.

$$\left.\begin{aligned}
&a_{11}a_{12}+a_{12}a_{22}+a_{13}a_{23}+a_{14}a_{24}=0\\
&a_{11}a_{13}+a_{12}a_{23}+a_{13}a_{33}+a_{14}a_{34}=0\\
&a_{11}a_{14}+a_{12}a_{24}+a_{13}a_{34}+a_{14}a_{44}=0\\
&a_{12}a_{13}+a_{22}a_{23}+a_{23}a_{33}+a_{24}a_{34}=0\\
&a_{12}a_{14}+a_{22}a_{24}+a_{23}a_{34}+a_{24}a_{44}=0\\
&a_{13}a_{14}+a_{23}a_{24}+a_{33}a_{34}+a_{34}a_{44}=0\\
&a_{11}^2+a_{12}^2+a_{13}^2+a_{14}^2=1\\
&a_{12}^2+a_{22}^2+a_{23}^2+a_{24}^2=1\\
&a_{13}^2+a_{23}^2+a_{33}^2+a_{34}^2=1\\
&a_{14}^2+a_{24}^2+a_{34}^2+a_{44}^2=1
\end{aligned}\right\}. \tag{2.62}$$

To determine the elements of the transformation matrix, this system of equations must be coupled to the system of equations (2.60). Thus, the equations for matrix elements are 20. Meanwhile, the number of equations in Eqs. (2.60) and (2.62) is more than the number of variables (the number of matrix elements). In this case, the solution of the equation in general does not exist.

As a special case, let us consider the case where $a_{12}=a_{13}=a_{23}=a_{24}=a_{34}=0$ and $a_{22}=a_{33}=1$. This case corresponds to the case of the Lorentz transformation. Then the transformation relation between the two inertial systems is

$$\begin{pmatrix} x\\ y\\ z\\ t\end{pmatrix}=\begin{pmatrix} a_{11} & 0 & 0 & a_{14}\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ a_{14} & 0 & 0 & a_{44}\end{pmatrix}\begin{pmatrix} X\\ Y\\ Z\\ cT\end{pmatrix}.$$

From Eq. (2.60) for the postulate of the constancy of the velocity of light, the following relations must hold

$$\left.\begin{aligned}
&a_{11}^2-a_{14}^2=1\\
&a_{44}^2-a_{14}^2=1\\
&a_{11}a_{14}-a_{14}a_{44}=0
\end{aligned}\right\}. \tag{2.63}$$

On the other hand, by Eq. (2.62), the following relations must hold

$$\left.\begin{aligned}
&a_{11}^2+a_{14}^2=1\\
&a_{14}^2+a_{44}^2=1\\
&a_{11}a_{14}+a_{14}a_{44}=0
\end{aligned}\right\}. \tag{2.64}$$

Combining Eqs. (2.63) and (2.64), the equations for matrix elements are given as

$$\left.\begin{aligned}
&a_{11}^2-a_{14}^2=1\\
&a_{44}^2-a_{14}^2=1\\
&a_{11}a_{14}-a_{14}a_{44}=0\\
&a_{11}^2+a_{14}^2=1\\
&a_{14}^2+a_{44}^2=1\\
&a_{11}a_{14}+a_{14}a_{44}=0
\end{aligned}\right\}. \tag{2.65}$$

We obtain $a_{11}=\pm 1$ by the first and fourth equations and $a_{44}=\pm 1$ by the second and fifth equations. By the third and sixth equations, we have $a_{14}a_{44}=0$. Thus, we get $a_{14}=0$, and as a result, the transformation matrix is

$$A=\begin{pmatrix}1&0\\0&1\end{pmatrix},\quad A=\begin{pmatrix}1&0\\0&-1\end{pmatrix},\quad A=\begin{pmatrix}-1&0\\0&1\end{pmatrix},\quad A=\begin{pmatrix}-1&0\\0&-1\end{pmatrix}.$$

It is clear that these transformation matrices do not account for the unification of space and time.

Let us consider the case where the transformation relation of space-time is given by

$$\begin{pmatrix}dx\\d(ct)\end{pmatrix}=\begin{pmatrix}a&b\\b&-a\end{pmatrix}\begin{pmatrix}dX\\d(cT)\end{pmatrix}.$$

Using this transformation relation, the squares of the differentials are calculated as follows.

$$\left.\begin{aligned}dx^2&=a^2dX^2+2abcdXdT+b^2c^2dT^2\\c^2dt^2&=b^2dX^2-2abcdXdT+a^2c^2dT^2\end{aligned}\right\}.$$

The condition that the speed of light in both inertial frames should be the same leads to the following relations.

$$\left.\begin{aligned}&\frac{dx^2}{c^2dt^2}=\frac{a^2dX^2+2abcdXdT+b^2c^2dT^2}{b^2dX^2-2abcdXdT+a^2c^2dT^2}=1\\&\frac{dX^2}{c^2dT^2}=1\end{aligned}\right\}.$$

We now rearrange the above equation as follows.

$$\left.\begin{aligned}&(a^2-b^2)dX^2+4abcdXdT+(b^2c^2-a^2c^2)dT^2=0\\&dX^2-c^2dT^2=0\end{aligned}\right\}.$$

The following relations are obtained from the requirement that the coefficients of the same differential terms must be equal.

$$\left.\begin{aligned}a^2-b^2&=1\\ab&=0\end{aligned}\right\}.$$

On the other hand, from the requirement that the matrix must be unitary, we have $a^2+b^2=1$. Thus, the relations of the elements of the transformation matrix for satisfying the fundamental postulates of STR are

$$\left.\begin{aligned}a^2-b^2&=1\\ab&=0\\a^2+b^2&=1\end{aligned}\right\}. \tag{2.66}$$

From the first and third equations, we have $a=\pm1,\quad b=0$. In this case, the transformation matrix is

$$A=\begin{pmatrix}1&0\\0&-1\end{pmatrix}\quad\text{or}\quad A=\begin{pmatrix}-1&0\\0&1\end{pmatrix}.$$

Of course, these matrices are unitary, but they have no physical meaning. Thus, if the transformation matrix of space-time is required to be unitary, then the Lorentz transformation cannot be obtained. This result contradicts the assumption about the intertwined space and time and shows that the two postulates of STR are incompatible.

## 2.6 Covariance of Lorentz transformation

Let us examine whether the Lorentz transformation is invariant for any two inertial systems. We suppose that there are three inertial frames: one inertial frame is at rest and the other two inertial frames move with velocities of $V_1$ and $V_2$, respectively, relative to the inertial frame at rest. The

Lorentz transformation for the first moving and the stationary inertial frames is

$$\left.\begin{aligned} x_1 &= \frac{x - \frac{V_1}{c} ct}{\sqrt{1 - \frac{V_1^2}{c^2}}} \\ ct_1 &= \frac{ct - \frac{V_1}{c} x}{\sqrt{1 - \frac{V_1^2}{c^2}}} \end{aligned}\right\}. \tag{2.67}$$

From this, the matrix representation of the Lorentz transformation can be written as

$$T(V_1) = \frac{1}{\sqrt{1 - \frac{V_1^2}{c^2}}} \begin{pmatrix} 1 & -\frac{V_1}{c} \\ -\frac{V_1}{c} & 1 \end{pmatrix}. \tag{2.68}$$

The Lorentz transformation for the second moving inertial frame and the inertial frame at rest is

$$\left.\begin{aligned} x_2 &= \frac{x - \frac{V_2}{c} ct}{\sqrt{1 - \frac{V_2^2}{c^2}}} \\ ct_2 &= \frac{ct - \frac{V_2}{c} x}{\sqrt{1 - \frac{V_2^2}{c^2}}} \end{aligned}\right\}. \tag{2.69}$$

From this, the matrix representation of the Lorentz transformation becomes

$$T(V_2) = \frac{1}{\sqrt{1 - \frac{V_2^2}{c^2}}} \begin{pmatrix} 1 & -\frac{V_2}{c} \\ -\frac{V_2}{c} & 1 \end{pmatrix}. \tag{2.70}$$

By Eqs. (2.68) and (2.70), the two transformation relations can be expressed as

$$\begin{pmatrix} x_1 \\ ct_1 \end{pmatrix} = T(V_1) \begin{pmatrix} x \\ ct \end{pmatrix}, \tag{2.71}$$

$$\begin{pmatrix} x_2 \\ ct_2 \end{pmatrix} = T(V_2) \begin{pmatrix} x \\ ct \end{pmatrix}. \tag{2.72}$$

Expressing Eq. (2.71) using the inverse matrix $T^{-1}(V_1)$ as

$$T^{-1}(V_1) \begin{pmatrix} x_1 \\ ct_1 \end{pmatrix} = \begin{pmatrix} x \\ ct \end{pmatrix}. \tag{2.73}$$

And substituting it into Eq. (2.72), it turns out that

$$\begin{pmatrix} x_2 \\ ct_2 \end{pmatrix} = T(V_2) T^{-1}(V_1) \begin{pmatrix} x_1 \\ ct_1 \end{pmatrix}. \tag{2.74}$$

Now, setting

$$T(V_{21}) = T(V_2)T^{-1}(V_1), \tag{2.75}$$

Eq. (2.74)

$$\begin{pmatrix} x_2 \\ ct_2 \end{pmatrix} = T(V_{21})\begin{pmatrix} x_1 \\ ct_1 \end{pmatrix} \tag{2.76}$$

becomes the Lorentz transformation for the first moving inertial frame and the second moving one. Here, $V_{21}$ is the relative velocity of the second inertial frame moving relative to the first inertial frame. Taking into consideration that the inverse matrix of $T(V_1)$ is represented by

$$T^{-1}(V_1) = \frac{1}{\sqrt{1-\frac{V_1^2}{c^2}}}\begin{pmatrix} 1 & \frac{V_1}{c} \\ \frac{V_1}{c} & 1 \end{pmatrix}, \tag{2.77}$$

the Lorentz transformation for the two moving inertial frames is determined by

$$T(V_{21}) = T(V_2)T^{-1}(V_1) = \frac{1}{\sqrt{1-\frac{V_1^2}{c^2}}\sqrt{1-\frac{V_2^2}{c^2}}}\begin{pmatrix} 1 & -\frac{V_2}{c} \\ -\frac{V_2}{c} & 1 \end{pmatrix}\begin{pmatrix} 1 & \frac{V_1}{c} \\ \frac{V_1}{c} & 1 \end{pmatrix}. \tag{2.78}$$

On the other hand, according to the principle of relativity, this transformation relation should be represented using the relative velocity $V_{21}$ as

$$T(V_{21}) = \frac{1}{\sqrt{1-\frac{V_{21}^2}{c^2}}}\begin{pmatrix} 1 & -\frac{V_{21}}{c} \\ -\frac{V_{21}}{c} & 1 \end{pmatrix}. \tag{2.79}$$

However, the right-hand sides of Eqs. (2.78) and (2.79) cannot be equal. Thus, the Lorentz transformation for any two inertial frames does not have covariance. From the above considerations, we can see that there does not exist a general linear transformation relation for space-time satisfying the principle of relativity and the postulate of the constancy of the speed of light altogether, and that the four-dimensional space-time geometry is devoid of real meaning.

# 3. Physical analysis of special theory of relativity

## 3.1 Experiments on speed of light

The history of STR must date back to the initiative experiment on the speed of light, since the principle of the constancy of the speed of light is an important hypothesis. A most significant experiment in the history of physics was the experiment performed by Michelson and Morley in 1887, designed to detect and quantify the light speed anisotropy supposed to be caused by the orbital speed of 30km/s of the Earth moving through the ether. The prevailing ontology was that reality consisted of an ether embedded in an unstructured static three-dimensional geometrical space, with time as a one-dimensional geometrical entity. The experiment used the light interferometer designed by Michelson. They reported, based on only 36 rotations, the observation of fringe shifts and inferred the anisotropy of the speed of light of 8-10km/s [71]. Based on an extensive analysis of the data, Miller reported in 1933 the experimental result assuming the existence of the ether causing an average light speed anisotropy of 208km/s [72]. De Witte performed a key experiment in 1991 measuring the varying speed of electromagnetic waves in coaxial cables as the Earth rotated, and reported an anisotropy speed of 500km/s [73,74].

In 1905, Einstein's paper "On the Electrodynamics of Moving Bodies" was published [1]. In that paper, STR was described almost completely, and assuming the constancy of the speed of light, relativistic electrodynamics which has covariant form in every inertial frame, independently of the ether was constructed. Thus, the Michelson-Morley experiment to deny the existence of the ethers became the experimental basis of STR, and, based on the unified nature of space-time, an essential change in understanding the Newtonian mechanics and electrodynamics occurred. In the end, the Newtonian mechanics is a nonrelativistic approximation of complete mechanics, and the equations of electrodynamics are generally assumed to be ether-independent and covariant in every inertial frame, unlike Maxwell's original idea that accepted the concept of ether.

From the outset, this theory aimed to extend the principle of relativity to all fields of mechanics, including electrodynamics, and claimed that all inertial systems are equivalent. As a result of the introduction of the principle of relativistic relativity and the principle of the constancy of the speed of light, the discussion about the existence of the ether was acknowledged to come to an end.

At that time, some experimental results and interpretation questioning the principle of the constancy of the speed of light were known, but altogether, they were ignored or denied in the circumstance of general recognition of believing in the validity of STR. In the Michelson-Morley experiments and later on the modern experiments with laser, it was possible to observe with very high accuracy the change in velocity that occurs when the Earth's astronomical direction of motion changes.

It has been confirmed repeatedly that the speed of light in vacuum is independent of the speed of light source. Remarkable was the experiment on the velocity of light in 1956 using light from the sun, a light source outside of the earth. If the speed of light depends on the motion of source, we would be able to detect the difference in speed by measuring the speeds of light coming from two points opposite the equator of the sun. However, it was no detecting the difference in speed in this experiment.

In the experiment conducted in the way of comparing the times elapsed when gamma quantum emitted by a stationary or very fast-moving light source traveled a definite distance, it was also confirmed that the speed of light is independent of the motion of light sources. Thus, it seemed to have been finally confirmed that there was no example showing the existence of a preferred reference frame associated with the ether or showing the differences in the speed of light in different inertial frames.

It should be emphasized, however, that these experiments are not all of the experiments on the speed of light. Historically, there have been proposed several experimental results showing the existence of an ether or a preferred inertial system which was assumed to be the medium of light propagation. The typical experiments are the experiments of Miller in 1925, D. G. Torr and P. Kolen in 1981, and R. De Witte in 1991 [68]. These experiments were carried out in different ways, but gave the same conclusion that there are the absolute motion and a preferred inertial frame. In 1925, experiments with light by Miller using the Michelson interferometer ascertained the anisotropy of the speed of light in the Earth-observational system. He determined the absolute velocity and the absolute direction of motion of the earth based on the observed data. In 1981, the experimental results of anisotropy of the speed of light were also reported by Torr and Kolen [68].

Regarding the experiments on the anisotropy of the speed of light, the experiments which measure the speed of electromagnetic wave conducted by R. De Witte in 1991 with a cesium atomic clock for timing, a coaxial cable for propagating 5 MHz radio waves, and a phase comparator attracted great attention. This experiment continued for 178 days and as a result, showed that the wave velocity varied periodically according to the astronomical state of motion of the earth, and thus the wave velocity was anisotropic [68].

As another example, the speed of light certainly changes in a system with rotational motion. A typical example is the Sagnac effect. In the experiment which Sagnac first carried out, there was used a method such as splitting a beam of light by means of a combined beam splitter/interferometer on a rotating disk, propagating in opposite directions along a circumference using a cable or a mirror, interfering them and observing the shift of the fringe pattern. That experiment showed that the velocity of light relative to the interferometer which plays the role of an observer, in case the disk rotates, was altered, and that the velocity of light was determined the Galilean rule of velocity addition for the linear speed of the disc and the speed of light. This effect is known to be the same independent of whether or not the phenomenon is observed in an inertial frame outside the rotating system or in the rotating system. Currently, this effect is widely used to measure the rotational speed of a rotating body by using optical methods. Using this method, experiments were carried out in 1925 by Michelson and Gale to measure the angular velocity of the earth. For the experiments, a tube of 2 km was installed and a device to determine the zero point at which the fringe pattern was moved was used. This experiment also showed very good agreement with the theoretical predictions adopted for the analysis of Sagnac effect. Thus, it was confirmed that the principle of the constancy of the speed of light does not hold in the noninertial system, or, more precisely, in systems with circular motions. A similar experiment was carried out by Saburi in 1974 with electromagnetic waves, and the same results were obtained.

The interpretation of these experiments, in fact, has not reached a consensus up to today yet. Some physicists argue that even if the speed of light in a system with circular motion satisfies the Galilean law of velocity addition, it is an experimental result in a noninertial system and therefore cannot affect STR which is a theory in inertial systems. However, the results of these experiments are not so simple because most experiments with the speed of light have been carried out in the Earth-based reference frame, i.e., in a noninertial system. It is not possible to explain why the properties of propagation of light in inertial and noninertial systems are significantly different. In fact, an ideal inertial system does not exist in practice, and the limit of inertial and noninertial systems cannot be clearly settled, so it is unreasonable to assert that the cause of the change in the velocity of light is ascribed only to a noninertial system. It has not yet unraveled whether it is a disproof of the principle of the constancy of the speed of light or a phenomenon beyond the scope of STR.

On the other hand, for the case of microwave, the superluminal tunneling of the wave packet was observed experimentally. Of course, the same result was obtained for a single photon and a coherent laser impulse. Many astronomical observations have shown that there are celestial bodies moving at a superluminal speed. Recent researches on Tachyon highlight the need to review the principle of the constancy of the speed of light.

Next, recent researches that reproduce the Michelson-Morley experiment or reinterpret the results have attracted attention [25,26,29,30-34]. These experiments lead to the examination of whether the second postulate of STR is valid or not. The conclusion of the researches is that from the present view, the Michelson-Morley experiment is not the confirmation of the absence of ether, but rather is a clear evidence of the existence of the ether, absolute space, and absolute motion.

The Doppler effect cannot be ruled out in the discussion on the principle of the constancy of the speed of light. Without the concept of the relative velocity of light source and observer, the Doppler effect cannot be explained. If the relative velocity of light and observer makes sense, we can never speak of the principle of the constancy of the speed of light. This is because the principle of the constancy of the speed of light means that the speed of light does not depend on both motions of light source and observer. The Mössbauer effect seems to be a decisive evidence indicative of the existence of a medium of light propagation.

It is clear that all experiments on the speed of light do not provide a complete experimental foundation for the second postulate of STR. On account of this situation, it should be considered that all the experimental results and the interpretation of the constancy of the speed of light that were historically proposed still have viability. Therefore, there still remains the task to find the truth to be able to explain all the experiments on the speed of light both comprehensively and essentially.

## 3.2 Physical paradoxes

The Lorentz transformation shows that for both observers in two inertial frames with relative motion, the wave front of a light wave becomes spherical or elliptic. This shows that at the cost of satisfying the principle of the constancy of the speed of light, it is inevitable that the requirement for the isotropy of space is violated.

The problematic points of the Lorentz transformation can be summarized as follows.

First, as a premise of the Lorentz transformation, the coordinate dependence of time is inconsistent in the physical aspect. This assumption states that a specific instant of time in an inertial frame corresponds to all instants of time in any other inertial reference frame. It can be seen from the relation

$$T = \left. \frac{t - \frac{V}{c^2}x}{\sqrt{1-\frac{V^2}{c^2}}} \right|_{t=t_0} = \frac{t_0 - \frac{V}{c^2}x}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{3.1}$$

That is, we can express all instants of time in the moving reference system by changing the coordinate $x$ in a stationary inertial frame. This is the concept of relativity of simultaneity which substantially is introduced by assumption and not by the confirmation by experiments. In fact, in an inertial frame there is no notion of relativity of the simultaneity. That is, in an inertial frame, time is independent of coordinates. However, time in a moving inertial system with relative motion, time is dependent on coordinates in a stationary reference frame and thus has multiple values by pairs of time and coordinates in the stationary reference system. This means that the two inertial frames with relative motion provide the possibility of reading the history of different inertial frames at any one instant of time thanks to the coordinate dependence of time. But in an inertial frame, this spectacular possibility disappears. This is certainly a nonphysical result.

Let us consider this problem in more detail. By the transformation of times in two inertial frames

$$T = \frac{t - \frac{V}{c^2}x}{\sqrt{1-\frac{V^2}{c^2}}} = \gamma\left(t - \frac{V}{c^2}x\right), \tag{3.2}$$

time in a moving inertial frame depends on the coordinates of the stationary inertial frame. That is, the positions in the direction of motion belong to the past, and the positions in the opposite direction of motion belong to the future. This means that the same instant of time in a stationary inertial frame covers the past, present, and future in a moving inertial frame. On the other hand, if the direction of motion of the moving inertial system is reversed, i.e., if $T = \gamma\left(t + \frac{V}{c^2}x\right)$, the places that represents the past and future are replaced by each other. But in fact, time must have the property that depends only on the magnitude of the relative velocity, not on the direction of motion of the inertial system. This is because the space is isotropic and the relationship between any two inertial frames should depend only on the relative velocity. This relation can be expressed in general as

$$T = \alpha t + \beta(V_r)x. \tag{3.3}$$

Here, $V_r$ is the relative velocity of the two inertial frames, as expressed as absolute values. Then, $x$ and $-x$ correspond simply to changing the direction of the coordinate axis, so the times at $x$ and $-x$ must be equal. Thus, the following relations:

$$T = \alpha t + \beta(V_r)x, \tag{3.4}$$

$$T = \alpha t - \beta(V_r)x \tag{3.5}$$

must hold. From the above two expressions, we have $\beta(V_r)x = 0$. Furthermore, from the arbitrariness of $x$, it follows $\beta(V_r) = 0$. Eventually, it is a contradiction to assume the coordinate dependence in the relation of time transformation between the two inertial frames.

Next, the reference system of space and time adopted to derive the Lorentz transformation is not general. The possibility of setting up coordinate systems in a general way in two inertial frames is a prerequisite for obtaining a general law relating to two inertial frames. However, in STR, two coordinate systems must be taken such that the three coordinate axes are necessarily coincident or parallel. Thus, it is clear that the results obtained using coordinate systems chosen in a special way cannot be of generality.

Next, the Lorentz transformation changes the space-time metrics of two inertial frames, thus violating the fundamental requirement for the homogeneity and isotropy of space-time in inertial frames. If a given theory has any one unexplained paradox, it cannot be recognized as a perfect theory. In this sense, the theory of relativity is not a complete theory.

Let us consider how STR gives results incompatible to physical reality. According to the principle of relativity, for two inertial systems with relative motion, the question of whether an inertial system is considered a stationary inertial system or a moving inertial system should have no effect on results which have to be obtained. The principle of relativity states that any two inertial frames are equivalent. If two synchronized clocks are located at each of two inertial frames, respectively, time would elapse equally in the both clocks. This is because the two inertial systems obey the same physical law by the principle of relativity, thus being equivalent systems that are not physically distinct.

In mechanics, the Galilean principle of relativity holds strictly. However, when we try to apply the principle of relativity to electrodynamics, we encountered difficulties because Maxwell's equation is not covariant with respect to the Galilean transformation. STR aims to solve this problem. STR introduced the principle of the constancy of the speed of light and used the Lorentz transformation which describes the relativity of space and time to ensure that the Maxwell equation is covariant in all inertial frames. However, the introduction of the Lorentz transformation leads to the result that the two inertial reference frames are not equal in space and time. That is, depending on the relative velocity, the scales of space and time in any two inertial frames change.

In this case, the following question is raised. Although according to the principle of relativity, inertial frames are equivalent, why do space and time of two inertial frames differ by relative motion? Whether an inertial frame is considered to be in rest or to be in motion is merely a choice of observers that can be arbitrarily done under the condition of the absence of absolute space. Then the question arises why this changes the objective nature of the space and time of inertial frames. In fact, for one inertial system, we can think of an infinite number of inertial systems with different relative velocities. How should we understand the fact that the characteristic of space and time in an inertial frame under consideration varies depending on which of a great number of inertial frames is chosen as a stationary inertial frames? In fact, for an observer in STR, the direction of motion has a special qualification. To derive the Lorentz transformation, a coordinate system of the stationary inertial frame and another coordinate system of the moving inertial frame must be fitted in a specific way. That is, one axis must coincide and the others must be parallel. This is not a generality and is a factitious condition. In fact, the relationship of space-time between two inertial frames should not depend on ways of setting up the coordinate systems in the two inertial frames.

Considering the scale ratios of the space-time coordinates of the two inertial frames, it can be seen that the Lorentz transformation breaks the symmetry of space-time. According to the Lorentz transformation, the ratios of the coordinate and time axes are

$$\left.\begin{aligned} &\frac{X}{x-Vt}=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}>1\\ &\frac{Y}{x}=1\\ &\frac{Z}{z}=1\\ &\frac{T}{t}=\frac{1-\frac{V}{c^2}\frac{x}{t}}{\sqrt{1-\frac{V^2}{c^2}}} \end{aligned}\right\}. \tag{3.6}$$

From the equation with respect to time of Eq (3.6), if we synchronize the times when the origins of the two inertial frames coincide, we have the following relation for the times in the two inertial frames:

$$\frac{T}{t}=\frac{1-\frac{V^2}{c^2}}{\sqrt{1-\frac{V^2}{c^2}}}=\sqrt{1-\frac{V^2}{c^2}}<1. \tag{3.7}$$

The ratios of space-time scales of two inertial frames are determined by

$$\left.\begin{aligned} &\frac{X}{x-Vt}=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}>1\\ &\frac{Y}{x}=1\\ &\frac{Z}{z}=1\\ &\frac{T}{t}=\sqrt{1-\frac{V^2}{c^2}}<1 \end{aligned}\right\}. \tag{3.8}$$

The above relation clearly shows that the Lorentz transformation is a transformation that breaks the symmetry of space-time. The change of length scale occurring only in the direction of motion results in the breakdown of the isotropy of space. Definitely, the ratios of scales in the y- and z-axes are 1, but the ratio of scales in the x-axis is greater than 1. Meanwhile, the ratio of scales of time is less than 1. From the first and fourth expressions of Eq. (3.8), the following relation holds:

$$XT=t(x-Vt). \tag{3.9}$$

This shows that the product of time and length in both inertial frames is constant. This relationship shows that the Lorentz transformation transforms the isotropic scale in an inertial frame into the anisotropic one in another. In this connection, it should be noted that there are infinitely many inertial frames that can be considered stationary for one inertial frame. In this case, the question is raised as to how to determine an inertial frame at rest. This gives an odd logic that the space-time properties of an inertial system essentially depend on the presence of observers. In order that the theory of relativity is logically consistent, at least the proper time and the proper length should not depend on the relative velocity of the two inertial frames. However, they also vary with relative velocity. This is not consistent with our intuition and is not logical.

According to the Lorentz transformation, a spherical wave in a stationary inertial frame becomes an ellipsoidal wave in a moving inertial frame [74]. Conversely, if we change the relative relations of rest and motion according to the principle of relativity, then the relation between a spherical and an ellipsoidal wave front is reversed. This contradicts the principle of relativity that the physical laws in inertial systems must be the same.

It is a usual intuition that the motion is relative, and therefore that only when the space-time scales in both inertial frames are equal, the physical laws in the two inertial frames would be identical. However, the Lorentz transformation is contradictory to this fact. Transformed time is uniform, but transformed space is anisotropic. The reason is that the transformation must satisfy the principle of the constancy of the speed of light. Eventually the isotropy of space is destroyed by the principle of the constancy of the speed of light. This shows that the principles of the constancy of the speed of light and of relativity are incompatible.

Next, let us consider the rule of relativistic velocity transformation. The Lorentz transformation shows that space and time are not independent and are intertwined with each other. From the Lorentz transformation

$$\left.\begin{aligned} X &= \frac{x - Vt}{\sqrt{1+\frac{V^2}{c^2}}} \\ Y &= y \\ Z &= z \\ T &= \frac{t - \frac{V}{c^2}x}{\sqrt{1+\frac{V^2}{c^2}}} \end{aligned}\right\}$$

and the inverse transformation

$$\left.\begin{aligned} x &= \frac{X + VT}{\sqrt{1+\frac{V^2}{c^2}}} \\ y &= Y \\ z &= Z \\ t &= \frac{T + \frac{V}{c^2}X}{\sqrt{1+\frac{V^2}{c^2}}} \end{aligned}\right\}$$

we can see that the relative velocities viewed from the two inertial frames are not relativistic. That is, the relative velocity is the same in a stationary or moving inertial frame. This is possible only if they have homologous properties, even if time and space are relativistic. That is, only if space and time increase or decrease at the same rate, their ratio would have relativistic invariance.

From the Lorentz transformation, the differentials of time and space are

$$\left.\begin{aligned} dx &= \frac{dX + VdT}{\sqrt{1+\frac{V^2}{c^2}}} \\ dy &= dY \\ dz &= dZ \\ dt &= \frac{dT + \frac{V}{c^2}dX}{\sqrt{1+\frac{V^2}{c^2}}} \end{aligned}\right\}. \tag{3.10}$$

Dividing the first expression of Eq. (3.10) by the fourth one yields the following relativistic rule of velocity transformation.

$$\frac{dx}{dt} = \frac{dX + VdT}{dT + \frac{V}{c^2}dX},$$

$$\upsilon_x = \frac{\upsilon_X + V}{1 + \frac{V}{c^2}\upsilon_X}. \tag{3.11}$$

This is different from the nonrelativistic rule of velocity transformation $\upsilon_x = \upsilon_X + V$.

We shall show another result that are different from the relativistic rule of velocity transformation considering in a different way. Suppose both observers are stationary in two inertial frames, respectively. The relationship between times measured by the both observers is not the time relation of Eq. (3.10), but the same as

$$dt = \frac{dT}{\sqrt{1+\frac{V^2}{c^2}}}. \tag{3.12}$$

In fact, since the observer in the moving inertial frame is stationary in the inertial frame, we must consider $dX$ to be zero in Eq. (3.10). On the other hand, the relationship between the displacements of the moving body observed in the two inertial reference frames is

$$dx = \frac{dX + VdT}{\sqrt{1+\frac{V^2}{c^2}}}. \tag{3.13}$$

To obtain the relationship between the velocities in the two inertial frames, the ratio of the time and displacement determined by the two observers, respectively must be calculated. Equation (3.11) is valid for the case of using the time of the clock set at each point of the inertial frame in motion, not the time of the observer in the inertial frame in motion. We only need the clocks that the two observers have, since we are interested in the speed which the two observers determine, respectively.

Dividing the both sides of Eq. (3.13) by the both sides of Eq. (3.12), respectively, we have

$$\frac{dx}{dt} = \frac{dX + VdT}{dT} = \frac{dX}{dT} + V.$$

Thus, we obtain the following rule of velocity transformation.

$$\upsilon_x = \upsilon_X + V,$$

where $\upsilon_x$ is the velocity determined by the observer in the stationary inertial frame and $\upsilon_X$ is the velocity determined by the observer in the moving inertial frame. Thus, the relative velocity is $\upsilon_x - \upsilon_X = V$. In the case of using the inverse transformation, we have

$$\upsilon_X - \upsilon_x = -V.$$

This is in good agreement with the fact that the relative velocities in both the Lorentz transformation and its inverse transformation are the same. This means that the relative velocity of the two inertial frames is determined according to the Galilean rule of velocity addition. In fact, by Eqs. (3.12) and (3.13) the scales of time and space should increase or decrease at a same rate. Therefore, the velocity is constant. Eventually, the Galilean rule of velocity addition also is maintained in the relativistic case. The same is true for light. According to the above equation, the expression is expressed as

$$\upsilon_x = c + V. \tag{3.14}$$

This fact shows that the Galilean rule of velocity addition holds for light. This result that is fundamentally different from the relativistic rule of velocity transformation shows that the principle of the constancy of the speed of light which is the basis of the Lorentz transformation is contradictory.

Let us consider an example of applying the relativistic rule of velocity transformation to light. The principle of the constancy of the speed of light is satisfied, since according to the Lorentz transformation, in the case of $\upsilon_X = \frac{dX}{dT} = c$, we have

$$\upsilon_x = \frac{dx}{dt} = \frac{\upsilon_X + V}{1 + \frac{V\upsilon_X}{c^2}} = c. \tag{3.15}$$

On the other hand, in the case of $\upsilon_Y = c$, we have $\upsilon_X = 0$, and thus the following relation holds

$$\upsilon_y = \frac{dy}{dt} = \frac{\upsilon_Y \sqrt{1 - \frac{V^2}{c^2}}}{1 + \frac{V\upsilon_X}{c^2}} = c\sqrt{1 - \frac{V^2}{c^2}} < c. \tag{3.16}$$

Also in the case of $\upsilon_Z = c$, we have $\upsilon_X = 0$, and thus the similar relation holds. That is,

$$\upsilon_z = \frac{dz}{dt} = \frac{\upsilon_Z \sqrt{1 - \frac{V^2}{c^2}}}{1 + \frac{V\upsilon_X}{c^2}} = c\sqrt{1 - \frac{V^2}{c^2}} < c. \tag{3.17}$$

Thus, when in a moving inertial frame, light travels with the velocity $c$ in the direction of $y$-axis or $z$-axis, the its speed in the stationary inertial frame is less than $c$. Consequently, the speed of light varies with direction, and thus the principle of the constancy of the speed of light does not hold true.

This reflects the fact that in a moving inertial frame, time elapses uniformly in all directions, but space is anisotropic. As inferred from the Lorentz transformation, in a stationary inertial frame, the space is isotropic, while in a moving inertial frame, it is anisotropic. On the other hand, if we replace the relative relations of rest and motion by each other, then the space of the inertial system in motion is isotropic, but the space of the inertial system at rest is anisotropic. This is not compatible with the principle of relativity and violates the initial assumption about the homogeneity and isotropy of space.

Next, let us consider the Lorentz transformation in the sense of relative velocity. For both reference frames $K$ and $K'$, the space-time variables are $x, t$ and $X, T$, respectively. Suppose that $K$ is stationary and $K'$ moves. Then the relative velocity of light and the moving reference frame, viewed in the system $K$, is $c - V$. It is usual to expect that this relative velocity is the velocity of light in the moving reference frame.

The velocity of light in the reference system $K'$ is determined by the relativistic transformation of this relative velocity by

$$\frac{X}{T}=\frac{x-Vt}{t-\frac{V}{c^2}x}=\frac{\frac{x}{t}-V}{1-\frac{V}{c^2}\frac{x}{t}}=\frac{c-V}{1-\frac{V}{c^2}c}=\frac{c-V}{1-\frac{V}{c}}=c.$$

Thus, for an observer in the reference frame at rest, the velocity of light with respect to a moving reference frame can vary arbitrarily with the velocity of the moving reference frame, but for an observer in the moving reference frame, the velocity of light always is *c*.

Next, let us consider the problem in the case of replacing the roles of the reference frames regarding rest and motion. By inverse transformation, the velocity of light in the system $K$ is

$$\frac{x}{t}=\frac{X+VT}{T+\frac{V}{c^2}X}=\frac{\frac{X}{T}+V}{1+\frac{V}{c^2}\frac{X}{T}}=\frac{c+V}{1+\frac{V}{c^2}c}=c.$$

Thus, the relative velocity of light and the inertial system $K$ in the system $K'$ is $c+V$, but the velocity of light in the inertial system $K$ is always $c$, irrespective of the relative velocity. It is a contradiction that in one reference frame the concept of relative velocity is meaningful for light, but in another reference frame with relative motion it is not meaningful at all.

It is necessary to physically consider the concept of the time delay. When the principle of relativity is adopted, the time delay must be relative. Inertial reference frames are equivalent, so if there is the time delay due to relative motion, it must appear equally for both inertial frames. For that reason, we cannot explain the essence of the time delay. By simply considering mathematically, we can show that the time delay in the sense of relativity is contradictory. From the Lorentz transformation

$$t=\frac{T+\frac{V}{c^2}X}{\sqrt{1-\frac{V^2}{c^2}}}, \tag{3.18}$$

the time difference at the same position in any two inertial frames is represented as

$$\Delta t=t_1-t_2=\frac{T_1-T_2}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{3.19}$$

That is,

$$\Delta t==\frac{\Delta T}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{3.20}$$

Similarly, using the inverse transformation

$$T=\frac{t-\frac{V}{c^2}x}{\sqrt{1-\frac{V^2}{c^2}}}, \tag{3.21}$$

the time interval at the same position in two inertial frames can be calculated. By Eq. (3.21), the relationship between the time intervals in the two inertial frames is expressed as

$$\Delta T = \frac{\Delta t}{\sqrt{1 - \frac{V^2}{c^2}}}. \tag{3.22}$$

By the principle of relativity, the relations between the time intervals in two inertial frames

$$\Delta T = \frac{\Delta t}{\sqrt{1 - \frac{V^2}{c^2}}}, \tag{3.23}$$

$$\Delta t = \frac{\Delta T}{\sqrt{1 - \frac{V^2}{c^2}}} \tag{3.24}$$

should be mathematically identical. However, we clearly can verify that these relations are incompatible. Substituting Eq. (3.24) into Eq. (3.23) yields

$$1 = 1 - \frac{V^2}{c^2}, \tag{3.25}$$

which is true only when

$$\frac{V^2}{c^2} = 0. \tag{3.26}$$

This is a contradiction, however, because the speed of light is finite. This is a mathematical expression for the twin paradox, which remains in fact still an open question.

The concept of the proper time also is not correct. The proper time should be related only to an individual inertial system. However, the proper time in an inertial system moving at velocity $V$ relative to a stationary inertial frame $\Delta T = \sqrt{1 - \frac{V^2}{c^2}}\Delta t$ depends on the relative velocity of the two inertial frames, and therefore, it has not an intrinsic property, but a relative property related two inertial systems. The relative velocity of two inertial frames is arbitrary, so the concept of the proper time is meaningless.

The same can be said about the length contraction. From the Lorentz transformations

$$X = \frac{x - Vt}{\sqrt{1 - \frac{V^2}{c^2}}}, \qquad x = \frac{X + VT}{\sqrt{1 - \frac{V^2}{c^2}}}, \tag{3.27}$$

we obtain relations such as

$$\Delta X = \frac{\Delta x}{\sqrt{1 - \frac{V^2}{c^2}}}, \qquad \Delta x = \frac{\Delta X}{\sqrt{1 - \frac{V^2}{c^2}}} \tag{3.28}$$

by replacing the relative relations of motion and rest for two inertial systems according to the principle of relativity.

Eq. (3.28) leads to the conclusion that the relation

$$\frac{V^2}{c^2} = 0 \tag{3.29}$$

should hold. These results raise the question of what the relativity of space-time is. Einstein's special theory of relativity asserts the principle of relativistic relativity which extends the principle of relativity beyond mechanical phenomena to electromagnetic ones. Since inertial reference frames are equivalent by the principle of relativity, the physical phenomena must occur equally in all inertial reference frames. This is impossible without the invariance of space-time scales in any both inertial frames. However, the relativistic transformation makes the natures of space and time of any two inertial frames different by changing the space-time scales of the two inertial frames. To satisfy the principle of relativity, inertial reference frames must be equivalent from the point of view of the uniformity and isotropy of space and time. However, the Lorentz transformation violates the requirement for the uniformity and isotropy of space and time. Therefore, the Lorentz transformation does not satisfy the principle of relativity as another fundamental postulate of this theory.

Let us consider the case of applying the Lorentz transformation continuously. Imagine an inertial system moving at a certain speed, with respect to a stationary inertial frame. We suppose a number of virtual inertial frames ( $K_i;\ i=1,2,\cdots,N$ ) that partition the velocity of this inertial frame. Then let us assume that the velocity $V_i$ of the system $K_i$ relative to the system $K_{i\text{-}1}$ has the following relation with the velocity $V$ .

$$V=\sum_i^N V_i. \tag{3.30}$$

Equation (3.30) follows from the fact that the relative velocities are identical. In fact, according to the Lorentz transformation, the relative velocities of any two inertial frames are the same. Generalizing this fact, we arrive at the conclusion that all relative velocities are invariant in any inertial frame.

For convenience, we can express the Lorentz transformation in the matrix form as follows.

$$\begin{pmatrix} x_i \\ ct_i \end{pmatrix} = \mathrm{T}(V_i)\begin{pmatrix} x_{i-1} \\ ct_{i-1} \end{pmatrix}, \tag{3.31}$$

where the space-time variables $\begin{pmatrix} x_{i-1} \\ ct_{i-1} \end{pmatrix}$ in the $i-1$ th inertial frame are transformed by a linear transformation $\mathrm{T}(V_i)$ into the space-time variable $\begin{pmatrix} x_i \\ ct_i \end{pmatrix}$ in the inertial frame moving with relative velocity $V_i$ . The transformation matrix of space-time of

$$x_i=\frac{x_{i-1}-V_i t_{i-1}}{\sqrt{1-\frac{V_i^2}{c^2}}}, \tag{3.32}$$

$$t_i=\frac{t_{i-1}-\frac{V_i}{c^2}x_{i-1}}{\sqrt{1-\frac{V_i^2}{c^2}}} \tag{3.33}$$

is represented as

$$\mathrm{T}(V_i)=\frac{1}{\sqrt{1-\frac{V_i^2}{c^2}}}\begin{pmatrix} 1 & -\frac{V_i}{c} \\ -\frac{V_i}{c} & 1 \end{pmatrix}. \tag{3.34}$$

From Eq. (3.31), the continuous implementation of the relativistic transformation such as

$$\begin{pmatrix} x_{i+1} \\ ct_{i+1} \end{pmatrix} = \mathrm{T}(V_{i+1})\begin{pmatrix} x_i \\ ct_i \end{pmatrix} = \mathrm{T}(V_{i+1})\mathrm{T}(V_i)\begin{pmatrix} x_{i-1} \\ ct_{i-1} \end{pmatrix}$$

yields

$$\begin{pmatrix} x_N \\ ct_N \end{pmatrix} = \mathrm{T}(V_N)\cdots\mathrm{T}(V_2)\mathrm{T}(V_1)\begin{pmatrix} x_0 \\ ct_0 \end{pmatrix} = \mathrm{T}(V)\begin{pmatrix} x_0 \\ ct_0 \end{pmatrix}.$$

It is clear that for the Lorentz transformation matrix, the following relation must hold. That is

$$\mathrm{T}(V) = \mathrm{T}\left(\sum_i V_i\right) = \prod_i \mathrm{T}(V_i). \tag{3.35}$$

But it is obvious that this relation cannot be established by the transformation matrix (3.34). In fact, since

$$\prod_i \mathrm{T}(V_i) = \prod_i \frac{1}{\sqrt{1-\frac{V_i^2}{c^2}}}\begin{pmatrix} 1 & -\frac{V_i}{c} \\ -\frac{V_i}{c^2} & 1 \end{pmatrix} \neq \mathrm{T}\left(\sum_i V_i\right), \tag{3.36}$$

Eq. (3.35) does not hold. The above discussion shows that the Lorentz transformation is contradictory.

Finally, let us review STR in terms of the phase of light waves, the number of crests or troughs of waves, or the number of wave segments corresponding to a period. It is clear that the phase of light waves in all inertial frames must be invariant. This means that the relativistic transformation does not affect the number of crests or troughs of light waves. In this condition, the wavelength and period must be increased or decreased with the same ratio to maintain the constant speed of light during relative motion. However, comparing the scale ratios of time and length based on the Lorentz transformation, it follows that the wavelength and period must be inversely proportional. That is, from Eq. (3.9) we have

$$\Delta X \cdot \Delta T = \Delta x \cdot \Delta t. \tag{3.37}$$

It is clear that for the relativistic transformation, the invariance of phase and the same number of crests or troughs of a wave observed in both inertial frames must be ensured. Consider whether this fact is guaranteed by Eq. (3.37). Multiplying Eq. (3.37) by $c$, we have

$$\Delta X \cdot c\Delta T = \Delta x \cdot c\Delta t, \tag{3.38}$$

$$\Delta X \cdot N\Lambda = \Delta x \cdot N\lambda, \tag{3.39}$$

where $\Lambda$ is the wavelength in a moving inertial frame and $\lambda$ the wavelength in a stationary inertial frame, and $N$ the number of wave segments determined by a period. It follows that from Eq. (3.39),

$$\frac{\Delta X}{\Lambda} \cdot \Lambda^2 = \frac{\Delta x}{\lambda} \cdot \lambda^2 \tag{3.40}$$

and by the condition of equality of the number of wave segments observed from the reference systems

$$\frac{\Delta X}{\Lambda} = \frac{\Delta x}{\lambda} = N. \tag{3.41}$$

With Eqs. (3.40) and (3.41), we arrive at

$$N \cdot \Lambda^2 = N \cdot \lambda^2. \tag{3.42}$$

Thus, we obtain the result that denies the length contraction:

$$\Lambda = \lambda. \tag{3.43}$$

This means that in a relativistic transformation the phase is not invariant, and the numbers of crests and troughs vary. This is clearly a contradiction. Eventually, the Lorentz transformation seems to satisfy the principle of the constancy of the speed of light, but violates the requirement that the phase in both inertial frames should be invariable.

Let us discuss the problem of relativistic covariance of the Maxwell equations. In a stationary inertial frame, the Maxwell equation for electromagnetic waves, by setting $\rho = 0,\ \boldsymbol{j} = 0$, are written as

$$\left.\begin{aligned} &\mathrm{div}\boldsymbol{D} = 0 \\ &\mathrm{rot}\boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t} \\ &\mathrm{rot}\boldsymbol{H} = -\frac{\partial \boldsymbol{D}}{\partial t} \\ &\mathrm{div}\boldsymbol{B} = 0 \end{aligned}\right\}. \tag{3.44}$$

By performing a series of mathematical operations on Maxwell's equations, we can obtain the following wave equation:

$$\Delta \boldsymbol{E} - \varepsilon_0 \mu_0 \frac{\partial^2 \boldsymbol{E}}{\partial^2 t} = 0. \tag{3.45}$$

This equation is the result obtained for a stationary system in which the Maxwell equations hold. It is natural to expect that if we do not know the Lorentz transformation, the result may be different for other reference systems in motion.

For a moving inertial system and a stationary inertial system, we have the following Galilean transformation.

$$\left.\begin{aligned} &\boldsymbol{R} = \boldsymbol{r} - \boldsymbol{V}t \\ &T = t \end{aligned}\right\}. \tag{3.46}$$

Taking into account these transformation relations, we can obtain the wave equation in the moving inertial system. By the relationships between the derivatives with respect to coordinate and time in two inertial systems:

$$\begin{aligned} &\frac{\partial}{\partial \boldsymbol{r}} = \frac{\partial}{\partial \boldsymbol{R}}\frac{\partial \boldsymbol{R}}{\partial \boldsymbol{r}} + \frac{\partial}{\partial T}\frac{\partial T}{\partial \boldsymbol{r}} = \frac{\partial}{\partial \boldsymbol{R}}, \\ &\frac{\partial}{\partial t} = \frac{\partial}{\partial \boldsymbol{R}}\frac{\partial \boldsymbol{R}}{\partial t} + \frac{\partial}{\partial T}\frac{\partial T}{\partial t} = \frac{\partial}{\partial T} - \left(\boldsymbol{V} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right), \end{aligned} \tag{3.47}$$

Laplacian in a stationary inertial system:

$$\Delta_r = \left(\frac{\partial}{\partial \boldsymbol{r}} \cdot \frac{\partial}{\partial \boldsymbol{r}}\right) = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial y^2} \tag{3.48}$$

is transformed with respect to space and time variables of a moving inertial frame into

$$\Delta_r = \left(\frac{\partial}{\partial \boldsymbol{r}} \cdot \frac{\partial}{\partial \boldsymbol{r}}\right) = \left(\frac{\partial}{\partial \boldsymbol{R}} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right) = \frac{\partial^2}{\partial X^2} + \frac{\partial^2}{\partial Y^2} + \frac{\partial^2}{\partial Z^2} = \Delta_R. \tag{3.49}$$

On the other hand, in a stationary inertial frame, $\frac{\partial^2}{\partial t^2}$ is transformed with respect to the space and time variables of the moving inertial frame into

$$\frac{\partial^2}{\partial t^2} = \frac{\partial}{\partial t} \cdot \frac{\partial}{\partial t} = \left[\frac{\partial}{\partial T} - \left(\boldsymbol{V} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right)\right]^2 = \frac{\partial^2}{\partial T^2} - 2\left(\boldsymbol{V} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right)\frac{\partial}{\partial T} + \left(\boldsymbol{V} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right)^2. \tag{3.50}$$

Thus, the standard wave equation in the stationary inertial frame is expressed in terms of the variables in an inertial frame in motion as

$$\Delta_R \boldsymbol{E} - \frac{1}{c^2}\frac{\partial^2 \boldsymbol{E}}{\partial T^2} + \frac{2}{c^2}\left(\boldsymbol{V} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right)\frac{\partial \boldsymbol{E}}{\partial T} - \frac{1}{c^2}\left(\boldsymbol{V} \cdot \frac{\partial}{\partial \boldsymbol{R}}\right)^2 \boldsymbol{E} = 0. \tag{3.51}$$

This equation is different from the wave equation in the inertial frame at rest (3.45). Eventually, Eq. (3.51) shows that any propagation process of a single light wave is observed differently in the two inertial frames, and that the speed of light varies with the velocity of an observer relative to the inertial frame at rest. In a word, the laws of electrodynamics are not invariant with respect to the Galilean transformation.

We can use the Galilean transformation as a nonrelativistic approximation of the Lorentz transformation. Then the wave equation must be Eq. (3.51). This means that in the nonrelativistic approximation the principle of the constancy of the speed of light does not hold true. However, Eq. (3.51) should be considered as a correct approximation, as long as the Galilean transformation is accepted as a nonrelativistic approximation. If so, it means that at least in the limit of nonrelativistic approximation the speed of light is not constant. Meanwhile, it means that if the principle of the constancy of the speed of light is absolute, there cannot be the nonrelativistic approximation of electrodynamics. This is because since the principle of the constancy of the speed of light is in absolute position, there cannot be an approximation that does not guarantee this principle. However, it is logically inconsistent that it is not possible to think of nonrelativistic approximations related to the relative motion of an observer.

Thus, it is worthwhile to think about whether the Maxwell equations are covariant for all inertial frames. In other words, the question is whether for all inertial systems the requirement that the wave equation for the same light wave should be expressed in a covariant form as

$$\left.\begin{aligned} \Delta\boldsymbol{E}-\frac{1}{c^2}\frac{\partial^2\boldsymbol{E}}{\partial t^2}=0, \\ \Delta\boldsymbol{H}-\frac{1}{c^2}\frac{\partial^2\boldsymbol{H}}{\partial t^2}=0 \end{aligned}\right\}, \tag{3.52}$$

is correct. This means that the observed wave phenomenon is completely independent of observers' motions. In this sense, the principle of relativistic relativity and the principle of the constancy of the speed of light are not independent, but are closely related to each other. In fact, Einstein's principle of relativity was assumed and has not yet been completely verified. Our study shows that adopting the principle of relativistic relativity, which advocates the covariance of physical laws, is by no means self-evident and does not guarantee the construction of consistent theories.

Now let us consider in detail the four-dimensional vector of the electromagnetic field. The four-dimensional vector is expressed as

$$a_1=a_x,\ a_2=a_y,\ a_3=a_z,\ a_4=a_\tau=ica_t,$$

where, $a_\tau=ica_t$ is understood in the same sense as the time denotation $\tau=ict$. Then the Lorentz transformation between the four-dimensional vectors is represented as

$$a_x=\frac{a'_x-i\frac{V}{c}a'_\tau}{\sqrt{1-\frac{V^2}{c^2}}}, \tag{3.53}$$

$$a_y=a'_y, \tag{3.54}$$

$$a_z=a'_z, \tag{3.55}$$

$$a_x=\frac{a'_\tau+i\frac{V}{c}a'_x}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{3.56}$$

According to the geometry of relativity, the following relationship of invariant holds for the quantity representing the length of this four-dimensional vector. That is,

$$a_x^2 + a_y^2 + a_z^2 + a_\tau^2 = invariant.$$

By the Lorentz condition, we obtain the expression

$$\frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} + \frac{\partial}{\partial (ict)}\left( i\frac{\varphi}{c} \right) = 0.$$

Hence, we introduce a four-dimensional vector potential $\boldsymbol{A}_\mu = \left( \boldsymbol{A},\, i\frac{\varphi}{c} \right)$. Then, by the axiom of relativity, the length of the four-dimensional vector potential is expressed as

$$A_x^2 + A_y^2 + A_z^2 + A_\tau^2 = A_x^2 + A_y^2 + A_z^2 - \frac{\varphi^2}{c^2} = const. \tag{3.57}$$

In the end, the relation between the scalar potential and the vector potential must be given as

$$\varphi = \pm c\sqrt{\boldsymbol{A}^2 + \Lambda}\ ,$$

where, $\Lambda$ is a constant. If $\Lambda$ is supposed to be zero, the scalar potential is expressed as

$$\varphi = \pm c|\boldsymbol{A}|. \tag{3.58}$$

Eventually, the scalar potential is equivalent to the magnitude of the vector potential. According to this relation, the relationship between the scalar potential and the vector potential is not independent. This is physically inconsistent.

The same is true for the case of the four-dimensional current density. From the current continuity equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial j_x}{\partial x} + \frac{\partial j_y}{\partial y} + \frac{\partial j_z}{\partial z} = 0,$$

we obtain the expression:

$$\frac{\partial \rho}{\partial t} + \frac{\partial j_x}{\partial x} + \frac{\partial j_y}{\partial y} + \frac{\partial j_z}{\partial z} = \frac{\partial (ic\rho)}{\partial (ict)} + \frac{\partial j_x}{\partial x} + \frac{\partial j_y}{\partial y} + \frac{\partial j_z}{\partial z} = \frac{\partial j_t}{\partial \tau} + \frac{\partial j_x}{\partial x} + \frac{\partial j_y}{\partial y} + \frac{\partial j_z}{\partial z}.$$

According to the four-dimensional geometry of relatvity, we have the relation.

$$j_x^2 + j_y^2 + j_z^2 + j_t^2 = j_x^2 + j_y^2 + j_z^2 - c^2\rho^2 = const.$$

This leads to the relationship between the current density and the charge density.

$$c\rho = \pm\sqrt{j^2 + \Lambda},$$

where, $\Lambda$ is a constant. Setting $\Lambda$ as zero, we obtain the relation

$$c\rho = \pm j,$$

which is physically inconsistent. Thus, it follows that we cannot view the 4-vector as a vector.

The same is true for the space-time vector. Its length is given by the definition of the four-dimensional geometry of relativity as

$$x^2 + y^2 + z^2 - c^2t^2 = const.$$

This relationship was derived from the fact that for any two inertial systems the equation for the front of light wave has the same form as follows.

$$x^2 + y^2 + z^2 - c^2t^2 = 0,$$

$$X^2 + Y^2 + Z^2 - c^2T^2 = 0.$$

This means that every observer with relative motion views a spherical wave as the spherical wave whose center is at self. Thus, in connection with this problem, we are faced with a contradictory result, namely, a spherical wave with different centers. This shows that the geometry of relativity is contradictory.

By the Lorentz transformation, the relationships between the components of a vector potential in the two inertial frames are represented as

$$A_1' = \frac{A_1 + i\frac{V}{c}A_4}{\sqrt{1-\frac{V^2}{c^2}}}, \tag{3.59}$$

$$A_2' = A_2, \tag{3.60}$$

$$A_3' = A_3, \tag{3.61}$$

$$A_4' = \frac{A_4 - i\frac{V}{c}A_1}{\sqrt{1-\frac{V^2}{c^2}}}. \qquad \text{b} \tag{3.62}$$

Since for the intensity of electromagnetic field $\boldsymbol{E}$ and the magnetic induction $\boldsymbol{B}$, the relations

$$\boldsymbol{E} = -\mathrm{grad}\,\varphi - \frac{\partial \boldsymbol{A}}{\partial t}, \tag{3.63}$$

$$\boldsymbol{B} = \mathrm{rot}\boldsymbol{A} \tag{3.64}$$

hold, in the case of two inertial frames with relative motion the following transformation relations hold.

$$E_x' = E_x, \tag{3.65}$$

$$E_y' = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\left(E_y - VB_z\right), \tag{3.66}$$

$$E_z' = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\left(E_z + VB_y\right), \tag{3.67}$$

$$B_x' = B_x, \tag{3.68}$$

$$B_y' = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\left(B_y - \frac{V}{c^2}E_z\right), \tag{3.69}$$

$$B_z' = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\left(B_z - \frac{V}{c^2}E_y\right). \tag{3.70}$$

Of course, if we adopt the Lorentz transformation, the laws of electrodynamics have relativistic invariance. Instead of obtaining the law of electrodynamics being covariant, the quantities of the electromagnetic field are viewed as being not independent, and thus as being mutually intertwined. In other words, the electric field and the magnetic field have relative characteristics related to reference frames. According to STR, we express equations of physics in a four-dimensional form, and determine the four-dimensional vector from it, and assume that it is a relativistic invariant by the Lorentz transformation. Thus, relativistic results based on the unification of space and time are obtained, which is an error, as shown by Eqs. (3.57) and (3.58).

From the above discussion, it follows that the Maxwell equations and the standard wave equation have meaning only in a preferred inertial frame and change into a different form in another inertial frame moving relative to that inertial frame. In conclusion, it should be considered that the principle of relativity is not valid in electrodynamics.

# 4. Theory of relativity based on universal quantum

## 4.1 Assumptions of universal quantum

We assume the universal quantum to formulate an alternative theory of relativity without recourse to STR. This purports that the newly presented theory of relativity has a different genesis from STR and GTR.

·We assume that the universal quantum is an entity that constitutes the universe and that the physical vacuum is also a physical entity made up of universal quanta. The universal quantum is not only a matter that forms the world, but also a matter that mediates physical interactions and can contain energy. We shall call this original quantum of the universe the cosmon briefly, as A. Martin did [76,77]. In the end, the universal quantum, that is, the cosmon is the quantum of the ether and thus gives concrete contents of the concept of the ether. In this sense, the ether-based system, that is, the absolute system will be referred to as the cosmonic system. In this light, reference systems are classified into the cosmonic system and non-cosmonic systems, and not into inertial system and noninertial one. All reference systems moving relative to the cosmonic system are the non-cosmonic system, whether they accelerate, or move uniformly. It is assumed that the species of matter particles are determined by the kind and the number of cosmons, their structure and the energy involved.

· We assume that the cosmon has the following properties. There are two kinds of cosmons. One is a positive cosmon and the other is a negative cosmon. Two kinds of independent free-state cosmons are coupled by pairing, which is very strong but unstable. The bond is easily broken and thus free cosmons are generated. These pair annihilation and pair generation occur constantly. This process leads to strong coupling of the cosmonic system on the one hand and to free motion of cosmons on the other hand. By means of coupled cosmons, a system of cosmons is similar to an ideally elastic body with strong tension. The cosmonic system exhibits a strong tension by coupling, while cosmons of uncoupled states always travel at the universal speed of light $c$ with respect to the cosmonic system. The number of cosmons traveling in any direction at each point in a homogeneous cosmonic system is the same. Therefore, the free-state cosmons in the cosmonic system can be viewed as an ideal gas consisting of particles with the universal speed of light $c$.

·We assume that a matter particle is composed of a definite number of cosmons, and the energy that the matter particle possesses is the localized energy that the combined cosmons have when forming the particle. Mass is determined by the number of cosmons and the energy possessed by the cosmons. When cosmons with localized energy are combined and form a complex structure, it becomes a matter particle, and if a partial system of cosmons has nonlocal energy, it becomes a gravitational wave or an electromagnetic wave. The motion of a body is regarded as the transfer of localized energy from a part of the cosmonic system to another due to the pair annihilation and pair generation.

·We assume that the cosmonic system produces the tension determined by the gradient of the cosmon density. Since a matter particle is formed by the packing of cosmons in a definite space, the cosmon density inside a body becomes dense and the cosmon density outside of the body gets more dilute than that in field-free space. As the distance from the body increases, the cosmon density outside of the body gradually increases and as a result, approaches the cosmon density in field-free space.

## 4.2 Probability of interaction, universal quantum density, and effective time of interaction

With the advent of STR, the ether theory, which assumed the existence of a medium of light propagation, had been negated, but today this theory is being revived with a more advanced form by researchers pursuing realistic theories. We believe that if there is the ether, it should be an entity that exhibits both gravity and electromagnetic fields, as Einstein thought. The argument about the ether was in the past, but today many physicists recognize the concept of the ether as a necessary and realistic concept to resolve the problem essentially. The fact that Einstein also came back to the ether theory in the 1920s and maintained that view until his end suggests that the ether theory is not entirely groundless.

Despite a contradictory fact, the breaker of the ether theory needed a preferred reference frame with equivalent meaning to the concept of the ether to build the general theory of relativity that is an extension of the theory of special relativity. In addition, Dirac, in his paper in 1951, shared the ideas of Einstein, and described the problems of quantum electrodynamics. In the 1980s, particle physicists T. D. Lee, V. F. Weisskopf, and J. D. Bjorken showed an idea for the ether relevance in the modern gauge field theory [46,78]. The ether theory is based on the idea that there is a medium of light propagation and that there exists a preferred inertial system connected with it.

The existence of the ether is quite reasonable from the point of view of quantum field theory and elementary particle theory. If there is the ether, the physical action of the field is related to the ether. The maximum speed of propagation of the interaction in the ether is the light velocity $c$. If we think of a world of field quanta with such physical properties, it is a system of the cosmons. In the sense of the cosmon, we claim the principle of the constancy of the speed of light. This is equivalent to the fact that in acoustics the velocity of sound waves on a medium is constant. In a reference frame fixed to a medium, the velocity of propagation of acoustic waves is constant independently of the motion of the source, but in a reference frame moving relative to the medium the velocity of propagation of acoustic waves depends on the velocity of the reference frame. For the propagation of light, the ether is similar to the medium of sound wave.

It is natural to assume that the action of cosmons on a body is represented by the probability of interaction depending on the relative velocity of a body and the cosmonic system, if the cosmon is not only a constituent particle of matter but also a mediator of interaction. If the velocity of interaction propagation is infinite, the interaction will not depend on the relative velocity of a body to the cosmonic system. A moving body which cosmons with the finite velocity $c$ exerts a force on in a preferred reference system can exhibit the characters of velocity-dependent interaction.

As the relative velocity of a body and a cosmonic system increases, the effectiveness of the interaction decreases. On the other hand, the effectiveness of the interaction increases with the high cosmon density, since the cosmon is the mediator of the interaction. The effective cosmon density, which represents the total effectiveness of the interaction, is assumed to be proportional to the product of the cosmon density and the probability of the interaction. That is,

$$\rho_{eff}(V) = \rho \cdot \mathrm{P}_V . \tag{4.1}$$

Here $\rho$ is the cosmon density and $\mathrm{P}_V$ is the probability of interaction associated with the motion of the body. We shall call $\mathrm{P}_V$ the velocity-dependent probability of interaction.

First, let us consider the velocity dependence of the probability of interaction. As a body moves, the relative velocity of body and cosmon in the direction of motion of the body changes with quantities related to $c - V$ and $c + V$, respectively. Then, the frequencies of the interactions between cosmon and body in both cases can be expressed respectively as

$$f_{V+} = \beta_+(c+V), \tag{4.2}$$

$$f_{V-} = \beta_-(c-V), \tag{4.3}$$

where $V$ is the instantaneous velocity. $\beta_+$ and $\beta_-$ are constants corresponding to the cosmons moving in opposite directions, respectively. The probability that a pair of bound cosmons is to be generated to form the moving body must be given as the product of the frequencies of two cases with different relative velocities. Hence, the probability of interaction is expressed as the geometric average of the frequencies of both cases. That is,

$$\mathrm{P}_V(V) = \sqrt{f_{V+} f_{V-}} = \sqrt{\beta_+\beta_-}\sqrt{c^2 - V^2} = c\beta\sqrt{1-\frac{V^2}{c^2}}.$$

This relation concludes that the velocity of motion of a body cannot exceed the speed of light as the maximum speed of interaction propagation.

In the case of $V = 0$, we have $\mathrm{P}_V(0) = c\beta$. Thus, the above expression is written as

$$\mathrm{P}_V(V) = \mathrm{P}_V(0)\sqrt{1-\frac{V^2}{c^2}}. \tag{4.4}$$

Since $\mathrm{P}_V(0) = 1$, the probability of interaction is simplified as

$$\mathrm{P}_V(V) = \sqrt{1-\frac{V^2}{c^2}}.$$

Thus, we have obtained the expression for the velocity-dependent probability of interaction.

Next, we define the effective cosmon density, $\rho_{eff}$, as

$$\rho_{eff} = \rho(V)\mathrm{P}_V(V).$$

Since the quantity of matter must be conserved, the effective cosmon density should be conserved during motion. That is,

$$\rho(V)\mathrm{P}_V(V) = const.$$

Thus, as the velocity-dependent probability of interaction is lowered, the density of cosmons as the source of matter should be increased. Considering the relation

$$\mathrm{P}_V(0)\rho(0) = \mathrm{P}_V(V)\rho(V) = \sqrt{1-\frac{V^2}{c^2}}\,\rho(V) \tag{4.5}$$

and $\mathrm{P}_V(0) = 1$, we get the cosmon density

$$\rho_V(V) = \frac{\rho(0)}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{4.6}$$

Therefore, the velocity dependence of the cosmon density has been determined. If the probability of interaction is low, the physical process generally gets slower. Due to the finiteness of the propagation velocity of interaction, the effect of action on a moving body depends on the velocity. This effect characterizes the rate of a real physical process, so we define as the effective time of interaction the equivalent time that specifies the effectiveness of the interaction.

In determining the relationship between absolute time and effective time, one must reflect the fact that the velocity of a body in a cosmonic system cannot exceed the velocity of interaction propagation. It should be described that the effective time of interaction in the cosmonic system is the absolute time, and as the velocity of the body approaches the speed of light, the effective time of interaction approaches zero.

Essential for the effective time of interaction is that it is the time taking into account the probability of interaction. The effective time can be considered to be proportional to the velocity-dependent probability of interaction and the time in a cosmonic system, i.e.,

$$\Delta T(V) \propto \mathrm{P}_V(V)\Delta t. \tag{4.7}$$

The effective time of interaction decreases with increasing speed, as seen in Eq. (4.7). The time in a non-cosmonic system becomes the effective time of interaction. Therefore, the effective time of interaction can be defined as

$$\Delta T(V) = \sqrt{1 - \frac{V^2}{c^2}}\, \Delta t. \tag{4.8}$$

Since velocity in general varies with time, the relative relation between times must be expressed by the differential relation

$$dT = \sqrt{1 - \frac{V^2}{c^2}} dt. \tag{4.9}$$

This shows that the effective time of interaction for a body moving relative to the cosmonic system is shorter than the absolute time of interaction in the cosmonic system. This means that in a non-cosmonic systems the force must be exerted for longer time than the time in the cosmonic system to produce the same kinetic effect (change of velocity). In other words, the higher the speed of motion, the greater the force needed to accelerate a body. This is explained by the increase in the cosmon density due to the increase in velocity, and consequently by the increase in the mass of a body.

The effective time of interaction in the cosmonic system becomes the absolute time. Therefore, the reference for evaluating relativistic time consists in the cosmonic system. As an extreme case, if a body moves almost at the speed of light relative to the cosmonic system, the effective time of interaction approaches zero. The analysis based on the effective time of interaction is more realistic than the analysis of STR that the higher the relative velocity, the longer the proper time in the moving system, and does not give any paradox. However, formally, the mathematical expression of the effective time of interaction is the same as that of the proper time of STR.

For a moving body, there exists the maximum velocity of interaction propagation, so that there is the effective time of interaction that can be considered as the effects of the time delay given by STR. This can be interpreted as the essence of the time delay as a relativistic effect. If an observer with a clock moves relative to the cosmonic system, the effective time of interaction the clock indicates has a real meaning in considering the physical processes that occur in the observer's reference frame.

In a reference system moving relative to the cosmonic system, the time variation must be expressed in terms of the effective time of interaction which is the actual time that determines the physical processes in the moving system. Note that the concept of the effective time of interaction does not result from the relativity of any two identical inertial frames, but from the relation that holds for a reference frame moving relative to the cosmonic system. Therefore, the effective time of interaction is not only significant for inertial systems but also for noninertial systems where the velocity varies. In this sense, in the theory of relativity based on the effective time of interaction, relativity is not a matter of the unified space-time in two inertial frames, but the matter of the relation between dynamical effects in the cosmonic system and in any reference frame moving relative to the cosmonic system. Finally, our theory of relativity has the potential to extend beyond the range of inertial systems to noninertial systems.

## 4.3 Equation of motion in terms of universal quantum density

We shall derive the equation of motion by taking into account the velocity dependence of the cosmon density. The force acting on a body causes a change in the state of motion of the body, which in turn causes a change in the cosmon density in the body. The gradient of the density created acts as a force opposite to the body that exerts a force. The magnitude of the force acting on a cosmon is assumed to be proportional to the gradient of the cosmon density due to the change of the state of motion of the body. That is,

$$\boldsymbol{f} = c_f \,\mathrm{grad}\rho. \tag{4.10}$$

In the direction of motion of a body, Eq. (4.10) is reduced to

$$f = c_f \frac{d\rho}{dx}.$$

In view of the velocity dependence of the cosmon density, we can calculate as follows.

$$\begin{aligned} f &= c_f \frac{d\rho}{dx} = c_f \frac{d}{dx}\left(\frac{\rho_0}{\sqrt{1-\frac{V^2}{c^2}}}\right) = c_f \frac{d}{dt}\left(\frac{\rho_0}{\sqrt{1-\frac{V^2}{c^2}}}\right)\frac{dt}{dx} \\ &= \frac{c_f\rho_0}{c^2}\frac{V\frac{dV}{dt}}{\left(1-\frac{V^2}{c^2}\right)^{3/2}}\frac{1}{V} = \frac{c_f\rho_0 c^{-2}}{\left(1-\frac{V^2}{c^2}\right)^{3/2}}\frac{dV}{dt}, \end{aligned} \tag{4-11}$$

where we have used the relation of differential $\frac{d}{dx} = \frac{dt}{dx}\frac{d}{dt}$. Multiplying both sides by the number of cosmons constituting the matter particle yields the force acting on the point of mass. That is,

$$F = N_0 f = \frac{c_f\rho_0 N_0 c^{-2}}{\left(1-\frac{V^2}{c^2}\right)^{3/2}} a. \tag{4.12}$$

Here, setting $m_0 = c_f\rho_0 N_0 c^{-2}$, we have $m(V) = \frac{c_f\rho_0 N_0 c^{-2}}{\left(1-\frac{V^2}{c^2}\right)^{1/2}} = \frac{m_0}{\left(1-\frac{V^2}{c^2}\right)^{1/2}}$.

We shall call $m_0$ the rest mass. Then, the relativistic mass $m(V)$ depends on the velocity of the body.

The rest mass $m_0$ can be interpreted as follows. By rewriting the definition of the rest mass as $m_0c^2 = c_f\rho_0 N_0$, the rest mass is an indicator of the energy of the cosmons forming a physical object. The quantity $c_f\rho_0$ is the energy that a cosmon has for the normal cosmon density. This fact is clearly explained by

$$c_f\rho_0 = \frac{f}{d\rho/dx}\rho_0 = \frac{f dx}{d\rho}\rho_0 = \frac{d\varepsilon}{d\rho}\rho_0. \tag{4.13}$$

From this, $c_f\rho_0$ can be interpreted as the energy that a cosmon possesses when its ambient density is $\rho_0$. Thus, $c_f\rho_0 c^{-2}$ is the mass of a cosmon and $c_f\rho_0 N_0 c^{-2}$ is the rest mass of body.

Also, it is possible to interpret the relativistic mass. From the following relation

$$m = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}} = \frac{c_f\rho_0 N_0 c^{-2}}{\sqrt{1-\frac{V^2}{c^2}}} = c_f\rho N_0 c^{-2}, \tag{4.14}$$

it can be seen that the number of the cosmons that form a body is constant, but as a result of the motion, the velocity-dependent probability of interaction is lowered, so the cosmon density involved in the body increases. Thus, as the number of cosmons coupled to the body is increased, the mass of the body increases. This gives a reasonable explanation of the nature of mass.

By introducing the concept of mass, we can express Eq. (4.12) for relativistic forces as follows.

$$\boldsymbol{F}=\frac{m_0}{\left(1-\frac{V^2}{c^2}\right)^{3/2}}\frac{d\boldsymbol{V}}{dt}. \tag{4.15}$$

This is the relativistic equation of motion. From the equation of motion (4.15), it can be seen that in the nonrelativistic approximation, the equation of motion are the same for all reference systems moving with constant velocity relative to the absolute rest system, i.e., the cosmonic reference system. This signifies the principle of relativity in classical mechanics.

Let us obtain another form of the relativistic equation of motion by calculating

$$\frac{d}{dt}\left(\frac{\boldsymbol{V}}{\left(1-\frac{V^2}{c^2}\right)^{1/2}}\right). \tag{4.16}$$

The above derivative with respect to time is calculated as

$$\frac{d}{dt}\frac{\boldsymbol{V}}{\left(1-V^2/c^2\right)^{1/2}}=\frac{1}{\left(1-V^2/c^2\right)^{1/2}}\frac{d\boldsymbol{V}}{dt}+\frac{\boldsymbol{V}}{\left(1-V^2/c^2\right)^{3/2}}\frac{1}{c^2}\left(\boldsymbol{V}\cdot\frac{d\boldsymbol{V}}{dt}\right).$$

By taking the scalar product of $\boldsymbol{V}$ with the both sides of the above expression, we get the following result.

$$\boldsymbol{V}\cdot\frac{d}{dt}\frac{\boldsymbol{V}}{\left(1-V^2/c^2\right)^{1/2}}=\frac{1}{\left(1-V^2/c^2\right)^{1/2}}\left(\boldsymbol{V}\cdot\frac{d\boldsymbol{V}}{dt}\right)+\frac{1}{\left(1-V^2/c^2\right)^{3/2}}\frac{V^2}{c^2}\left(\boldsymbol{V}\cdot\frac{d\boldsymbol{V}}{dt}\right)=$$

$$=\frac{1}{\left(1-V^2/c^2\right)^{3/2}}\left(\boldsymbol{V}\cdot\frac{d\boldsymbol{V}}{dt}\right).$$

Thus, we obtain

$$\frac{d}{dt}\left(\frac{\boldsymbol{V}}{\left(1-V^2/c^2\right)^{1/2}}\right)=\frac{1}{\left(1-V^2/c^2\right)^{3/2}}\frac{d\boldsymbol{V}}{dt}.$$

Multiplying the both sides by $m_0$, we get

$$\frac{d}{dt}\left[\frac{m_0\boldsymbol{V}}{\left(1-V^2/c^2\right)^{1/2}}\right]=\frac{m_0}{\left(1-V^2/c^2\right)^{3/2}}\boldsymbol{a}. \tag{4.17}$$

Combining Eqs. (4.15)와 (4.17), we find

$$\boldsymbol{F}=\frac{d}{dt}\left(\frac{m_0\boldsymbol{V}}{\left(1-\frac{V^2}{c^2}\right)^{1/2}}\right)=\frac{m_0}{\left(1-V^2/c^2\right)^{3/2}}\boldsymbol{a}. \tag{4.18}$$

Putting $\boldsymbol{p}=\frac{m_0\boldsymbol{V}}{\sqrt{1-\frac{V^2}{c^2}}}$, $m=\frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}}$, we identify the relations

$$\boldsymbol{p}=m\boldsymbol{V},\quad \boldsymbol{F}=\frac{d\boldsymbol{p}}{dt}. \tag{4.19}$$

This shows that the concept of the cosmon produces exact relativistic formulae. In addition, Eq. (4.18) draws the crucial conclusion that all inertial reference frames are not equivalent. In fact, according to Eq. (4.18) all inertial reference systems are distinguished by its relative velocity with respect to the cosmon system. This fact directly demonstrates that the principle of relativity is an approximation relation.

Equation (4.18) shows that a body accelerates when force is applied. Meanwhile, this means that another body that exerts a force on the body is subjected to the same magnitude of force due to the gradient of the cosmon density. This is the content of Newton's third law, the law of action and reaction. This law is relativistic and does not involve approximation. From Eq. (4.11), it can be seen that if a body performs uniform motion, the gradient of cosmon density due to its motion does not occur, and thus the body does not experience any force from the cosmonic system. That is, the body maintains its state of motion. Thus, the content of Newton's first law has been explained. But this result shows that every inertial system is distinguished by relative velocity to the cosmonic system as the preferred reference system. Consequently, the principle of relativity presuming the equivalence of all inertial reference frames loses its meaning.

In the nonrelativistic approximation, Eq. (4.19) becomes

$$\boldsymbol{F} = m_0 \boldsymbol{a}. \tag{4.20}$$

This is nothing but the description of Newton's second law based on the notion of the cosmon. Finally, all Newton's laws have been explained. Ultimately, it is revealed that the cosmon-based mechanics is the generalized theory of mechanics that involves the Newtonian mechanics as its nonrelativistic case, and the relativistic mechanics is no other than the very mechanics itself based on the cosmon.

## 4.4 Relativistic mechanics based on effective time of interaction

Applying the concept of the effective time of interaction corresponding to the proper time, we can derive the same relativistic dynamic relations as STR gives. Let us consider the problem of whether the proper time is physically valid. The proper time, which is the time of an observer comoving with a moving object, must be independent of the presence of an observer in the stationary coordinate system. However, the proper time depends on the relative velocity of the two reference frames. This situation results in different proper times for all inertial frames distinguished by relative velocities. Finally, all inertial frames are distinguished by their proper time. It can be shown briefly that for any two inertial systems, the proper time defined as such is contradictory. All inertial frames are equivalent, so for two inertial frames the rest and motion are relative. Thus, for two inertial systems, one choice of rest and motion results in $dT = \sqrt{1-\frac{V^2}{c^2}}dt$ , while the other choice gives $dt = \sqrt{1-\frac{V^2}{c^2}}dT$ . From these two relations, it follows that $dT = \left(1-\frac{V^2}{c^2}\right)dT$ , and thus we have $\frac{V^2}{c^2} = 0$. But this is impossible. This shows that the concept of the proper time is inconsistent. Since the effective time of interaction is associated with the relative velocity of a body to the cosmonic system, we do not encounter such a contradiction that the proper time gives in relation to relativity.

Since we deal with free particles, the Lagrangian consists of only kinetic energy and therefore can be considered as a constant. The relativistic action for a dynamical system can be taken as in STR as

$$S = \int K\sqrt{1-\frac{V^2}{c^2}}dt, \tag{4.21}$$

where $dt$ is the time in a cosmonic system and $\sqrt{1-\frac{V^2}{c^2}}dt$ is the effective time of interaction in a non-cosmonic system. Then compared to the nonrelativistic Lagrangian, the relativistic Lagrangian is written as

$$L=-m_0c^2\sqrt{1-\frac{V^2}{c^2}}. \tag{4.22}$$

Since this is the same as the Lagrangian of STR, it is clear that all the dynamic relations, as obtained in STR are derived. That is, in the case of energy, taking into consideration

$$E=\boldsymbol{p}\boldsymbol{V}-L=\frac{m_0V^2}{\sqrt{1-\frac{V^2}{c^2}}}+m_0c^2\sqrt{1-\frac{V^2}{c^2}}=\frac{m_0c^2}{\sqrt{1-\frac{V^2}{c^2}}},$$

we obtain the relativistic energy, which is the same as the result of STR,

$$E=\frac{m_0c^2}{\sqrt{1-\frac{V^2}{c^2}}}=mc^2. \tag{4.23}$$

Another expression for energy is given as

$$E^2=m_0^2c^4+c^2p^2. \tag{4.24}$$

For the momentum, taking into consideration $\boldsymbol{p}=\frac{\partial L}{\partial \boldsymbol{V}}$, we obtain

$$\boldsymbol{p}=\frac{m_0\boldsymbol{V}}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{4.25}$$

On the other hand, by calculating the work done for a particle, we can find the relativistic kinetic energy of the particle. The energy that is carried out for a particle per unit time is expressed as

$$\frac{dA}{dt}=\boldsymbol{V}\cdot\boldsymbol{F}=\boldsymbol{V}\cdot\frac{d\boldsymbol{p}}{dt}.$$

Substituting the relativistic momentum into the momentum of the above equation yields

$$\frac{dA}{dt}=\boldsymbol{V}\cdot\frac{d}{dt}\left(\frac{m\boldsymbol{V}}{\sqrt{1-\frac{V^2}{c^2}}}\right)=\frac{m_0}{\left(1-\frac{V^2}{c^2}\right)^{3/2}}\left(\boldsymbol{V}\cdot\frac{d\boldsymbol{V}}{dt}\right),$$

where it is an important starting point to assume that relativistic relations also hold in noninertial systems. On the other hand, we have

$$\frac{d}{dt}\left(\frac{m_0c^2}{\sqrt{1-\frac{V^2}{c^2}}}\right)=\frac{m_0}{\left(1-V^2/c^2\right)^{3/2}}\left(\boldsymbol{V}\cdot\frac{d\boldsymbol{V}}{dt}\right). \tag{4.26}$$

Therefore, we obtain

$$\frac{dA}{dt}=\frac{d}{dt}\left(\frac{m_0c^2}{\sqrt{1-\frac{V^2}{c^2}}}\right). \tag{4.27}$$

Since the work performed is equal to the kinetic energy increased, i.e.,

$$dA=dE,$$

the derivative of the performed work with respect to time can be expressed as the derivative of the derivative of kinetic energy with respect to time is,

$$\frac{dE}{dt} = \frac{d}{dt}\left(\frac{m_0c^2}{\sqrt{1-\frac{V^2}{c^2}}}\right). \tag{4.28}$$

Integrating the above expression over time, we get

$$K = \int_0^t \frac{dE(t')}{dt'}dt' = E(t) - E(0) = \frac{m_0c^2}{\sqrt{1-\frac{V^2(t)}{c^2}}} - \frac{m_0c^2}{\sqrt{1-\frac{V^2(0)}{c^2}}}. \tag{4.29}$$

If the velocity at the initial moment is zero, then $K = E(t) - E(0)$ is the kinetic energy. Therefore, the kinetic energy is

$$K = \frac{m_0c^2}{\sqrt{1-(V^2/c^2)}} - m_0c^2. \tag{4.30}$$

Thus, it has been demonstrated that relativistic dynamics can be built based on the cosmonic reference system. The relativity we say here means not the relativity related to any two equivalent inertial frames, but the relativity in the sense of the motion relative to the cosmonic reference system. In fact, the meaning of the relativistic energy relation in STR is ambiguous. This is because the relativistic relation is a relativistic relation for arbitrary two inertial systems. This shows that there is no criterion of motion in STR, even if the upper limit of velocity as the universal speed of light is given. This upper limit only represents the constraint on the relative movement of equivalent inertial systems, so cannot offer any reference for the whole system requiring the addition of relative motions.

Next, to interpret the meaning of the effective time, we consider the following four-dimensional velocities, expressed using the effective time,

$$V_x = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dx}{dt}, \tag{4.31}$$

$$V_y = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dy}{dt}, \tag{4.32}$$

$$V_z = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dz}{dt}, \tag{4.33}$$

$$V_0 = \frac{ic}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dt}{dt} = \frac{ic}{\sqrt{1-\frac{V^2}{c^2}}}. \tag{4.34}$$

These components of velocity have a real meaning. For example, the relativistic velocity $V_x$ can be interpreted as follows. Since the time that has a real meaning in a non-cosmonic reference system is the effective time of interaction $dT = \sqrt{1-\frac{V^2}{c^2}}\,dt$ when the displacement $dx$ occurs, the change in the actual state of motion must be expressed as the ratio of the displacement to the effective time $V_x = \frac{dx}{dT}$. Then the following relation holds.

$$V_x^2 + V_y^2 + V_z^2 - \frac{c^2}{1-\frac{V^2}{c^2}} = \frac{1}{1-\frac{V^2}{c^2}}\left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2 - c^2\right]$$

$$= \frac{1}{1-\frac{V^2}{c^2}}\left[V^2 - c^2\right] = -c^2.$$

Using the above relation, let us consider the components of the so-called four-dimensional momentum as follows.

$$p_x = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dx}{dt}, \quad (4.35)$$

$$p_y = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dy}{dt}, \quad (4.36)$$

$$p_z = \frac{m_0}{\sqrt{1-\frac{V^2}{c^2}}}\frac{dz}{dt}, \quad (4.37)$$

$$p_0 = \frac{im_0 c}{\sqrt{1-\frac{V^2}{c^2}}} = i\frac{E}{c}. \quad (4.38)$$

The sum of squares of the momentum components is

$$p_0^2 + p_x^2 + p_y^2 + p_z^2 = \frac{m_0^2}{1-\frac{V^2}{c^2}}\left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2 - c^2\right]$$

$$= \frac{m_0^2}{1-\frac{V^2}{c^2}}\left[V^2 - c^2\right] = -m_0^2 c^2. \quad (4.39)$$

From this, we obtain

$$p_x^2 + p_y^2 + p_z^2 - \frac{E^2}{c^2} = -m_0^2 c^2 \quad (4.40)$$

and arrive at the same relativistic energy relation as shown in Eq. (4.24). That is,

$$E^2 = c^2 p^2 + m_0^2 c^4. \quad (4.41)$$

However, this is not a new independent result. This is because this result only gives the formal relations of the previously obtained results (4.23) and (4.25). From Eq. (4.40), it follows that the sum of the squares of the four-dimensional momentum components is a relativistic invariant in terms of the effective time of interaction.

However, the four-dimensional momentum is not a vector in the true sense. This is because it does not satisfy the most important axiom of vector whose length must have positive real values. In fact, Eq. (4.39) is not a self-scalar product of a vector giving the length of the vector. Therefore, Eq. (4.39) does not satisfy the relation of the real vector, and only gives a formal relation.

Thus, our theory of relativity gives relativistic results of the same form as what STR gives. Eventually, we have demonstrated that without depending on the idea for the unified space-time, we can construct a unified theory of mechanics that can explain relativistic effects reasonably, based on the concept of the effective time of interaction.

It is remarkable that the effective time of interaction is in accord with the mathematical expression of the proper time in STR. However, the effective time and the proper time are essentially distinguished in the physical sense. The difference is that the proper time is determined by the relationship between any two inertial systems, while the effective time of interaction is determined by the relation between the cosmonic reference system and a non-cosmonic reference system. In the case of the proper time, it is related to any two inertial systems so that each inertial system has a distinct time and thus it is not possible to set a reference of time for many-body system. However, for the effective time of interaction, the reference of time and the relativity of inertial systems have a clear meaning. The time reference consists in the cosmonic system, and the relativity is determined by the relative motion with respect to the cosmonic system.

## 4.5 Relationship of relativistic velocity with effective time of interaction

Let us consider the velocity observed in the cosmonic system and the relative velocity observed in a non-cosmonic system. We believe that relativistic effects are independent of space and dependent only on time. It is shown that Eqs. (4.31)-(4.33) giving relativistic velocities implicitly assume that the spatial scale is independent of the relative velocity of reference frames. In fact, these equations give the ratio of the displacement in the stationary coordinate system to the time in the moving coordinate system, and therefore do not have a physical meaning. For the equations to have physical meaning, the scales of space in the moving and stationary coordinate systems must be the same.

We therefore understand the absolute nature of space in the sense that the scale of space in any reference frame must be equal, and write the relationship between the infinitesimal displacements in the two reference frames as in the nonrelativistic case as follows.

$$d\mathbf{X} = d\mathbf{x} - \mathbf{V}dt. \tag{4.42}$$

This means that the scale of length is the same in both the cosmonic reference frame and non-cosmonic reference frames. Therefore, this relation is independent of the concept of the length contraction.

Let us find the relativistic relation between the velocities observed in the cosmonic reference frame and a non-cosmonic reference frame. We already know the relativistic relation of absolute time with the effective time of interaction

$$dT = \sqrt{1-\frac{V^2}{c^2}}\,dt. \tag{4.43}$$

The effective time of interaction for the whole process is expressed as

$$T = \int_0^t \sqrt{1-\frac{V^2(t')}{c^2}}\,dt'. \tag{4.44}$$

If an inertial system is in a uniform motion relative to the cosmonic reference system, Eq. (4.44) is given as

$$T = \sqrt{1-\frac{V^2}{c^2}}\cdot t.$$

The transformations of space and time can be collected in the vector form as follows.

$$\left.\begin{aligned} d\mathbf{X} &= d\mathbf{x} - \mathbf{V}dt \\ dT &= \sqrt{1-\frac{V^2}{c^2}}\,dt \end{aligned}\right\}. \tag{4.45}$$

where there is no dependency of time on coordinates. To determine the relativistic relation of velocity, dividing the both sides of the expression for coordinates of Eq. (4-45) by the both sides of the expression for time, we get

$$\frac{d\boldsymbol{X}}{dT}=\boldsymbol{v}'=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}\frac{d\boldsymbol{x}-\boldsymbol{V}dt}{dt}=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}(\boldsymbol{v}-\boldsymbol{V}). \tag{4.46}$$

In the end, the relativistic relationship between the velocities observed in the cosmonic reference frame and the non-cosmonic reference frame is determined by

$$\boldsymbol{v}'=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}(\boldsymbol{v}-\boldsymbol{V}). \tag{4.47}$$

From the above expression, it follows that the relative velocity observed in a non-cosmonic reference system is $\left(1-\frac{V^2}{c^2}\right)^{-1/2}$ times larger than the relative velocity in the nonrelativistic case. This is essentially related to the existence of the effective time of interaction as a relativistic effect.

The transformation relation (4.45) becomes the relationship between the space and time in the cosmonic reference frame and the space and time in any non-cosmonic reference frame which moves relative to the cosmonic reference frame, and not the transformation relation of space-times between any two inertial frames. As can be seen, space is absolute and time is relative in the sense of a clock fixed to a non-cosmonic reference frame moving relative to the cosmonic reference frame. Here is a remarkable problem. In STR, it is interpreted that the delay of time and the extension of length in a moving system occur, but in our theory, only the time delay in a moving system due to the effective time of interaction occurs.

Our relativistic transformation of space and time does not give such paradoxes as the twin paradox. Since the time that represents the rate of physical process depends on the state of motion of physical systems relative to the cosmonic system, the relation between the times in the two inertial reference frames cannot be regarded as the relativistic relation between two equivalent inertial frames. The two inertial frames are distinguished from each other by the relative motion to the cosmonic system, in which case the two inertial frames are not equivalent. The reference of the time delay is in the time in the cosmonic reference frame. In this sense, in our theory, the time delay has not relative but absolute meaning. Based on our relativity theory, we can reasonably explain the fact that the fast muon's lifetime gets longer. The relative motion in the cosmonic system shortens the effective time of interaction taking place inside the muon. Thus, the duration of physical processes until the muon itself is annihilated by the interaction in the interior of a cosmon-mediated muon, i.e., the lifetime lengthens. This gives the same result as if it was obtained by analyzing the time delay in STR. However, these two interpretations are essentially different in physical essence. In STR, the time delay is not consistent with the principle of relativity, as we have seen, and cannot be imagined physically. In fact, according to the principle of relativity, all inertial frames are equivalent, so that the rest and motion are relative. Thus, the time delay should be also relative. Therefore, it is impossible to interpret such relativistic physical effects as the time delay in the sense of relativity of STR. However, the effective time of interaction is related to the actual physical effects due to relative motions to the cosmonic system, and therefore does not pose any difficulty in interpretation.

The characteristics of the cosmon-based relativistic transformation can be summarized as follows.

First, this transformation relation is not the transformation between any two inertial systems but the relativistic transformation between the cosmonic reference system and a non-cosmonic reference system including noninertial systems. Therefore, our theory of relativity is a generalized theory and is not limited to inertial systems.

Next, the relativity we mean is the relativity in terms of the relative motion to the cosmonic system, and this relationship is expressed by the effective time of interaction ascribed to the cosmon. The effective time of interaction can be compared with absolute time measured using a clock in the cosmonic system. Time is originally measured using physical phenomena with a certain period. However, the periodicity of the physical phenomena can vary with given physical conditions, e.g., gravity or velocity, and thus if we do not look at this cause and do consider it in a phenomenological way, time looks like flowing differently. In this sense, a concept such as time being created or time being stopped should be considered a confused concept that is physically unjustified. If there is something real that is concerned with time, it is a real physical phenomenon such as the beginning, slowing, accelerating, or stopping of a physical process.

Essentially, our theory is independent of the unified space-time and ascribes the relativity to the interaction due to the relative motion to the cosmonic system. From the physical point of view, nature is formed by cosmons, and the view that there exists the maximum speed of interaction propagation in the cosmonic system is a starting point for building a new theory of relativity. In this theory, the concept of the effective time of interaction giving real meaning plays an essential role, and this concept enables us to obtain in a simple way all the relativistic results

## 4.6 Universal quantum and gravitational field

Our aim is to describe the relativistic effects related to motion and gravity in a unified way based on the cosmon. In the presence of a gravitational field, no matter whatever law of transformation of the time coordinate may be, we cannot find the expression for the interval between events expressed in the form of a sum of squares of the coordinate differentials. Thus, in a noninertial reference system the square of an interval has the general form concerned with non-diagonal terms:

$$ds^2 = g_{jk} x^j x^k,$$

where non-diagonal $g_{jk}$ in general are not zero. In GTR, it is considered that the space-time metric $g_{jk}$ determine all the geometric properties of space-time and are equivalent to a certain field of force. A gravitational field corresponds just to a change in the metric of space-time metric $g_{jk}$. By the way, an actual gravitational field cannot be eliminated by any transformation of coordinates. That is, in the presence of a gravitational field, by any coordinate transformation, space-time metric $g_{jk}$ cannot be brought to their Galilean values over whole space. However, by an appropriate choice of coordinates, it is possible to bring the space-time metric $g_{jk}$ to the Galilean form at any individual point of the non-Galilean space-time. This fact shows that the space-time metric is not sufficient to represent gravitational fields exactly and is not perfectly equivalent to gravity. On the other hand, the introduction of the concept of space-time interval of STR to GTR is an assumption to require a rigorous proof. Furthermore, the concept of space-time interval, as shown already, is problematic even in STR. Therefore, we aim to formulate an alternative theory to GTR.

In order to reveal relativistic effects due to gravity with the help of a single-mechanism model, let us start from the cosmon density around a gravitational body. Matter is formed by the condensation of the combining cosmons, so that the cosmon density around gravitational bodies is accordingly low. As the distance from a gravitational body increases, the cosmon density gradually increases and approaches that in field-free space. The cosmon density around a gravitational body is deviated from the density in field-free space, and therefore the tension of the cosmonic system occurs that acts to retrieve the density in field-free space. This tension and gravity are balanced.

Let us consider a spherical surface with a radius $r$ centered on a gravitational body. The force exerted by a gravitational body on a cosmon on this spherical surface is expressed by the cosmon density as

$$f = -c_f \operatorname{grad} \rho. \tag{4.48}$$

In the case of spherical symmetrical field of gravity, we have

$$f = -c_f \frac{d\rho}{dr}.$$

On the other hand, the cosmons around a gravitational body are coupled together to exhibit the similar tension as an elastic object, so that this tension is opposed to the force exerted by a gravitational body. The nearer the cosmons are attracted to a gravitational body, the greater the tension, so that in some limit the tension and gravity are counterbalanced. The tension of the spherical surface is proportional to the force exerted by a gravitational body on a spherical surface of cosmons. That is, $\sigma = \alpha f$ . Then the force by tension acting on the whole spherical surface is

$$F = -\alpha c_f \frac{d\rho}{dr} \cdot 4\pi r^2. \tag{4.49}$$

At any distance, this tension force must be equal. This is because if the tension force is not the same, all spherical surfaces are attracted to the gravitational body and, as a result, are absorbed into the body. Thus, we obtain the following relation.

$$4\pi\alpha c_f \frac{d\rho}{dr} \cdot r^2 = const. \tag{4.50}$$

From this follows the density relation:

$$\frac{d\rho}{dr} = \frac{A}{r^2}. \tag{4.51}$$

Integrating both sides yields the following relation:

$$\int_\infty^r \frac{d\rho}{dr} dr = \int_\infty^r \frac{A}{r^2} dr. \tag{4.52}$$

From this, we obtain as the distance dependence of the cosmon density

$$\rho(r) = \rho_0 - \frac{A}{r}. \tag{4.53}$$

where $\rho(r)$ is the cosmon density at a distance $r$ from a gravitational body, and $\rho_0$ is the cosmon density at an infinite distances far from a gravitational body.

It should be noted that the cosmon density inside a body also changes with the distance dependence of the above density by the action of gravity. Thus, the distance-density law of cosmons inside a body in a gravitational field can be written as

$$\rho(r) = \rho_0 \left(1 - \frac{B}{r}\right), \tag{4.54}$$

where $\rho(r)$ is the cosmon density inside a body at a distance $r$ from the gravitational body, and $\rho_0$ is the cosmon density inside the body in field-free space. From the above expression, we can see that as $r$ tends to an infinity, $\rho(r)$ approaches the cosmon density $\rho_0$ in field-free space. Thus, we have obtained a general form of the expression for the cosmon density in a body.

To obtain a more detailed expression of Eq. (4.54), we shall compare it with the law of universal gravitation. In a gravitational field, one cosmon present inside a body is exerted by the following force proportional to the negative value of the gradient of cosmon density.

$$\mathbf{f} = -c_f \operatorname{grad} \rho. \tag{4.55}$$

In the direction of the force, the above expression is given as

$$f = -c_f \frac{d\rho}{dr}.$$

The force exerted on a particle can be determined by multiplying by the number of cosmons that constitute it as

$$\boldsymbol{F} = N_0 \boldsymbol{f}, \tag{4.56}$$

where $N_0$ is the number of cosmons constituting the matter particle. Accordingly, the tension acting on a body is represented as

$$F_t = -c_f N_0 \frac{d\rho}{dr} = -c_f N_0 \frac{d}{dr}\left[\rho_0\left(1-\frac{B}{r}\right)\right] = -c_f \rho_0 N_0 \frac{d}{dr}\left(1-\frac{B}{r}\right). \tag{4.57}$$

This force must be equal to the gravitational force

$$F_g = -\frac{GmM}{r^2}. \tag{4.58}$$

Thus, we have the following equality

$$c_f \rho_0 N_0 \frac{d}{dr}\left(1-\frac{B}{r}\right) = \frac{GmM}{r^2}.$$

Taking into account the following relation:

$$m = \frac{c_f \rho_0 N_0}{c^2},$$

we get

$$\frac{d}{dr}\left(1-\frac{B}{r}\right) = \frac{GM}{c^2 r^2}.$$

From this, we find

$$B = \frac{GM}{c^2}. \tag{4.59}$$

Thus, we obtain the expression for the cosmon density around a gravitational body

$$\rho(r) = \rho_0\left(1-\frac{GM}{c^2 r}\right). \tag{4.60}$$

It is supposed that gravitational bodies universally adjust the cosmon density both in the ambient space and in the interior of other bodies, according to Eq. (4.60). In fact, since the world of matter is the world of cosmons, there is no reason to distinguish between the inside of bodies and the outside of bodies.

By Eqs. (4.55), (4.56) and (4.60), the following relation holds:

$$\boldsymbol{F} = N_0 \boldsymbol{f} = -c_f N_0 \mathrm{grad}\rho = -\frac{GmM}{r^2}. \tag{4.61}$$

Meanwhile, the density-dependent probabilities of interaction in gravitational fields are defined as

$$\mathrm{P}_\rho(\rho) = \frac{\rho(r)}{\rho_0}. \tag{4.62}$$

By Eq. (4.60), we obtain the following detailed expression for the density-dependent probability.

$$\mathrm{P}_\rho(\rho(r)) = \frac{\rho_0\left(1-\frac{GM}{c^2 r}\right)}{\rho_0} = 1-\frac{GM}{c^2 r}. \tag{4.63}$$

Then the density-dependent effective time in gravitational fields is determined by

$$\Delta t(\rho) = \mathrm{P}_\rho(\rho)\Delta t(\rho_0) = \left(1-\frac{GM}{c^2 r}\right)\Delta t(\rho_0) = \left(1-\frac{U(r)}{c^2}\right)\Delta t(\rho_0), \tag{4.64}$$

where $U(r) = \frac{GM}{r}$ formally represents the magnitude of the potential energy in a gravitational field in case the velocity dependence of the potential energy is ignored. Consequently, the formula is concluded as

$$\Delta t(\rho)=\left(1-\frac{U(r)}{c^2}\right)\Delta t(\rho_0), \tag{4.65}$$

where $U(r)$ is regarded as the magnitude of the potential energy in gravitational fields when neglecting the relativistic effects related to velocity. Thus, it follows that the stronger the gravitational field, the shorter the effective time, i.e., the larger the time delay. This is in accordance with the result of GTR.

Let us consider the periodic process in gravitational fields. Since the effective time of interaction and period are inversely proportional, i.e., the following relationship

$$T(\rho)\Delta t(\rho)=const. \tag{4.66}$$

holds, we have

$$T(\rho)\Delta t(\rho)=T(\rho_0)\Delta t(\rho_0). \tag{4.67}$$

Thus, we obtain the relation of the period with the cosmon density as

$$T(\rho)=T(\rho_0)\frac{\Delta t(\rho_0)}{\Delta t(\rho)}=\frac{T(\rho_0)}{\left(1-\frac{U(r)}{c^2}\right)}. \tag{4.68}$$

Expressing the angular frequency of a light wave in the gravitational field using the above relation gives the relation:

$$\omega(\rho)=\frac{2\pi}{T(\rho)}=\frac{2\pi}{T(\rho_0)}\left(1-\frac{U(r)}{c^2}\right). \tag{4.69}$$

That is,

$$\omega(\rho)=\omega(\rho_0)\left(1-\frac{U(r)}{c^2}\right). \tag{4.70}$$

This means that the frequency of light emitted by an atom in a gravitational field is less than that of light emitted by the atom in field-free space. Thus, the redshift of the spectrum in the gravitational field has been explained.

Next, let us consider the gravity dependence of the speed of light. Light is an electromagnetic wave propagating in a cosmonic system, i.e., in a cosmon-based system. Light propagating in the gravitational field is supposed to satisfy the following relation:

$$c(\rho)=\frac{\omega(\rho)}{k(\rho)}, \tag{4.71}$$

where $k(\rho)$ is the wavenumber in case the cosmon density is $\rho$. Meanwhile, the velocity of light in field-free space is written as

$$c=c(\rho_0)=\frac{\omega(\rho_0)}{k(\rho_0)}. \tag{4.72}$$

Assuming $k(\rho_0)\approx k(\rho)$ and combining Eqs. (4.71) and (4.72), we obtain

$$c(\rho)=c\frac{\omega(\rho)}{\omega(\rho_0)}.$$

Taking Eq. (4.70) into consideration, we obtain

$$c(\rho)=c\left(1-\frac{U(r)}{c^2}\right). \tag{4.73}$$

Thus, it can be seen that the speed of light in the gravitational field is lower than that in field-free space. Based on this argument, we can explain the bending of the path of light in the gravitational field near the sun. Since the speed of light depends on the cosmon density at each point of the gravitational field, the propagation of light in the gravitational field is as if light propagates in a medium where the refractive indexes at each point are different. At the shorter distance from the sun, the lower the speed of light, so that light always must bend toward the sun. Thus, we have explained the phenomenon of light bending in a gravitational field close to the sun.

In the case of a body moving in a gravitational field, the number of cosmons involved in the body increases. Then, the velocity dependence of the cosmon density can be naturally expressed as

$$\rho(r,V)=\frac{\rho_0}{\sqrt{1-\frac{V^2}{c^2}}}\left(1-\frac{GM}{c^2 r}\right)=\rho_0\gamma\left(1-\frac{GM}{c^2 r}\right)=\rho_0\gamma\left(1-\frac{B}{r}\right), \tag{4.74}$$

where we have used the notations $\gamma=\frac{1}{\sqrt{1-\frac{V^2}{c^2}}}$, $B=\frac{GM}{c^2}$.

Using Eq. (4.74), the tension in the gravitational field is calculated as

$$\begin{aligned} F_t &= -c_f N_0 \frac{d\rho}{dr} = -c_f N_0 \rho_0 \frac{d}{dr}\left[\gamma\left(1-\frac{B}{r}\right)\right] == -m_0 c^2 \frac{d}{dr}\left[\gamma\left(1-\frac{B}{r}\right)\right] \\ &= -m_0 c^2 \frac{d}{dt}\left[\gamma\left(1-\frac{B}{r}\right)\right]\frac{dt}{dr} = -m_0 c^2 \frac{d}{dt}\left[\gamma\left(1-\frac{B}{r}\right)\right]\frac{1}{V} = \\ &= -m_0 c^2\left(\frac{BV}{r^2}\gamma+\frac{V\frac{dV}{dt}}{c^2}\left(1-\frac{B}{r}\right)\gamma^3\right)\frac{1}{V} = -m_0 c^2\left(\frac{B}{r^2}\gamma+\frac{a}{c^2}\left(1-\frac{B}{r}\right)\gamma^3\right), \end{aligned} \tag{4.75}$$

where $a$ is the acceleration of a body in the gravitational field. Taking into consideration that this tension should be counterbalanced with the universal gravity, we get

$$-m_0 c^2\left(\frac{B}{r^2}\gamma+\frac{a}{c^2}\left(1-\frac{B}{r}\right)\gamma^3\right)=-\frac{GmM}{r^2}. \tag{4.76}$$

With the help of this expression, the relativistic mass is represented as

$$m=\frac{m_0 c^2}{GM}\left(B\gamma+\frac{a}{c^2}\left(r^2-rB\right)\gamma^3\right). \tag{4.77}$$

As can see in Eq. (4.77), the relativistic mass depends on the position, velocity and acceleration in the gravitational field altogether. Then the relativistic total energy of a moving body in a gravitational field is expressed as

$$E=mc^2=\frac{m_0 c^4}{GM}\left(B\gamma+\frac{a}{c^2}\left(r^2-rB\right)\gamma^3\right). \tag{4.78}$$

Based on the cosmon, the zero gravity is also reasonably explained. Gravity is the force exerted on a body by the gradient of the cosmon density around a gravitational body. This force causes the acceleration of bodies. On the other hand, the acceleration of a body leads to an increase in the cosmon density in the direction of its motion. Due to this density gradient due to the increase in density, a force proportional to the acceleration acts on the cosmons of matter. Eventually, the two forces in the accelerating body are counterbalanced, resulting in the zero gravity.

Based on the cosmon, the principle of equivalence is also briefly explained. The gradient of the cosmon density inside the accelerating body is created by the compaction of cosmons due to the accelerated motion relative to the cosmonic system. Therefore, inside of an accelerating system, a force proportional to the density gradient is exerted, which is the inertial force and is opposite to the force acting on the body. Meanwhile, when a body is formed by the condensation of cosmons, in the space around the gravitational body is produced a gradient of the cosmon density, which exhibits the force of gravity. Thus, both inertial and gravitational forces associated with accelerated motions are due to the gradient of the cosmon density. The principle of equivalence is sufficiently interpreted based on the fact that both the inertial force in a system accelerating relative to an inertial system and gravitational force are due to the cosmon density.

However, since the gradient of the cosmon density is created with quite different causes, in reality the inertial force field and gravitational fields cannot be considered equivalent. We must analyze the curvature of space that we discuss in GTR. If space is an absolutely empty space, the concept of the curvature of space is meaningless. This is because the curvature of space means the property of no entity. According to our theory, the curvature of space-time is ultimately related to the inhomogeneity of the cosmon density. The curvature of space is reasonably explained by the gradient of cosmon density as a real physical entity. Regarding this curvature, it is not necessary to discuss time.

## 5. Explanation of experiments on speed of light based on preferred reference frame

Experiments on the speed of light require an essential interpretation of the propagation of light. The analysis is considered to have to give the answers to the following questions.

The first question is whether there exists a medium of light propagation, i.e. the ether. Lorentz and Poincaré asserted the possible existence of the ether that is a medium of light propagation. Maxwell also claimed that the Maxwell system of equations holds only in the ether-based reference frame. If there is the ether, the speed of propagation of light is meaningful only in a preferred inertial frame where the ether is at rest. The speed of light is different for any inertial system moving relative to the ether. In other words, the speed of light is independent of the motion of a light source, but dependent on motions of an observer relative to the ether. Fig. 1 shows the propagation of light for two inertial systems and an ether system.

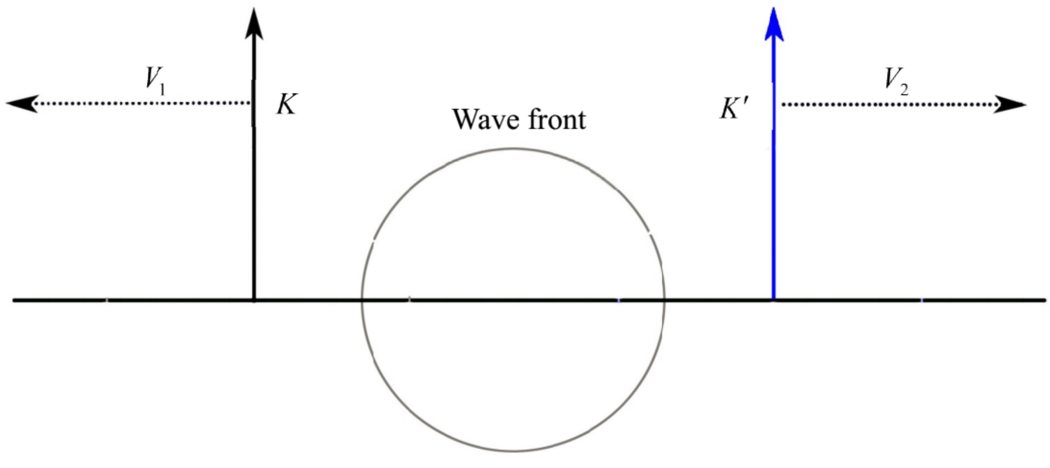


Figure 1: A light wave seen in two inertial frames $K$ and $K'$ moving relative to the ether: According to Lorentz's image, light wave radiated when the origins of the two inertial frames coincide propagates with respect to the ether. Thus, the center of a spherical wave is fixed at the ether system and the origins of the two moving inertial systems move at a constant velocity relative to the ether system.

On the contrary, Einstein's principle of the constancy of the speed of light concludes that the ether, which is assumed to be the medium of light propagation, do not exist.

As the second question, does the speed of light depend on the speed of a light source or an observer? It is the view of Ritz that the speed of light depends on the speed of the light source. If for the speed of light source, the speed of light obeys the Galilean law of velocity addition, the speed of light is $c$ only in the inertial frame where the light source is at rest, and for any inertial frame the speed of light is different. This situation is shown in Fig. 2.

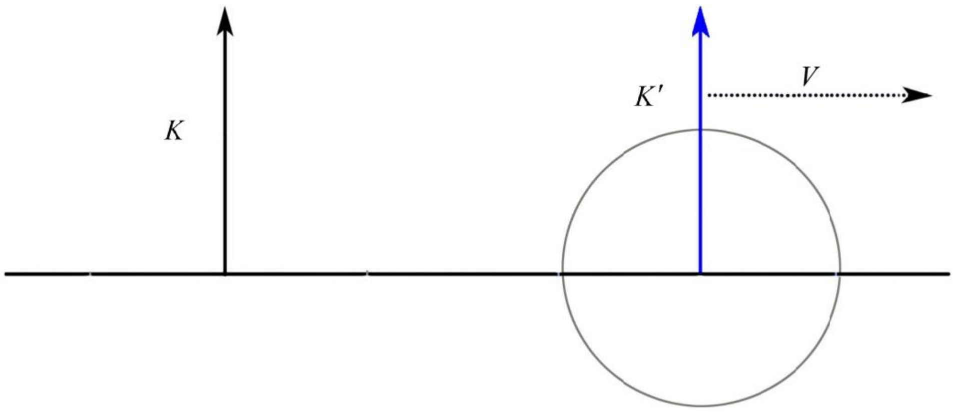


Figure 2: A light source secured to an inertial frame $K'$ moving relative to a stationary inertial frame $K$: According to Ritz's image, the speed of light in the moving inertial frame $K'$ is $c$ and the speed of light in the stationary inertial frame $K$ is $c+V$. According to Ritz, the speed of light in a stationary inertial frame depends on the velocity of light sources.

Contrary to this, Einstein's theory of relativity states that the speed of light does not related to the relative motion of light source and observer.

As the third question, does the principle of the constancy of the speed of light hold? According to the ether theory, the speed of light is a universal constant in the ether system. For other inertial systems with motion relative to the ether system, the light velocity is considered to satisfy the Galilean law of velocity addition. On the contrary, it is Einstein's principle of the constancy of the speed of light that for any inertial system, the velocity of light is a universal constant. This means that the speed of light is independent of the speed of light source or observer. Fig. 3 shows the propagation situation of light based on the principle of the constancy of speed of light.

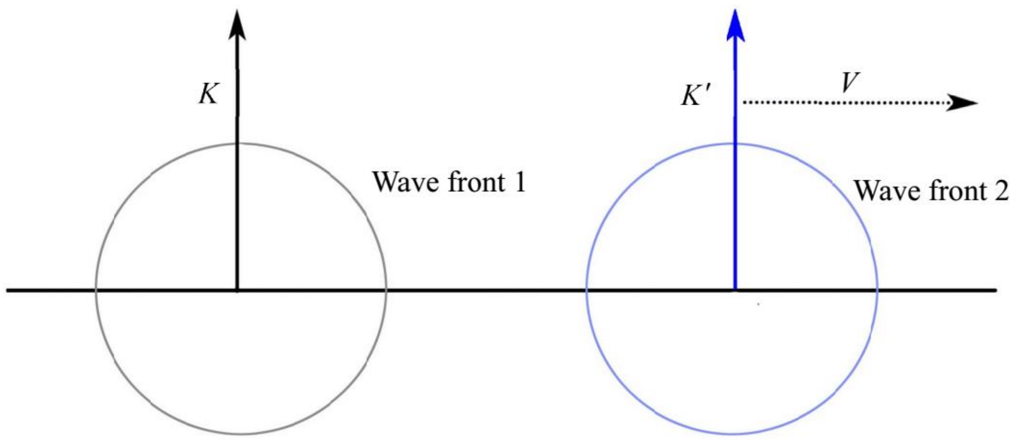


Figure 3: The relation of a light waves radiated when the origin of a stationary inertial frame $K$ coincides with that of the moving inertial frame $K'$: Two observers are located at the origins of two inertial frames, respectively. According to Einstein's image, the light wave becomes a spherical wave centered on each of the two observers of the two inertial frames. Here the wave front 1 and the wave front 2 indicate the same wave front. Thus, it turns out that for a light wave, the two separate centers of the spherical wave arise and then move with a relative velocity.

Thus, according to the principle of the constancy of the speed of light, a given light wave must show the same shape to the both observers stationary in two inertial frames with relative motion. This is, therefore, an illogical result suggestive of a single light wave with two centers. The principle of the constancy of the speed of light brought about a strange concept that we cannot accept by our usual intuition and judgment.

Several images of the light velocity contradictory to the others include all possible cases that can explain the nature of the light velocity. On the basis of one of them, we have to build a theory of relativity, and as a choice, STR was built by taking the principle of the constancy of the speed of light as the truth. By adopting the principle of the constancy of the speed of light, the idea for the unification of space and time was established. This theory was acknowledged to be powerful in explaining experiments related to light velocity then, but is not perfect in revealing all details of the experiments at this point of time. It cannot be neglected that this principle has brought physical paradoxes that cannot be resolved.

In relation to the second question, we cannot explain a series of experiments, including the measurement of the speed of light coming from a double star, assuming that the speed of light depends on the velocity of light sources. Of course, Ritz's theory succeeded in describing the covariance of the electrodynamic equation by introducing the velocity of the light source, but cannot be regarded to be complete because all experiments are not explained by the theory.

We shall consider the question of whether experiments on the speed of light can be explained based on the answer to the first question, i.e., the assumption that the ether exists. If based on this assumption, the experiments are totally explained, this would be a sure evidence for the existence of the ether, although there is no direct experiment for ascertaining the existence of the ether. In fact, the existence of electromagnetic and gravitational fields is assumed in an indirect way based on the observation of interactions. Therefore, it is reasonable to assume the ether based on experiments on the speed of light.

The Sagnac effect is an important experimental evidence to lead to questioning the credibility of the postulates of STR [5,8]. Recent astronomical studies have shown that there is superluminal radiation in the nuclei of galaxies or in active clouds emitted from quasar. It was reported that the velocity of light by the M87 radiation is not less than even 5 to 6 times the speed of light and does not depend on the redshift, the distance to which is presumed to be 50 million light years. Although the experiments confirming that the speed of light in the inertial frame is constant have been reported, this principle is still questionable, as there are other obvious experiments that are contradictory to this. To be a perfect theory of relativity, the theory must explain these experimental results completely.

We may consider theoretically the question of whether the individual postulates of STR are valid or whether the two postulates are compatible. If this review provides negative results, STR is not justified. Is the speed of light constant and are there evidences that space and time can be considered to be unified? If the principle of the constancy of the speed of light is verified, the speed of light must be independent of the velocity of a light source or that of an observer. If so, the speed of light may be concluded to be attributed to the nature of space-time. But in this case, the unified nature of space-time should not yield any paradox that is incompatible with logic.

Let us consider the following problems. There is a question of whether the principle of the constancy of the speed of light means that the relative velocity for light cannot be thought of. The constancy of the speed of light is experimentally verified in the case of a moving light source and an observer stationary in the Earth-based reference system. However, it is necessary to consider the question of whether we cannot think of the relative velocity of a stationary light source and a moving observer. If the velocity of light relative to an observer could be greater than the speed of light $c$, it is necessary to review the principle of the constancy of the speed of light.

For example, let us consider the relative velocity of two bodies in one inertial frame. Applying the Galilean rule of velocity addition in case the velocities of the bodies in the inertial frame are $\boldsymbol{V}_1$ and $\boldsymbol{V}_2$, respectively, the relative velocity of them is

$$\boldsymbol{V}_{12} = \boldsymbol{V}_1 - \boldsymbol{V}_2. \tag{5.1}$$

In view of the relativistic transformation of velocity, such rule of velocity addition in an inertial frame should hold true even in the relativistic case. That is, if we consider a photon as an object, we can think of the following relative velocity

$$\boldsymbol{V}_{po} = \boldsymbol{c} - \boldsymbol{V}_{\text{o}}, \tag{5.2}$$

where the subscripts $p$ and $o$ represent a photon and a body, respectively. From the relation (5.2), one can think of the relative velocity between light and bodies in an inertial system, and apply the Galilean rule of velocity addition. In fact, it is clear that in a reference system, when light is incident straightforward towards a moving body and when it propagates toward a stationary body, the relative velocity of the light and body in the two cases cannot be considered equal. There is nothing strange about the fact that this relative velocity may be greater or less than the speed of light. However, if we transform the relative velocity of light to a body in an inertial frame into the relative velocity of light and the body in another inertial frame by the relativistic law of velocity transformation, this transformed relative velocity must always be the universal speed of light $c$. The theory of relativity can explain this result of transformation using the difference between the elapsed times in the two inertial frames, but the explanation is not logical. This is because motion and rest are relative and not absolute.

To say that relative velocity is inconceivable for light, there must be no physical phenomenon related to relative velocity. However, as a typical example, there is the Doppler effect that depends on the relative velocity of light and observer. It is clear that the Doppler effect is responsible for the existence of its relative velocity [39]. The theory of relativity cannot explain this in any way. The Doppler effect depends on the relative velocity of light source and observer. Essentially, it depends on the relative velocity of photon and observer. This means that the relative velocity of light and observer is meaningful and thus the speed of light depends on the reference frame.

Experiments on the speed of light can be explained based on the ether theory. The existence of the ether cannot be ignored because recent experiments and many studies on the reproduction and reanalysis of the Michelson-Morley experiment and the drift of the ether are sure evidences that confirm the absolute motion, the existence of a preferred inertial system, and the anisotropy of the speed of light [25,29].

As an example, let us consider the validity of several hypotheses about the propagation of light, by dealing with the Sagnac effect. When light travels in the direction of rotation, the relative speed of light and the circle is $c - V = c - \Omega R$, and when it travels in the opposite direction, the relative velocity of them is $c + V = c + \Omega R$. Here $\Omega$ is the angular velocity of the disc. The time it takes for light to return to the starting point on the circumference in the direction of rotation of the circumference is

$$\tau_1 = \frac{2\pi R}{c - V} \tag{5.3}$$

and the time taken to return to the starting point on the circumference in the opposite direction is

$$\tau_2 = \frac{2\pi R}{c + V}. \tag{5.4}$$

Thus, the time difference is determined by

$$\Delta\tau = \tau_1 - \tau_2 = 2\pi R\left(\frac{1}{c - V} - \frac{1}{c + V}\right) = \frac{4\pi RV}{c^2}\frac{1}{1 - \frac{V^2}{c^2}} \approx \frac{4SQ}{c^2}, \tag{5.5}$$

where $S$ is the area of the disk and $Q$ is the angular velocity.

Sagnac confirmed that the shift of the fringe pattern was in very good agreement with this formula. This shows that the speed of light in a rotating system depends on the relative velocity of observer and light source. This phenomenon gives a convincing answer to the question of which picture rationally explains the propagation of light; the pictures involve Einstein's idea of the principle of the constancy of the speed of light, Ritz's picture of the speed of light dependent on the velocity of light sources, and Lorentz's picture of the ether as a medium of light propagation. Fig. 4 shows the relationship between an observer and two light sources; the two light waves radiated by the light sources propagate in the opposite directions, respectively. Suppose the circle of the disc is straitened. The two light waves propagate in the opposite directions to be interfered. Then an interferometer that plays the role of an observer clearly confirms the shift of the fringe pattern. Obviously, Einstein's principle of the constancy of the speed of light does not explain this phenomenon. This is because, by the principle of the constancy of the speed of light, the speed of light in the two directions must be equal, regardless of the velocities of the observer and light source, and therefore the observer cannot find the time difference of light propagation.

Same goes for The Ritz's picture of light propagation. As the disc rotates, the relative velocity of the observer and light is the universal constant $c$, since both the light source and the observer rotate at the same speed. Thus, for the observer there is no time difference, and thus no shift of interference pattern is observed.

The last possibility for explaining this phenomenon is offered by Lorentz's ether theory. Let us explain the formula (5.5) based on the ether theory. The ether is considered not to be attracted to the disk. Two separated light waves can be considered as two light sources, and an interferometer as an observer. In this case, they move uniformly with respect to the ether. Fig. 4 shows the relationship between two light sources, an observers, and ether, when the circle of the disc is imagined to be straightened. The relative velocities of the interferometer and the two beams satisfy the Galilean rule of velocity addition, since the speed of light relative to the ether system is constant. Thus, the light waves coming from the two sources to the observer has different relative velocities, and in the interferometer a time difference according to formula (5.4) occurs and the subsequent shift of the fringe pattern takes place, depending on the difference in the relative velocities of the two light beams. The Sagnac effect shows that the speed of light varies with the relative velocity of light source and observer.

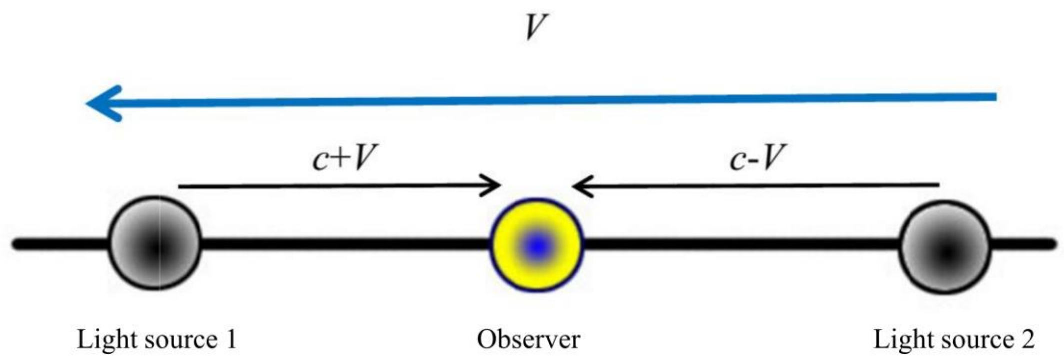


Figure 4: The relationship between two light sources, observer, and ether when a disc rotates. If the ether exists, the velocities of the two light waves visible to the observer are $c+V$ and $c-V$, respectively.

This phenomenon is not explained based on the Doppler effect. This is because the observer and the light sources move with the same speed, the relative velocity is constant $c$, and therefore there is no change in the frequency and wavelength. Thus, the Sagnac effect is an optical phenomenon that is only explained by supposing the existence of the ether, and as a result is contradictory to the principle of the constancy of the speed of light.

The experimental results indicative of the constant velocity of light coming from double stars can be explained on the basis of the ether theory. The two beams of light propagate in an ether medium, so that the beams of light from two stars have the same velocity regardless of the speed of the light sources.

The Michelson-Morley experiment is also explained in the same way based on the ether. Taking into consideration that the ether medium is not at rest but rather drifted, but mainly is accompanied by the Earth, it is natural that no significant change of the fringe pattern is observed in the Michelson-Morley experiment. The fact that light emitted from a particle with a very fast velocity, as done in CERN shows the universal speed of light *c* also can be explained based on the fact that this experiment was also carried out in the laboratory accompanied with an ether medium. For an observer stationary in an ether system, the speed of light is constant. This is obvious when we consider acoustic waves. However, for an observer who moves relative to the ether, the speed of light should be considered to change. Light always propagates in an ether medium at the speed of *c*, and the observer moves with a constant relative velocity relative to the ether, so that the relative velocity of light and the observer varies with the observer's relative velocity relative to an ether medium.

The Doppler effect is a typical phenomenon that shows the presence of the relative velocity of light and observers. If there is no relative velocity between light and observer according to the principle of the constancy of the speed of light, then the observer with a relative velocity to a light source still has to feel the speed of light as the universal constant. Therefore, the Doppler effect should therefore appear to be a phenomenon independent of the relative velocity of light source and observer, and only to be dependent on the time delay associated with the motion. However, since rest and motion is relative, the time delay cannot be explained objectively and reasonably.

On the other hand, if light is considered to propagate through an ether medium in the same manner as the sound wave, it can be reasonably explain the Doppler effect when the light source and observer are moving relative to each other. In the case of the motion of a light source, the wavelength of light propagating through an ether medium is shortened in the direction of motion, and consequently, the frequency is increased. So the Doppler effect appears. On the contrary, when a light source is stationary and an observer moves relative to the ether, there is no change in wavelength in the ether system, but the change in the relative velocity of the light and the observer causes a change in the frequency of the light that the observer experiences, resulting in a Doppler effect.

The Doppler effect clearly indicates that there is a medium of the light propagation. Without a medium of light propagation, the frequency of incident light cannot change with the relative velocity of light source and observer because of the principle of the constancy of the speed of light. Therefore, we cannot fully explain the Doppler effect by relying on the principle of the constancy of the speed of light. The possibility of frequencies of light being raised involves two cases: one with the existence of a medium of light propagation and the other with the light emitted from a moving light source satisfying the Galilean rule of velocity addition. However, many experiments have shown that the speed of light does not depend on the speed of light sources and does not satisfy the Galilean rule of velocity addition for light sources. Thus, the Doppler effect corresponds to the first case. That is, the existence of a medium of light propagation leads to a change in the frequency due to motions of a light source or an observer.

To explain based on the ether the results of experiments that found light velocities greater than the universal constant *c*, it is necessary to consider the ether to have local and dynamic properties and not to have stationary property in the universe. This view is well validated by the results of recent experiments on the ether drift.

## 6. Relativistic electrodynamics based on preferred reference frame

If the preferred reference system exists, there is no reason that the equations of electrodynamics must have covariance. If the ether is not fixed over the cosmic scale and has local properties, the Maxwell equations are the one that is valid only in that local reference system [10]. The equations of electrodynamics must be considered to hold in a preferred reference system referred to as the cosmonic system, and for all inertial systems the equations of electrodynamics are not covariant [79]. Let us consider how the complete system of equations of electrodynamics should be represented. In order for the equations of electrodynamics to be complete in the sense of relativity, it is necessary that the Maxwell systems of equations

$$\left.\begin{aligned} \operatorname{div}\boldsymbol{E} &= \frac{\rho}{\varepsilon_0} \\ \operatorname{rot}\boldsymbol{E} &= -\frac{\partial \boldsymbol{B}}{\partial t} \\ \operatorname{rot}\boldsymbol{H} &= \boldsymbol{j} + \frac{\partial \boldsymbol{D}}{\partial t} \\ \operatorname{div}\boldsymbol{B} &= 0 \end{aligned}\right\}$$

have relativistic covariance. However, if the cosmon exists, as Maxwell viewed, the electrodynamic equations in an inertial system must be expressed in consideration of motions relative to the cosmonic system. To construct covariant electrodynamics, we must adopt the Lorentz transformation, which, as seen above, is inconsistent. If there is a constant speed of light, it is possible only in the cosmonic system. This is as if the velocity of propagation of an acoustic wave were constant in the reference system comoving with the medium.

By introducing the concept of the cosmonic system, electrodynamics remains the theory based on an absolute reference system, and only the relativistic concept of the effective time of interaction is added. Time is determined in terms of the physical phenomena that occur with a periodic change. Therefore, if an absolute reference system exists, relative motions of reference frames to it give rise to the time delay as a relativistic effect.

Let us consider how the relations of electrodynamics for a non-cosmonic system are expressed in terms of the effective time of interaction. First, we shall the relativistic relation of the current density in a non-cosmonic system. Using the four-dimensional velocity, the relativistic four-dimensional current density is calculated as

$$\begin{aligned} j_0^2 + j_x^2 + j_y^2 + j_z^2 &= \frac{\rho^2}{1-\frac{V^2}{c^2}}\left[\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2 - c^2\right] \\ &= \frac{\rho^2}{1-\frac{V^2}{c^2}}\left[V^2 - c^2\right] = -\rho^2 c^2. \end{aligned}$$

Thus, we can see that the four-dimensional current density is a relativistic invariant. The components of the four-dimensional current density in non-cosmonic systems must be considered to have the following relationship:

$$j_1' = \frac{\rho_0 V_x}{\sqrt{1-\frac{V^2}{c^2}}},\quad j_2' = \frac{\rho_0 V_y}{\sqrt{1-\frac{V^2}{c^2}}},\quad j_3' = \frac{\rho_0 V_z}{\sqrt{1-\frac{V^2}{c^2}}},\quad j_4' = \frac{ic\rho}{\sqrt{1-\frac{V^2}{c^2}}}.$$

Next, consider the relativistic relation for the continuity equation. The continuity equation is expressed in four dimensions as

$$\operatorname{div}\boldsymbol{j} + \frac{\partial \rho}{\partial t} = 0, \tag{6.1}$$

$$\frac{\partial j_x}{\partial x} + \frac{\partial j_y}{\partial y} + \frac{\partial j_z}{\partial z} + \frac{\partial \rho}{\partial t} = 0, \tag{6.2}$$

$$\frac{\partial j_1}{\partial x_1}+\frac{\partial j_2}{\partial x_2}+\frac{\partial j_3}{\partial x_3}+\frac{\partial j_4}{\partial x_4}=\sum_{\mu=1}^{4}\frac{\partial j_\mu}{\partial x_\mu}=0, \tag{6.3}$$

where $x_4=ict,\ \ j_4=ic\rho.$ By the transformation relations

$$\left.\begin{aligned} X&=x-V_x t\\ Y&=y-V_y t\\ Z&=z-V_z t\\ T&=\sqrt{1-\frac{V^2}{c^2}}\,t \end{aligned}\right\},$$

we have

$$\begin{aligned}
\frac{\partial}{\partial x}&=\frac{\partial}{\partial X}\frac{\partial X}{\partial x}+\frac{\partial}{\partial Y}\frac{\partial Y}{\partial x}+\frac{\partial}{\partial Z}\frac{\partial Z}{\partial x}+\frac{\partial}{\partial T}\frac{\partial T}{\partial x}=\frac{\partial}{\partial X},\\
\frac{\partial}{\partial y}&==\frac{\partial}{\partial X}\frac{\partial X}{\partial y}+\frac{\partial}{\partial Y}\frac{\partial Y}{\partial y}+\frac{\partial}{\partial Z}\frac{\partial Z}{\partial y}+\frac{\partial}{\partial T}\frac{\partial T}{\partial y}=\frac{\partial}{\partial Y},\\
\frac{\partial}{\partial z}&==\frac{\partial}{\partial X}\frac{\partial X}{\partial z}+\frac{\partial}{\partial Y}\frac{\partial Y}{\partial z}+\frac{\partial}{\partial Z}\frac{\partial Z}{\partial z}+\frac{\partial}{\partial T}\frac{\partial T}{\partial z}=\frac{\partial}{\partial Z},
\end{aligned}$$

$$\frac{\partial}{\partial t}=\frac{\partial}{\partial X}\frac{\partial X}{\partial t}+\frac{\partial}{\partial Y}\frac{\partial Y}{\partial t}+\frac{\partial}{\partial Z}\frac{\partial Z}{\partial t}+\frac{\partial}{\partial T}\frac{\partial T}{\partial t}=-V_x\frac{\partial}{\partial X}-V_y\frac{\partial}{\partial Y}-V_z\frac{\partial}{\partial Z}+\sqrt{1-\frac{V^2}{c^2}}\frac{\partial}{\partial T}.$$

Thus, we obtain the following relations for a non-cosmonic system:

$$\begin{aligned}
\frac{\partial j_x}{\partial x}&=\frac{\partial j_x\big(X(x,t)\big)}{\partial X}\frac{\partial X}{\partial x}+\frac{\partial j_x\big(X(x,t)\big)}{\partial T}\frac{\partial T}{\partial x}=\frac{\partial j'_X}{\partial X},\\
\frac{\partial j_y}{\partial y}&=\frac{\partial j'_Y}{\partial Y},\\
\frac{\partial j_z}{\partial z}&=\frac{\partial j'_Z}{\partial Z},\\
\frac{\partial \rho}{\partial t}&=\frac{\partial \rho'}{\partial X}\frac{\partial X}{\partial t}+\frac{\partial \rho'}{\partial Y}\frac{\partial Y}{\partial t}+\frac{\partial \rho'}{\partial Z}\frac{\partial Z}{\partial t}+\frac{\partial \rho'}{\partial T}\frac{\partial T}{\partial t}\\
&=\left[\frac{\partial \rho'}{\partial X}\left(-V_x\right)+\frac{\partial \rho'}{\partial Y}\left(-V_y\right)+\frac{\partial \rho'}{\partial Z}\left(-V_z\right)\right]+\sqrt{1-\frac{V^2}{c^2}}\frac{\partial \rho'}{\partial T}\\
&=\sqrt{1-\frac{V^2}{c^2}}\frac{\partial \rho'}{\partial T}-\nabla\rho'\cdot\boldsymbol{V}.
\end{aligned}$$

Thus, the continuity equation in the cosmonic system

$$\frac{\partial j_x}{\partial x}+\frac{\partial j_y}{\partial y}+\frac{\partial j_z}{\partial z}+\frac{\partial \rho}{\partial t}=0$$

is transformed into that in the non-cosmonic system:

$$\frac{\partial j'_X}{\partial X}+\frac{\partial j'_Y}{\partial Y}+\frac{\partial j'_Z}{\partial Z}+\sqrt{1-\frac{V^2}{c^2}}\frac{\partial \rho'}{\partial T}-\nabla\rho'\cdot\boldsymbol{V}=0. \tag{6.4}$$

From this, it follows that the continuity equation does not have covariance.

Next, we shall consider the Lorentz condition.

$$\mathrm{div}\boldsymbol{A}+\varepsilon_0\mu_0\frac{\partial \varphi}{\partial t}=0. \tag{6.5}$$

Expressing Eq. (6.5) in the four-dimensional form, we have

$$\frac{\partial A_x}{\partial x}+\frac{\partial A_y}{\partial y}+\frac{\partial A_z}{\partial z}+\frac{1}{c^2}\frac{\partial \varphi}{\partial t}=0, \tag{6.6}$$

$$\frac{\partial A_x}{\partial x}+\frac{\partial A_y}{\partial y}+\frac{\partial A_z}{\partial z}+\frac{\partial\left(i\dfrac{\varphi}{c}\right)}{\partial(ict)}=0, \tag{6.7}$$

$$\frac{\partial A_1}{\partial x_1}+\frac{\partial A_2}{\partial x_2}+\frac{\partial A_3}{\partial x_3}+\frac{\partial A_4}{\partial x_4}=0. \tag{6.8}$$

Considering similarly to the case of the continuity equation, we obtain

$$\frac{\partial A'_X}{\partial X}+\frac{\partial A'_Y}{\partial Y}+\frac{\partial A'_Z}{\partial Z}+\frac{1}{c^2}\sqrt{1-\frac{V^2}{c^2}}\frac{\partial \varphi'}{\partial T}-\frac{1}{c^2}(\nabla\varphi'\cdot\boldsymbol{V})=0.$$

Thus, the Lorentz condition does not have a relativistic covariance.

Next, let us consider the wave equation. The wave equation is expressed in terms of the vector potential as

$$\begin{aligned}\Delta\boldsymbol{A}-\varepsilon_0\mu_0\frac{\partial^2\boldsymbol{A}}{\partial t^2}&=\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}+\frac{\partial^2}{\partial(ict)^2}\right)\boldsymbol{A}\\&=\left(\frac{\partial^2}{\partial x_1^2}+\frac{\partial^2}{\partial x_2^2}+\frac{\partial^2}{\partial x_3^2}+\frac{\partial^2}{\partial x_4^2}\right)\boldsymbol{A}=-\mu_0\boldsymbol{j}\end{aligned} \tag{6.9}$$

and in terms of the scalar potential as

$$\begin{aligned}\Delta\varphi-\varepsilon_0\mu_0\frac{\partial^2\varphi}{\partial t^2}&=\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}+\frac{\partial^2}{\partial(ict)^2}\right)\varphi\\&=\left(\frac{\partial^2}{\partial x_1^2}+\frac{\partial^2}{\partial x_2^2}+\frac{\partial^2}{\partial x_3^2}+\frac{\partial^2}{\partial x_4^2}\right)\varphi=-\frac{\rho}{\varepsilon_0}.\end{aligned} \tag{6.10}$$

The equation for the vector potential of the four-dimensional representation is expressed as

$$\sum_{\mu=1}^{4}\frac{\partial^2}{\partial x_\mu^2}\boldsymbol{A}=-\mu_0\boldsymbol{j}, \tag{6.11}$$

the equation for the scalar potential of the four-dimensional representation, as

$$\sum_{\mu=1}^{4}\frac{\partial^2}{\partial x_\mu^2}\left(i\frac{\varphi}{c}\right)=-i\frac{\rho}{c\varepsilon_0}. \tag{6.12}$$

If in the above equation, the expressions of $A_4=i\dfrac{\varphi}{c}$ and $-i\dfrac{\rho}{c\varepsilon_0}=-i\dfrac{c\rho}{c^2\varepsilon_0}=-\mu_0 j_4$ are taken into account, the equation for the scalar potential is expressed as

$$\sum_{\mu=1}^{4}\frac{\partial^2}{\partial x_\mu^2}A_4=-\mu_0 j_4. \tag{6.13}$$

Adding the equations for the vector potential and scalar potential yields an equation expressed as

$$\sum_{\mu=1}^{4}\frac{\partial^2}{\partial x_\mu^2}A_\nu=-\mu_0 j_\nu. \tag{6.14}$$

This equation is a wave equation in a cosmonic system. Considering the wave equation in a non-cosmonic system in a similar way to the cases of the continuity equation or the Lorentz condition, it can be revealed that the relativistic covariance is not satisfied. Let the wave equation in the cosmonic system be expressed as

$$\sum_i \left( \frac{\partial^2}{\partial x_i^2} - \frac{1}{c^2} \frac{\partial^2}{\partial t^2} \right) \psi = 0. \tag{6.15}$$

Taking into consideration the relativistic transformations:

$$\left. \begin{aligned} \boldsymbol{R} &= \boldsymbol{r} - \boldsymbol{V}t \\ T &= \sqrt{1 - \frac{V^2}{c^2}t} \end{aligned} \right\}, \tag{6.16}$$

we get

$$\left[ \nabla'^2 - \frac{1 - \frac{V^2}{c^2}}{c^2} \frac{\partial^2}{\partial T^2} + \frac{2\sqrt{1 - \frac{V^2}{c^2}}}{c^2} (\boldsymbol{V} \cdot \nabla') \frac{\partial}{\partial T} - \frac{1}{c^2} (\boldsymbol{V} \cdot \nabla')^2 \right] \psi = 0. \tag{6.17}$$

In the first expression of Eq. (6.16), $\boldsymbol{r}$ and $\boldsymbol{R}$ are the position vectors in the cosmonic system and in the non-cosmonic system, respectively. That is,

$$\boldsymbol{R} = (X, Y, Z), \ \boldsymbol{r} = (x, y, z).$$

For acoustic waves, the wave equation in a reference frame moving relative to a medium of wave propagation is expressed by the coordinate transformation from one reference frame to another

$$\left. \begin{aligned} \boldsymbol{R} &= \boldsymbol{r} - \boldsymbol{V}t \\ T &= t \end{aligned} \right\}$$

as

$$\left[ \nabla'^2 - \frac{1}{\upsilon^2} \frac{\partial^2}{\partial T^2} + \frac{2}{\upsilon^2} (\boldsymbol{V} \cdot \nabla') \frac{\partial}{\partial T} - \frac{1}{\upsilon^2} (\boldsymbol{V} \cdot \nabla')^2 \right] \psi = 0,$$

where $\upsilon$ is the phase velocity of the wave. The above equation coincides with Eq. (6.17) when neglecting the relativistic relation of time.

When the speed of a non-cosmonic system reaches nearly the speed of light, Eq. (6.17) is reduced to the following equation which does not depend on time

$$\left[ \nabla'^2 - \frac{1}{c^2} (\boldsymbol{c} \cdot \nabla')^2 \right] \psi = 0$$

and further to

$$\left[ \nabla'^2 - \frac{1}{c} (\boldsymbol{e}_c \cdot \nabla')^2 \right] \psi = 0.$$

In the above equation, $\boldsymbol{e}_c = \frac{\boldsymbol{c}}{c}$ is the unit vector in the direction of wave propagation. This equation describes the fact that the observer comoving with the wave front sees a static profile of wave. Based on these considerations, it is clear that the wave equation in the cosmonic system is different from the wave equation in a non-cosmonic system. Of course, when the relative velocity of the two systems is much smaller than the speed of light, Eq. (6.17) is reduced to the standard wave equation (6.15) for the cosmonic system.

This indicates that the wave equations in any two reference systems are not identical. That is, the wave equation is not covariant. In fact, there is no absolute requirement that the equations of electrodynamics must have covariance. Just as the standard equation for acoustic waves is meaningful only in a particular reference frame secured to a medium of wave propagation, so the equation for electromagnetic waves has the standard form only for observers in the cosmonic system, while for the observer stationary in a non-cosmonic system, the shape of the equation must change.

## 7. Discussion

Our aim has been to formulate an alternative theory of relativity in a unified way based on the assumption of the universal quantum. For this purpose, to begin with we have analyzed the present theory of relativity critically. But we recognize that it is impossible to achieve our aim without relying on Einstein's outstanding scientific wealth. This paper has been realized by pursuing Lorentz and Poincaré's original idea and realistic insight into relativity. In this work, we have presented a generalized theory of relativity that incorporates relativity in both inertial and noninertial reference frames, based on the concept of the cosmon postulated as an original substantial quantum. The assumption about the cosmon does not additionally require the fundamental postulates of STR and GTR, and enables us to construct unified mechanics starting from a generalized theory based on a single mechanism.

STR is based on Einstein's two postulates. If the two postulates of STR are completely independent and compatible, we can assume that the foundations of STR are consistent. However, the theory of relativity loses its foundations when by mathematical and physical considerations it is revealed that the two postulates are incompatible or that any individual postulate is inconsistent. On the other hand, if results of the relativistic transformation lead to paradoxes incompatible with realism, then the theory of relativity is no longer justified. In our view, without decisive experiments, it is possible to test the validity of STR by reviewing the logical, mathematical and physical aspects of the postulates, and by analyzing the obtained results.

Starting from this point of view, our study has shown in several ways that the idea for the unified space-time is inconsistent. First, we began our discussion by examining whether the space-time vector satisfies the axioms of vectors. If vectors of the Minkowski space do not satisfy the axioms of vectors, STR loses its mathematical foundations. We have shown by purely mathematical considerations that the space-time vector does not satisfy the axioms of vectors, and therefore the space-time vector, which defines the interval of events, is meaningless.

Next, we have considered the question of whether there exists a relation of general linear transformation of space-time for any two inertial systems. It has been clearly proved that for any two inertial systems taken in an arbitrary way, it is not possible to derive a linear transformation relation of space-time. This shows, in a sense, that there cannot be the unification of space and time. In Sect. 2, we showed that there does not exist a general linear transformation relation of space-time for any two inertial frames satisfying the principle of the constancy of light speed and the principle of relativity, which gives the conclusion that the Lorentz transformation is not an exact result satisfying all physical and mathematical requirements. In inertial systems, the coordinate systems can be established arbitrarily, and this general method must be applied in order to obtain a generalized relativistic transformation.

We have shown in the previous discussions that the Lorentz transformation was derived without generality using the method of taking a specific coordinate system and using a one-way velocity of light. It seems that by the derived transformation, the unification of space and time is explained, but the obtained results clearly violate the principles of relativity and show paradoxes incompatible with physical realism. Indeed, according to the Lorentz transformation, the space-time scales in two inertial frames are distinguished from each other by relative motion. Thus, the meaning of relativity becomes contradictory. By the Lorentz transformation, the equations of electrodynamics are covariant, but instead, since the scales of space and time are changed, space and time which underlay all physical laws become essentially different. Thus, the principle of relativity and the principle of the constancy of the speed of light are contradictory. In the end, it has been clarified that Lorentz transformation does not guarantee the compatibility of the two postulates of STR, and that there cannot exist other linear transformation between any two inertial systems. Such theoretical consideration and conclusions adduce reason in support of Refs. [5,7,9,10,12-16].

A mathematical basis for constructing STR is the concept of the interval between two events. Our study has proved that the concepts of events and space-time intervals are not both mathematically and physically meaningful. Thus, we have demonstrated that there cannot be the unified space-time, and that the Lorentz transformation based on the unification of space and time does not have physical meaning. This means a failure of the geometry of relativity and leads to the theoretical conclusion that the starting point of general relativity also is incorrect. Our research has provided reasonable answers to the arguments given in Refs. [10,17-20].

Our study has shown that the two principles of STR cannot be established individually, and it is impossible to resolve the physical paradoxes that we encounter in the theory of relativity within the framework of this theory. The time delay and the length contraction cannot be reasonably explained in terms of relativity. They are mathematically contradictory results and are physically unrealistic. The mathematical contradictions have been explained in detail in Sect. 2. In the sense of relativity, the time delay and the length contraction are physically inconsistent. If in the sense of relativity, there is the time delay, then as a limit case, a stop of time also must be possible. What is the stop of time? Perhaps if there is the time delay, it means that physical phenomena proceeds relatively slowly, and the stop of time would mean that the physical process has stopped. Therefore, these physical properties should be interpreted not on the basis of the properties of space and time but by considering physical effects.

If the time delay exists in the sense of relativity, it is indicative of the fact that there is a simple physical cause related to the correlation of two inertial frames, i.e., to the relative velocity. Then, it follows that the nature of space-time of an inertial system depends on other physical entities that do not interact, which cannot be regarded as objective truth. Obviously, according to the principle of relativity, the relative velocity must have no effect on the inertial system itself. Nevertheless, it is a contradiction to imagine the time delay as the change of a physical process due to the existence of another reference system independent of interaction. In fact, the Lorentz transformation, determined by the relative velocity, produced this strange law that is incompatible with physical reality. Therefore, both postulates of STR are incompatible.

In the real sense, the stop of time means the stop of physical processes. But it is not logic that the relative motion of the two inertial frames can produce a physical world in which all motions would have ceased. In this world, the atomic clock would stop, and thus, the world of this state would be a primitive world in which all physical laws, including classical mechanics and quantum mechanics, would have disappeared. Surprisingly, this strange world can be created by the relative motion of two inertial frames of equal qualification. Moreover, because of the presence of one virtual stationary inertial system, which is related to relative motion, it is possible that the delay or stop of time in another inertial system without interaction can occur. Thus, the concepts such as the time delay or the stop of time by STR are physical fictions brought by wrong concepts.

The delay and relativity of time can be considered logically. Dingle pointed out that slow elapse of time in a moving clock is purely a fantasy. His argument was ignored at that time, but still remains a legacy for the posterity of criticizing STR. His syllogism clearly shows the logical shortcoming of STR today. Considering that syllogism is a complete deductive approach, the results derived using this approach are completely true and provide an absolute criterion for evaluating rational ways of thinking in science.

Dingle's syllogism states as follows [6].

Main premise: According to the philosophy of relativism, if two bodies (for example two identical clocks) separate and reunite, there is no observable phenomenon that will show in an absolute sense that one rather than the other has moved.

Minor premise: If upon reunion, one clock were retarded by a quantity depending on its relative motion, and the other not, that phenomenon would show that the first clock had moved (in an observer-independent "absolute" sense) and not the second.

Conclusion: If the principle of relativity is universally true, the both clocks all together are time-delayed or not time-delayed at all. In other words, when the clocks meet again, they must point to the same time. If the two clocks show different times, the postulate of relativity would be wrong. However, the calculation method given by the second postulate of STR shows different times. This clearly shows that the two postulates are mutually exclusive.

Dingle continues to mention: According to the logic of relativity, in fact, everything must be relative. In this connection, if there is an absolute effect as a function of velocity, then velocity must be absolute [6]. This is Dingle's syllogistic disproof of Einstein's theory of relativity.

The time delay that STR explains based on the two principles cannot be physically imagined. To consider this in a comprehensible way, let us recall the description in textbooks [80]. Observer $O'$ is in motion and observer $O$ is stationary. Refer to Fig. 5. The observer $O'$ considers that a light pulse is reflected on the mirror and propagates through the distance of $2d$ along the paths of BD and DB. On the other hand, the observer $O$ sees that the light pulse moves along the diagonal path ABC, and judges the propagation length to be greater than $2d$.

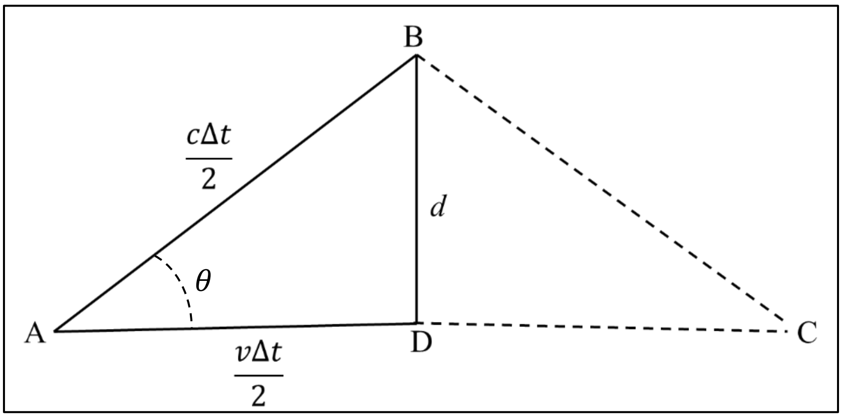


Figure 5: The propagation path of light observed in both inertial frames

Finally, the moving inertial frame and the stationary inertial frame have no equivalent status in the propagation of light. From the point of view of the ether, $O'$ is located at a system accompanying the ether, while $O$ is located at a system that moves relative to the ether system. Then, for the observers, commonly the following relation holds:

$$\left(\frac{c\Delta t}{2}\right)^2 = \left(\frac{\upsilon\Delta t}{2}\right)^2 + d^2, \tag{7.1}$$

where $\Delta t$ is the time interval in the inertial system at rest. Solving Eq. (7.1) with respect to time yields

$$\Delta t = \frac{2d}{c\sqrt{1-\frac{\upsilon^2}{c^2}}}. \tag{7.2}$$

By the principle of the constancy of the speed of light, taking into consideration that $\frac{2d}{c}$ is the time of propagation of light in the moving inertial system, $\Delta t_m$, Eq. (7.2) is expressed as

$$\Delta t = \frac{\Delta t_m}{\sqrt{1-\frac{\upsilon^2}{c^2}}}. \tag{7.3}$$

Hence, it follows that time in the moving inertial system is delayed. Regrettably, in this explanation the relativity of length, or, the length contraction has been disregarded.

It is useful to consider this problem from the viewpoint of the velocity addition. From Fig. 5, the following transformation must hold.

$$T\left(c^2-\upsilon^2\right)=c^2. \qquad (7.4)$$

where $T$ signifies the transformation operator of velocity from a stationary reference frame into a moving reference frame. Eq. (7.4) tells us that since $c^2-\upsilon^2=(c\sin\theta)^2$, the projection of the velocity of light in an inertial reference system onto a given direction always is viewed as the universal constant $c$ in another inertial system. In other words, while the relative velocity of light and an object in an inertial frame satisfies the classical law of velocity addition, in all other inertial frames the relative velocity under consideration is viewed as being equal to the universal constant $c$. According to the relativistic rule of velocity addition, a relative velocity of any two bodies in an inertial system can take an arbitrary value between 0 and $2c$ but in any other inertial system this relative velocity cannot exceed $c$.

It is instructive to consider physically this example from the standpoints of the two observers. In the above example, the stationary observer states that light does not propagate with reference to his inertial frame. This is because the light reflected from the mirror does not come back to him, but goes back to the moving observer. On the other hand, the moving observer recognizes that his or her inertial system is a preferred inertial system in the propagation of light, since the reflected light from the mirror returns to him, not to the stationary observer. Based on this fact, both the stationary observer and the moving observer have common view that the moving inertial system is a preferred inertial system in relation to the propagation of light. Thus, the both observers recognize the existence of the preferred inertial frame and calculate the relative velocity of light in the stationary inertial frame using the law of velocity composition. As a result, the observers come to see that the relative velocity of light in the stationary inertial frame must differ from the velocity of light in the preferred inertial frame. However, if the observers measure the one-way velocity of light in two inertial frames, the obtained values must always be the same, according to the principle of the constancy of the speed of light. Thus, the observers are faced with the surprising fact that the law of velocity composition does not hold for light. No physical explanation can be made for this strange physical phenomenon, and the reason only should be found from the nature of space and time. But there is a problem here. It is the following reason: while one says that all inertial frames are equivalent in relation to the propagation of light, why should one think of a preferred inertial frame. In fact, from the physical point of view, there must be the preferred inertial frame related to the propagation of light. This is because if there is no preferred inertial frame, the reflected light can come back to the observers stationary in any two inertial frames simultaneously. If so, this means that light is separated by the relative motion of the observers. If light does not return to the two observers with relative velocity, the both inertial frames are not the preferred inertial frame. If the preferred inertial frame exists, then all other inertial frames are inertial frames moving relative to this preferred inertial frame. If there is the preferred inertial system in the propagation of light, it is clear that for any inertial system, one spherical light wave cannot be a spherical wave that satisfies the principle of the constancy of the speed of light.

It is difficult to find ways to overcome the physical paradoxes that result from the concept and interpretation of the theory of relativity within the framework of STR. They are paradoxes concerning the core results of the relativity theory, such as the time delay and the length contraction. Indeed, the twin paradox is a mystery related to the fate of the theory itself. However, we have relied on it to explain the relativistic phenomena aside from the problem of this paradox. It is not a true scientific methodology to interpret physical phenomena using problematic paradoxes and to produce plausible results. Against this background of logical, philosophical and physical viewpoints, several discussions concerning the philosophical and physical interpretation of the nature of space and time have attracted attention [21,66].

Not only the time delay but also the length contraction is a contradiction which cannot be justified in the sense of STR. If there is the length contraction, we are faced with the contradictory result that the length contraction depends on the existence of other inertial systems that do not interact, while according to the principle of relativity we encounter the question of how to explain the opposite result obtained when we change the qualifications of inertial systems. This fact is directly contradictory to the principle of relativity and causality. If the length contraction is real, then it is illogical to consider that the physical objects present in any inertial system, such as atoms or molecules, must undergo spatial changes due to relative motion.

But logically judging, we would see the same world of nature in any inertial system, and we could never find a physical world in which a distorted atom or a three-dimensional object is transformed into a two-dimensional object. Just according to the Lorentz transformation, when the velocity of motion of an object approaches the speed of light, an observer in a stationary inertial frame would find that the contraction in the direction of motion occurs, and all physical objects change into shapes of two-dimensional objects of zero volume. It is a miracle that arises not in the objective condition of the inertial system, but from the existence of another unrelated inertial system at rest.

The apparatus of measuring the space also raises the question. Even if there is the relativity, an experiment comparing the relativity of space is never possible. Since the ruler also is relativistic and varies with space, so the scales of space in the two inertial frames cannot be compared, in practice. Measurements in an inertial frame obey the law of relativity. In other words, we cannot identify relativistic changes in scales of space in any way, since rulers also obey the Lorentz transformation. Therefore, an absolute ruler is required to confirm the validity of the present theory of relativity. However, this contradicts the principle of relativity, so in the theory of relativity, it is completely impossible to compare the scales of space of the two inertial frames. Unlike space, it is possible to identify the relativity of time because the times read by each of the two inertial frames are comparable by the two observers being in communication with each other. Thus, our theory has fundamentally resolved issues associated with paradoxes of STR posed in Refs. [12,16,23,24,37-41].

One should not forget the fact that the wrong concept may well explain physical phenomena within certain limits. The geocentric theory and the theory of phlogiston belong to such theories. The idea for the unified space-time has shown the bewitching power of deductive thinking in establishing an extended theory of mechanics and electrodynamics. However, this theory cannot be considered to have completely succeeded in constructing a theory that is free of paradoxes and is compatible with physical reality.

Of course, relativity associated with the motion and gravity exists in reality. The time delay also is possible. Therefore, the theory of relativity is necessary. But unless we could completely explained in the realistic view what relativity is and what physical cause of relativity is, the theory of relativity would remain an incomplete theory that cannot explain the physical essence and causality.

There is an important issue needing detailed considerations in relation to the principle of relativity. It is the question of whether all the physical laws necessarily should obey the principle of relativity. At least in acoustic waves, the principle of relativity does not hold. Acoustic waves are described by a standard form of equation only in a reference frame fixed to a medium of wave propagation. If we try to establish the principle of relativity in acoustics, there is no alternative but to redefine the acoustical quantities incompatible with physical meaning, instead of preserving the formula. There is no reason that electrodynamics must be built based on the principle of relativity. The principle of relativity is an assumption, and we cannot yet say that it has been fully verified experimentally.

It is clear that the laws of mechanics are covariant in all inertial frames, since it depends only on acceleration. But if a physical law has a velocity-dependent relationship, it cannot hold equally in all inertial frames, and the principle of relativity generally cannot hold true. The laws of electrodynamics belong to this case..

We have explained the results of several experiments on the speed of light, based on the concept of the cosmon embodying the concept of the ether. The interpretation based on the cosmon gives a good explanation of why the speed of light is independent of the velocity of the light source. The speed of light is determined by the medium of light propagation not by the speed of the light source. In this sense, the speed of light is constant. However, the speed of light is not constant for observers moving relative to the ether. An experimental evidence for this is the Doppler effect. In fact, this effect is impossible if there is no relative velocity of light source and observer.

We have constructed relativistic dynamics, based on the notion of the probability of interaction in terms of the cosmon. In the relativistic dynamics of STR, there is a difficulty that cannot explain the asymmetry in the time delay and the length contraction which we are faced with when changing the relative relation of motion and rest. In our theory, the effect of the time delay is explained by the effective time of interaction. In nature, the effective time of interaction plays an essential role in all interactions, because of the existence of the maximum velocity of interaction propagation. The existence of the maximum propagation velocity of interaction is due to the ether. Therefore, two inertial frames with relative velocity are not always equivalent inertial frames. Only when considering the motion relative to the ether, the status of inertial systems can be evaluated correctly. In our view, the relativity of length is meaningless. In fact, changes of lengths in any two reference systems cannot be detected and cannot compared, because the lengths under consideration change homologously along with rulers. The study showed that the Lagrangian can be found with the help of the concept of effective time of interaction, and that the new relativistic mechanics can gives the similar results to those that Einstein's relativistic mechanics gives. For this reason, the results given by STR are justified, if we regard the relativistic dynamics of STR as a theory that holds in a preferred reference frame.

As shown in sect. 4, in our relativistic mechanics there are no unexplainable concepts such as the twin paradox or relativistic mass of motion, and these concepts can be explained in a realistic sense by the notion of the probability of interaction of the cosmon. Thus, our theory becomes an alternative theory of relativity based on ether-mediated interactions. Our theory has shown that the essence of mass as an open question is reasonably explained on the basis of the cosmon, and that field and matter can be treated in a unified way on the basis of the cosmon. Thus, our work has confirmed that the recent researches [26,34,65-69] assuming the existence of the ether and the preferred reference systems have practical value. Our study can also give a clear answer to the question of relativistic electrodynamics. We have shown that electrodynamic formulas are not necessarily covariant in the four-dimensional form. Of course, the requirement for relativistic covariance of the laws of electrodynamics is only one assumption. We have proved that there is no relativistic transformation with physical meaning derived based on the two postulates of STR, since the two postulates are not compatible. Thus, it is meaningless to construct relativistic electrodynamics based on the Lorentz transformation. Electrodynamics is a theory in a preferred inertial system based on the cosmon, and if there is relativistic electrodynamics, it should be considered relativistic electrodynamics based on the probability of interaction related to the relative motion to the cosmon.

The theory based on the cosmon enables us to explain consistently and in a unified way the nature of the gravitational field, the nature of time and the speed of light in the gravitational field, and the principles of equivalence, zero gravity and to build the theory of relativity in a context unifying STR and GTR. Newtonian mechanics as the nonrelativistic mechanics is automatically given as a nonrelativistic approximation of generalized mechanics in terms of the cosmon. In this theory, there is no need to build the theories of relativity in the special and general cases separately, and the theory of relativity is a natural consequence of the generalized theory. According to this theory, time and dynamic properties in the gravitational field can be dealt with in a comprehensive way to consider the cosmon density dependent on motion and gravity. Thus, the cosmon-based mechanics is expected to provide an important key to constructing unified physics for everything.

## 8. Conclusions

Einstein's outstanding and unparalleled contributions to the theory of relativity that had opened up an avenue towards a new physical world of relativity cannot be forgotten forever. However, the task to complete the theory of relativity still remains up to today, so it is indispensible to make a breakthrough for an alternative consistent theory of relativity. Meanwhile, the great thinkers, Lorentz and Poincaré's profound idea and inspiration have led us to a new perspective and promising plans.

In this context, we have proposed a generalized theory of relativity that covers inertial and noninertial reference frames altogether, based on the cosmon postulated as an original elementary particle which makes up the physical vacuum and matter. The assumption about the cosmon does not additionally require any of the fundamental postulates of the theory of relativity, such as the principle of relativity, the principle of the constancy of speed of light, and the principle of equivalence, and provides the possibility of constructing unified mechanics.

First of all, we have interpreted the concepts, principles and results of STR from a new mathematical angle, and have shown that the principle of relativity and the principle of the constancy of speed of light are incompatible with each other, and that the individual postulates also are not valid. The theory of relativity must be discarded if by experiments and mathematical and physical considerations, it is confirmed that either one of the two postulates of STR is inconsistent or the two postulates are incompatible with each other. Also, if the results of relativistic transformation are not physically consistent, then the theory of relativity should be regarded as being wrong.

We have shown from this point of view that the Lorentz transformation, which is the transformation of the space-time coordinates between any two inertial frames, does not have unitary properties and that the Minkowski space does not satisfy the axioms of vector. In addition, we have demonstrated that geometry in four-dimensional space-time cannot be established, since there is no invariance of space-time intervals as the underlying concept of STR.

We have logically and mathematically considered the physical consequences of the Lorentz transformation and have demonstrated that the concepts of the time delay and the length contraction which are explained within the framework of STR are unrealistic. The mathematical proofs given in this paper confirm that the Lorentz transformation is not mathematically general and is incompatible with physical reality, and that the relativity and unification of space and time are meaningless.

We have established a relativistic dynamics from a realistic point of view by introducing the concept of the probability of interaction and of the effective time of interaction based on the cosmon, which is distinguished from the concept of the unified space-time at the root points. The existence of the cosmon and the maximum speed of propagation of the interaction in the ether system leads to the concept of the effective time of interaction. Our relativistic dynamics based on the effective time of interaction altogether has reproduced main results of the relativistic dynamics which STR had obtained. But their physical essences are different: Einstein's theory of relativity adopts the concept of the proper time, while in our theory is introduced the concept of the effective time of interaction which differs in essence from the former concept. To tell the truth, the notion of the time delay in STR should be replaced by the notion of the effective time of interaction. This is because the relativity between the cosmonic system and a non-cosmonic system, rather than the relativity between any equivalent inertial frames, makes a real sense.

Meanwhile, our theory has provided a new theory of relativistic electrodynamics based on the cosmonic system. This theory has drawn the conclusion that the requirement that the law of electrodynamics must have covariance in every inertial frame is meaningless. Furthermore, we have formulated a simple theory of gravity based on the cosmon, where all relativistic effects related to the gravity including the time delay, frequency of oscillation, and the speed of light in the gravitational fields are successfully explained. Our theory of gravity is characterized by not relying on the concept of space-time and the equivalence principle. Since only the concepts of practical meaning are used, in our theory there is no paradox to be unexplainable, such as the time delay and the length contraction due to the nature of space-time. Of course, we do not deny that there may be some errors in our work.

But we believe that our study has a correct starting point and can contribute to establishing the solid foundations for developing the theory of relativity into a perfect theory without paradoxes incompatible with physical realism.

## References


[1] A. Einstein, Zur Electrodynamik bewegter Körper," Annalen der Physik 17, 891 (1905).

[2] C. M. Will, Special Relativity: A Centenary Perspective, In: *Einstein, 1905–2005, Poincaré Seminar 2005* edited by Thibault Damour, Olivier Darrigol, Bertrand Duplantier, Vincent Rivasseau, Birkhäuser Verlag, 2006.

[3] M. Barone, Some Almost Unknown Aspects of Special Relativity Theory, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[4] A. A. Tyapkin, On the History of the Special Relativity Concept, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[5] V. A. Ugarov, Special Theory of Relativity, Mir Publisher (Moscow), 1977.

[6] Z. Jacyna-Onyszkiewicz, B. Lange, The Simplest Inflationary Scenario in Relativistic Quantum Cosmology, In: *Open Questions in Relativistic Physics* edited by Franco Seller, Apeiron (Montreal), 1998.

[7] F. Selleri, Preface, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[8] P. Fleming, An Explanation of the Sagnac Effect Based on the Special Theory of Relativity, the de Broglie/Bohm Interpretation of Quantum Mechanics, and a NonZero Rest Mass for the Photon, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[9] J. R. Croca, Experiments on the Velocity *c*, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[10] H. Weiß, Alternative to the principle of constant speed of light, arXiv:physics/0606242v9 [physics.gen-ph] 22 Aug 2006.

[11] N. A. Tambakis, On the Question of Physical Geometry, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[12] J. Lévy, Is Simultaneity Relative or Absolute?, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron, 1998.

[13] A. Jannussis, S. Baskoutas, On Superluminal Velocities, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron, 1998.

[14] M. Consoli, Modern Michelson-Morley experiments and gravitationally-induced anisotropy of c, arXiv:gr-qc/0306105v1 23 Jun 2003.

[15] F. Selleri, On a Physical and Mathematical Discontinuity in Relativity Theory, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[16] L. Gonzalez-Mestres, Lorentz Symmetry Violation, Vacuum and Superluminal Particles, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[17] G. Tarozzi, Nonlocality, Relativity, and Two Further Quantum Paradoxes, In: *Open Questions in Relativistic Physics* edited by Franco Seller, Apeiron (Montreal), 1998.

[18] M. Farhoudi, M. Yousefian, Ether and Relativity, Int. J. Theor. Phys 55:2436–2454 (2016).

[19] J. M. Carmona, *et al,* Locality and the relativity principle beyond special relativity, Phys. Rev. D 84, 085010 (2011).

[20] B.G. Sidharth, Noncommutativity and relativity, arXiv: 1707.07553v1 [physics.gen-ph] 21 Jul 2017.

[21] E. Bitsakis, Space and Time: Who was Right, Einstein or Kant?, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.

[22] T. V. Flandern, What the Global Positioning System Tells Us about Relativity, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[23] V. S. Barashenkov, Nature of Relativistic Effects and Delayed Clock Synchronization, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron, 1998.
[24] A. Horzela, Remarks on Clock Synchronization, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[25] R. T. Cahill, K. Kitto, Re-Analysis of Michelson-Morley Experiments Reveals Agreement with bCOBE Cosmic Background Radiation Preferred Frame so Impacting on Interpretation of General Relativity, arXiv:physics/0205070vl [physics.gen-ph] 24 May 2002.
[26] L. Kostro, The Physical and Philosophical Reasons for A. Einstein's Denial of the Ether in 1905 and its Reintroductionin, In: *Open Questions in Relativistic Physics* edited by Franco Seller, Apeiron (Montreal), 1998
[27] R. T. Cahill, Discovery of Dynamical Space: Experiments and Theory, Proc. of SPIE Vol. 9570, 957018 (2015)
[28] R. T. Cahill, The Michelson and Morley 1887 Experiment and the Discovery of Absolute Motion, arXiv:physics/0508174v1 [physics.gen-ph] 24 Aug 2005.
[29] M. Consoli, E. Costanzo, The Michelson-Morley experiment and the cosmic velocity of the Earth arXiv:physics/0311054v1 [physics.gen-ph] 13 Nov 2003.
[30] M. oli, E. Costanzo, The motion of the Solar System and the Michelson-Morley experiment, arXiv:astro-ph/0311576v1 26 Nov 2003.
[31] M. Consoli, E. Costanzo, The motion of the Solar System and the Michelson-Morley experiment, arXiv:astro-ph/0311576v1 26 Nov 2003.
[32] M. Consoli, Relativistic analysis of Michelson-Morley experiments and Miller's cosmic solution for the Earth's motion, arXiv:physics/0310053v1 [physics.class-ph] 13 Oct 2003.
[33] M. Consoli and E. Costanzo, An easy reading of modern ether-drift experiments, arXiv:physics/0702112v1 [physics.class-ph] 14 Feb 2007.
[34] H. Ghaffarnejada, Razieh Dehghani, Galaxy rotation curves and preferred reference frame effects, Eur. Phys. J. C 79, 468(2019).
[35] R. Risco-Delgado, Inertial Transformations from the Homogeneity of Absolute Space, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[36] G. Salesi, *et al*, Modified Lorentz transformations in deformed special relativity, arXiv: 168.00322v2 [hep-th] 29 Jan 2017.
[37] F. Goy, On Synchronisation of Clocks in Free Fall Around a Central Body, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron, 1998.
[38] A. G. Kelly, Synchronisation of Clock-Stations and the Sagnac Effect, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[39] A. Martin, Reception of Light Signals in Galilean Space-Time, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[40] V. Onoochin, On the size of moving rigid bodies determined from conditions of equilibrium of Ions in a crystalline lattice, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[41] H. A. Múnera, The Evidence for Length Contraction at the Turn of the 20th Century: Non-existent, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[42] I. Perez, The physics surrounding the Michelson-Morley experiment and a new ether theory, arXiv:1004.0716v3 [physics.gen-ph] 15 Dec 2010.
[43] J. Brandes, A Lorentzian Approach to General Relativity: Einstein's Closed Universe Reinterpreted, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron, 1998.
[44] J. J. Prokhovnik, An Introduction to the Neo-Lorentzian Relativity of Builder, Speculation in Science and Technology Vol l2, N3, 225 (1979).

[45] V. Krasnoholovets, The Tessellattice of Mother-Space as a Source and Generator of Matter and Physical Laws, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[46] J.-P. Hsu, Y.-Z. Zhang, Lorentz and Poincaré invariance; 100 years of relativity, World Scientific (New Jersey • London • Singapore • Hong Kong), 2001.
[47] B. H. Lavenda, A New Perspective on Relativity: An odyssey in non-Euclidean Geometries, World Scientific (New Jersey, London, Singapore, Beijing), Chaps. 2, 4, 2012.
[48] J.-P. Hsu, L. Hsu. A Broader View of Relativity: General Implications of Lorentz and Poincaré Invariance, World Scientific (New Jersey • London • Singapore • Beijing), 2006
[49] M. C. Duffy, The Ether Concept in Modern Physics, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[50] M. Farhoudi, M. Yousefian, Ether and Relativity, Int J Theor Phys 55, 2436–2454 (2016).
[51] P. R. S. Carvalho, M. I. Sena-Junior, Exact Lorentz-violating all-loop ultraviolet divergences in scalar field theories, Eur. Phys. J. C 77, 753 (2017).
[52] E. K. Kunst, Is the kinematics of special relativity incomplete?, Natural Science Vol.6 No.4, 226-247 (2014).
[53] N. Dimakis, *et al*, Quantization of Einstein-aether scalar field cosmology, Eur. Phys. J. C 81, 152 (2021).
[54] R. T. Cahill, The Einstein Postulates: 1905-2005 A Critical Review of the Evidence, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[55] A. P. Bredimas, Schrödinger's "Aether" Unifies Quantum Mechanics and Relativistic Theories, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[56] M. A. B. Whitaker, Relativistic Physics and Quantum Measurement Theory, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[57] J. L. Sánchez-Gómez, Are Quantum Mechanics and Relativity Theory really Compatible?, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[58] C. H. Thompson, Behind the Scenes at the EPR Magic Show, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[59] A. Garuccio, Entangled States and the Compatibilty Between Quantum Mechanics and Relativity, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[60] G. Tarozzi, Nonlocality, Relativity, and Two Further Quantum Paradoxes, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[61] A. M. Awobode, A New Appraisal of the Relativistic Quantum Theories of the Electron, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[62] H. Broberg, The Interface between Matter and Time: a Key to Gravitation, In: *Open Questions in Relativistic Physics* edited by Franco Seller, Apeiron (Montreal), 1998.
[63] W. A. Hofer, Internal Structures of Electrons and Photons and some Consequences in Relativistic Physics, In: *Open Questions in Relativistic Physics* edited by Franco Seller, Apeiron (Montreal), 1998.
[64] H. Arp, Evolution of Quasars into Galaxies and its Implications for the Birth and Evolution of Matter, In: *Open Questions in Relativistic Physics* edited by Franco Seller, Apeiron (Montreal), 1998.
[65] M. Consoli, E. Costanzo, Indications for a preferred reference frame from an ether-drift experiment, arXiv:gr-qc/0511160v1 30 Nov 2005.
[66] R. T. Cahill, K. Kitto, Michelson-Morley Experiments Revised and Cosmic Background Radiation Preferred Frame, arXiv:physics/0205065vl [physics.gen-ph] 23 May 2002.
[67] J. P. Wesley, Evidence for Newtonian Absolute Space and Time, In: *Open Questions in Relativistic Physics* edited by Franco Selleri, Apeiron (Montreal), 1998.
[68] R. T. Cahill, The Roland De Witte 1991 Detection of Absolute Motion and Gravitational Waves, arXiv:physics/0608205v1 [physics.gen-ph] 21 Aug 2006.

[69] R. D. A. Martins, Searching for the Ether: Leopold Courvoisers Attempts to Measure the Absolute Velocity of the Solar System, The International Journal of Scientific History, 17, 3-33 (2011).
[70] T. E. Phipps, Old Physics for New: a worldview alternative to Einstein's relativity theory, Apeiron (Montreal), Chap. 1, 2006.
[71] A. A. Michelson, E. W. Morley, On the Relative Motion of the Earth and the Luminiferous Ether, Am. J. Sc. 34, 333-345 (1887).
[72] D. C. Miller, The Ether-Drift Experiment and the Determination of the Absolute Motion of the Earth, Rev. Mod. Phys. 5, 203-242 (1933).
[73] R. T. Cahill, The De Witte 1991 Experiment, Progress in Physics 3, 60-65 ( 2006).
[74] R. T. Cahill, One-Way Speed of Light Measurements Without Clock Synchronisation, Progress in Physics 3, 43-45 ( 2012).
[75] Y. Pierseaux, Einstein's Spherical Wavefronts versus Poincaré's Ellipsoidal Wavefronts, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[76] A. Martin, The electron as an extended structure in cosmonic gas, in: What is the Electron?, ed. V. Simulik, Apeiron (Montreal), 2005.
[77] A. Martin, Gravitation in a Gaseous Ether, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[78] P. A. M. Dirac, Is There an Aether, Nature Vol. 168 pp. 906-907 (1951).
[79] D. F. Roscoe, Maxwell's Equations: New Light on Old Problems, In: *Einstein and Poincaré*: *The Physical Vacuum* edited by Valeri V. Dvoeglazov, Apeiron (Montreal), 2006.
[80] H. D. Young, R. A. Freedman, A. Lewis, University physics with modern physics, Addison Wesley (Boston • Columbus • New York), Chap. 37, 2012.