DARK ENERGY IN THE LIGHT OF RELATIVISTIC KINEMATICS

Vinogradov Evgeniy Leonidovich
d.t.s., professor
St. Petersburg Polytechnic
University of Peter the Great

Abstract: Relativistic kinematics (or, in other words, Einstein's special theory of relativity – SRT) is one of the most important parts of modern physics. In particular, in the framework of SRT, the inseparable connection of space and time, the impossibility of overcoming the "light barrier" by moving material objects, that is, the propagation velocity of electromagnetic waves $c = const$, is proved. Nevertheless, it is impossible not to note some limitations of SRT – it considers only the relations between the characteristics of space-time measured in two inertial reference systems (IRS immobile and moving). The purpose of this study is to find patterns of transformation of spatial coordinates and time during the transition from IRS to a non-inertial system. The proposed additions to relativistic kinematics have found practical application in cosmology: the accelerations of distant galaxies have been calculated with their consideration, the unsoundness of hypothesis of the existence of dark energy has been established.

Key words: Relativistic kinematics, reference systems, speed and acceleration of galaxies, dark energy.

Introduction

Relativistic kinematics is a physical theory of philosophical categories – space and time [1]. It strictly proves the inseparable (and far from obvious) connection of these categories, the impossibility of overcoming the "light barrier" *c*, the equivalence of mass and energy, the monotonous increase in the mass of substance objects with increasing speed of their movement.

The conclusions of relativistic kinematics (more precisely, the kinematics of objects moving at very high speeds) go far beyond the scope of "everyday" experience, and therefore they seem paradoxical. One of them – the statement about the slowing down of the passage of time in a moving inertial system of reference – generally looks implausible. However, this conclusion, like all other provisions of SRT, is the result of unmistakable mathematical transformations of the original equations; it is experimentally confirmed, for example, by the results of measurement by a motionless observer of the lifetime of unstable elementary particles accelerated in the CERN ring accelerator to a speed approaching *c* [2].

In SRT, two inertial systems of reference are studied, the first of which, having space-time characteristics $\{x, y, z, t\}$, is motionless, and the second with characteristics $\{\xi, \eta, \zeta, \tau\}$ at $t > 0$ is moving away from the first at a constant speed $\vec{v}_0$, which can tend to *c*. The systems coincide at $t = \tau = 0$, then the system of reference II moves so that the equally directed axes *x* and ξ continue to remain on the same straight line, and the other two pairs of axes maintain parallelism. In these circumstances, at $v_0 \to c$ the values *t* and τ do not coincide, $x \neq \xi + v_0 t$, the simple rule of addition of velocities $\frac{dx}{dt} = \frac{d\xi}{d\tau} + v_0$ of Galileo-Newton's kinematics, corresponding to "everyday" experience, is not fulfilled. In the "relativistic" case

$$x = (\xi + v_0 t) \Big/ \sqrt{1 - v_0^2 / c^2}, \qquad (1)$$

$$\frac{dx}{dt} = \left(\frac{d\xi}{d\tau} + v_0 \right) \Big/ \left(1 + \frac{d\xi}{d\tau} \frac{v_0}{c^2} \right) \qquad (2)$$

and an experimenter who, being in system I, measures the speed of an object moving at a speed $\frac{d\xi}{d\tau}$ in system II, receives its value $\frac{dx}{dt} < \frac{d\xi}{d\tau} + v_0$.

The inertial systems of reference considered in the special theory of relativity are "mirror-like" indistinguishable: the second of them also moves away from the first with a constant velocity ($-\vec{v}_0$), in both of them the laws of Newton's dynamics apply. However, this indistinguishability of the IRS disappears if one of them, for example, the second one begins to move with acceleration. Inertia forces are detected in such a system – it becomes non-inertia, equations (1) and (2) are not valid for her. *Transformations of spatial coordinates and time during the transition from a motionless inertial system I to a non-inertial system II are not described by known SRT formulas, in this part relativistic kinematics requires additions. The purpose of this article is to form such additions and use them to describe in details the accelerated movement of "relativistic" objects.*

In order to achieve the above purpose, it was necessary to solve the following tasks: *firstly*, to determine the direction of the necessary mathematical transformations (their basis); *secondl*y, to make precise specification the methods of transformations and write down calculation formulas; *thirdly*, to carry out calculations using these formulas in relation to "obviously relativistic" objects.

The completed research is based on the unquestionable postulate of the special theory of relativity about the existence of a "light barrier" [1].

The mathematical transformations do not go beyond of the "school" mathematical analysis and are not too complicated [3].

The results of the calculations are used to describe the motion of distant galaxies, that is, massive material objects moving in outer space, as shown by astronomical observations, at very high speeds [4].

The relevance of the proposed modernization of the SRT is determined by the need to improve ideas about the expansion of Metagalaxy.

Literature review

There are no literature sources devoted to the problem of transformation of the characteristics of space-time during the transition from an inertial system of reference to a non-inertial one. But, since the first third of the twentieth century up to the present time, a huge number of publications (articles, monographs, textbooks, etc.) have accumulated containing experimental data on the properties of remote space objects, theoretical ideas about the evolution of the observable part of the Universe (Metagalaxy) and about the universal laws of "everything that exists". In other words, about 150 years ago, an interesting natural science discipline, cosmology, emerged and has been developing rapidly ever since. It is generally assumed that the birthday of cosmology is determined by the date of publication of Hubble's article on the results of measuring the radial velocity of observed star clusters [5].

With rare exceptions, these objects are moving away from the Milky Way, and Hubble's law is fulfilled (though not strictly), declaring the proportionality of the velocities of the scattering galaxies and the distances R from them to terrestrial observers [5]:

$$v = HR, \qquad (3)$$

where $H \approx 22 \cdot 10^{-19} \frac{1}{c}$ is the Hubble constant. Extrapolation of these experimental data into the distant past leads to the hypothesis of the Big Bang (BB), from which the age of Metagalaxy should be counted. Currently, the implementation of the Big Bang is beyond doubt, within the framework of cosmology, this event is considered as an axiom of the generally accepted standard model of the birth and transformation of "all things" [4].

It is assumed that the current moment separates approximately $\frac{1}{H} = 4{,}5 \cdot 10^{17}$ seconds (~14 billion years) from the Big Bang. After about $5 \cdot 10^{16}$ seconds BB, in the era of reionization of matter, a set of elements of Metagalaxy was formed [6], which then evolved in accordance with the laws of STR. Thus, during most of the existence of Metagalaxy (about 90%), the movements of its large-scale elements should be described by the equations of relativistic kinematics proposed in this message.

So, it should be noted that Hubble's law is of great importance for the formation of cosmology as a science.. Nevertheless, the regularity corresponding to formula (3) can in no case be considered accurate and strictly justified for the following reasons:

1) There are a small number of galaxies that are approaching the Earth observer, and not moving away from him. These include, for example, the nearest neighbor of the Milky Way – the Andromeda nebula.

2) There is no reason to believe that the velocities of all galaxies and quasars equidistant from the Milky Way are the same or close. This assumption is clearly refuted by the results of measuring the quantities v and R, which form a point cloud in the "space" $v – R$, the width of which reaches 10^6 m/s [5].

3) The validity of Hubble's law was postulated for space objects distant from the Milky Way "only" at R ~ 10^{23} m, while the farthest of the discovered galaxies is located at a distance of about a thousand times greater from the terrestrial observer. The comparison of the above numbers raises serious doubts that the effect of this law applies to the entire Metagalaxy at all times.

4) It is impossible to agree with the opinion about the validity of equation (3) for all star clusters observed at a certain point in time, since information about their velocities is received by the observer with a time delay, the value of which varies significantly with R (at R ~ 10^{23} m corresponds to ten million years, and at $R \sim 10^{26}$ m the time delay is approximately ten billion years).

5) Experimental data presented in the "space" v – R by a set of widely scattered points relate to various space objects characterized by mismatched initial velocities and different equations of motion $R = f(t)$.

6) If the path x traversed by the object under study and a velocity of this object $\frac{dx}{dt}$ are related by equation (3), then both of these values increase over time equally infinitely – exponentially. However, the speed of any object in accordance with the fundamental provisions of SRT cannot exceed the speed of propagation of electromagnetic radiation c. So equation (3) is just an imperfect approximation of the real dependence $v = f(R)$.

Hubble's law served as the basis for the hypothesis of antigravity, which is actively discussed in modern cosmology, which supposedly overcomes the gravitational attraction of its elements at the border of the Metagalaxy and accelerates their removal from each other [7]. It is assumed that the source of antigravity is dark energy – a kind of homogeneous substance, pervasive, occupying ~ 70% of the Universe in terms of mass-energy and, at the same time, not amenable to experimental study (?). The existence of dark energy could be confirmed by calculations of the acceleration of distant galaxies, but such calculations have not been carried out.

Methodology

This work was carried out in three stages. *First*, the picture of movement in any direction of a non-inertial system of reference relative to a motionless IRS was concretized. *Then*, in the language of mathematical formulas, I wrote

- time dependences of the velocity of an object that rests in a non-IRS and moves with it, $v = \frac{dx}{dt} = f(t)$,

- the corresponding equations of motion of this object;

- time intervals Δt and $\Delta\tau$, measured, respectively, in ISO and in non-ISO;

at the final stage, the derived formulas were used to rethink the known experimental data on the kinematics of space objects.

"Traditional" mathematical transformations and calculations were not too complicated.

Results

Let's assume that at the initial moment of time in the center of the inertial reference system I $\{x, y, z, t\}$ there is a real object (a material point – MP). The center of system II $\{\xi, \eta, \zeta, \tau\}$, which coincides with the center of the first system, is rigidly connected with it. At this moment, the MP begins to move along the *x*-axis with acceleration $\vec{a}$. Together with it, the second system also moves rapidly, without rotating.

The MP in system II remains motionless during the entire observation time, so that $\xi = \eta = \varsigma = 0$, $\frac{d\xi}{dt} = 0$. If the reference systems were moving apart at a constant speed $\vec{v}_0$, then. as follows from equality (2), an observer located in the center of a motionless system would have recorded the coincidence of the velocities of MP and system II, $\frac{dx}{dt} = v_0$. It is natural to assume that in a more difficult situation $\frac{dx}{dt} = v(t)$. At the same time, however, one should not forget about the existence of an insurmountable "light barrier", and the rise of the speed of MP (and system II) should decrease to zero over time. By the way, it should be noted that *for the interpretation of this phenomenon it is not necessary to invent some retarding forces*

– it is explained within the framework of SRT by the fundamental properties of space-time.

In this article, the exact type of dependence *v*(*t*) is not determined; it is proposed to approximate it with a function that (at $t \to 0$) tends to *at* , and whose slope to the abscissa axis (at $t \to \infty$) monotonically decreases to zero,

$$v(t) = \frac{dx}{dt} = c\left[1 - \exp\left(-\frac{at}{c}\right)\right]. \qquad (4)$$

Integrating equality (4) in the range from 0 to *t*, we obtain the time dependence of the *x* coordinate (equation of motion):

$$x = \int_0^t v(t)dt = ct + \frac{c^2}{a}\exp\left(-\frac{at}{c}\right) - \frac{c^2}{a}. \qquad (5)$$

It follows from formula (5) that

- when $t \to 0$ the path length of the object gaining speed is proportional to the square of the observation time (as in the classical kinematics of a material point, $x = at^2/2$);

- when $t \to \infty$, the motionless observer will fix the approximate proportionality of the values *x* and *t* ($x \approx ct - c^2/a$).

If the object and the non-inertial reference system II accelerated away from the stationary system I, reached a speed $\vec{v}_0$, and then at *t* = 0 began to approach the stationary observer with acceleration ($-\vec{a}$) and move away from the "light barrier", then up to a stop at $t = v/a$ speed of this object will decrease at the modulus:

$$v(t) = \frac{dx}{dt} = v_0 - at. \qquad (6)$$

As you know, the results of measuring time intervals Δt and $\Delta\tau$ do not coincide if the experimenters are in two inertial systems of reference that are moving apart at a speed $\vec{v}_0$ [1]. Then the “effect of twins” is observed:

$$\Delta\tau < \Delta t; \quad \Delta\tau = \Delta t\sqrt{1 - \left(v_0^2/c^2\right)}. \qquad (7)$$

In the situation under discussion, system II is non-inertial, $v = v(t)$. Hence the ratio between the values Δt and $\Delta\tau$ must be calculated using the integral formulas given below, which had obtained after replacement v_0 in equality (7) on the functions (4) and (6):

$$\Delta\tau = \int_0^{\Delta t}\left[1 - \left(1 - e^{-at/c}\right)^2\right]^{1/2} dt \ , \qquad (8)$$

$$\Delta\tau = \int_0^{\Delta t} \left[1 - \left(\frac{v_0 - at}{c} \right)^2 \right]^{1/2} dt \ . \qquad (9)$$

It follows from these formulas that $\Delta\tau < \Delta t$ regardless of the magnitude and direction of acceleration of the mobile non-inertial reference system. On this basis, non-ISO does not differ from a moving inertial system – the so-called "twins paradox" (a decrease in the speed of time flow) should be detected in both of them.

Let us now consider the motion of the elements of Metagalaxy taking into account equations (4) and (5), which approximate time dependencies $v(t)$ and $x(t)$ in an infinitely wide interval, 0 < t < ∞. These equations, after excluding the exponential function of time from them, can be represented in this form:

$$at = -c \ln(1 - v/c), \qquad (10)$$

$$aR = cat - cv. \qquad (11)$$

It can be seen that if the velocity of a receding space object *v* and its distance to the Milky Way *R* are found, then it is not difficult to calculate unknown values of the acceleration modulus of this object and the time it takes to travel the measured distance (*a* and *t*).

Experiments have shown that when $R \approx 3 \cdot 10^{22} m$ the speed of removal of Metagalactic elements away the Milky Way is about $0{,}8 \cdot 10^6 m/s$, and with an increase in the specified distance by half, galactic star clusters scatter at a speed $\sim 1{,}2 \cdot 10^6 m/s$ [5].

Calculations performed on the basis of the above data give the following results:

- the acceleration of fleeing galaxies is negligible, it is equal to $(1{,}1 - 1{,}2) \cdot 10^{-11}\, m/s^2$; it means that these objects are affected by negligibly small forces, the nature of which is not discussed in kinematics, *in fact, fleeing galaxies move uniformly;*

- some elements of Metagalaxy overcame a distance $R \approx 3 \cdot 10^{22} m$ in $\sim 7{,}5 \cdot 10^{16} s$, others moved $6 \cdot 10^{22} m$ away from the Milky Way $\sim 10^{17} s$.

Suppose that the galaxies discovered in recent years, the most distant from the terrestrial observer and having a velocity of about 0.98 *c*, are sent after the Big Bang to the boundaries of the observable Universe with the same acceleration of $1{,}2 \cdot 10^{-11} m/s^2$ as slower moving space objects, whose velocity at *t* = 0 was much lower. Then it follows from equations (10) and (11) that such high-speed objects reached the boundaries of Metagalaxy in ~ $9{,}8 \cdot 10^{19}$ s, having moved away from the Milky Way by ~$22 \cdot 10^{22}$ m during this time.

In cosmology, it is customary to estimate the age of the Metagalaxy and its size based on Hubble's law – by the values of "Hubble time" $1/H \approx 4{,}5 \cdot 10^{17} c$ and "Hubble distance" $c/H \approx 13{,}5 \cdot 10^{25} m$ [4]. However, a critical analysis of the mentioned law (see above) proves that these estimates cannot be considered reliable. The characteristics of Metagalaxy given in this article are more realistic; it follows from them that *the age and size of the observable Universe are underestimated by Hubble calculations by 220 and 160 times, respectively*.

An alternative statement to the concept presented here is that the galaxies farthest from the Milky Way are moving with a large positive acceleration, and not almost uniformly. It is based on the discrepancy between the results of measuring distances to these objects R_b by the brightness of "standard candles" (type 1a supernovae located in them [8, 9] and R_{rs} by the redshift of lines in their emission spectra (that is, by Hubble's law, recognized as universal). It turned out that the brightness of supernovae is weaker than expected and $R_b > R_{rs}$.

It was proposed to explain this discrepancy between photometry and spectrometry data within the framework of Einstein's general theory of relativity (GRT), the fundamental equations of which contain a cosmological constant, traditionally denoted by the Greek letter Λ. The Λ-term in the GRT equations makes sense of antigravity, the source of which is considered to be dark energy [7].

Although the hypothesis of the existence of dark energy has many very authoritative supporters, there are numerous reasons for its criticism:

1) A. Einstein introduced the cosmological constant into the GRT equations, taking for truth the hypothesis of a stationary Universe, long ago refuted by astronomical observations of E. Hubble and many other researchers.

2) Back in 1922-1924, A. A. Friedman solved the GRT equations for the real Universe, that is, non-stationary, which did not contain the "antigravity" Λ-term [10]

3) Any models of a non-stationary Universe based on the recognition of the universality of Hubble's law cannot but cause doubts.

4) The introduction of the antigravity force into theoretical constructions contradicts the principle of universal simplicity – one of the main provisions of the methodology of scientific research formulated by W. Occam back in the XIV century: entities should not be multiplied unnecessarily. Dark energy is obviously a redundant entity, since the "unexpectedly" weak brilliance of distant galaxies is easily explained by the results of the calculations of the distances R to these objects from

the Milky Way given in this message, performed according to the equations of relativistic kinematics, in which there is no concept of dark energy.

5) If the accelerations of distant galactic star clusters are $\sim 10^{-11}\, m/s^2$, then there is no need to talk about the effect of a large negative pressure on them, exceeding the gravitational attraction. "Galaxies run away nor because some mysterious force is pulling them apart. Similarly, a stone does not fly up because it is repelled by the Earth. *Galaxies are moving away from each other because they were scattered by the Big Bang in the past*" [10].

6) Without the introduction of redundant entities (provisions that complement the fundamental concepts of the Universe), one can do not only when studying the laws of the evolution of Metagalaxy after the reionization of matter, but also when describing its "maturation" in much earlier times – at the dust stage and in the "dark ages". In any case, it was not necessary to accept the dark energy hypothesis in order to construct the theory of primary nucleosynthesis [11].

Conclusion

The main results of the work performed are as follows:

1) Mathematical expressions are proposed that approximate the time dependence of the velocity of an object that is moving away from a stationary observer with constant acceleration, and the equation of motion of this object. Thus, logically justified additions have been made to the classical relativistic kinematics.

2) These additions are practically significant. They made it possible to prove the universality of the relativistic "twins paradox", to calculate the acceleration of scattering space objects, to clarify the size and age of the Metagalaxy, to point out the doubtful existence of dark energy.

Hence, the stated purpose of the work has been achieved. The conducted research opens up the prospect of using modified relativistic kinematics to clarify ideas about the laws of motion of any objects, including elementary particles, with velocities approaching the "light barrier".

References

1. Fok V. A. Theory of space, time and gravitation. – Moscow: State Publishing House of Technical and Theoretical Literature, – 1955. – 504 p. (rus).

2. Bailey et al. Measurements of relativistic time dilatation for positive and negative muons in a circular orbit // Nature. – 1974. – No 268 (5618). – P. 301-305.

3. Vygodsky M. Ya. Handbook of Higher Mathematics. – Moscow: AST Publishing House, – 2008. – 991 p. (rus).

4. Weinberg S. Cosmology. – Moscow: URSS, – 2013. – 608 p. (rus).

5. Hubble E. A relation between distance and radial velocity among extragalactic nebulae // Proceeding of the National Academy of Sciences. – 1929. – No 15 (3). – P. 168-173.

6. Kuznetsov V. M. Concepts of the universe in modern physics. – Moscow: Academic book, – 2006. – 144 p. (rus).

7. Chernin A.D. Dark energy and global anti-gravity // Advances in Physical Sciences. – 2008. – No 178 (3). – P. 267-300. (rus).

8. Pearlmutter S. et al. Measurement of the acceleration of cosmic expansion by supernovae // Astrophys. J. – 1998. – No 517. – P. 565-586.

9. Riess A. G. et al. Observation evidence from supernovae for an accelerating Universe and cosmological constant // Astron. J. – 1998. – No 116. – P. 1009-1038.

10. Weinberg S. The first three minutes. – Moscow: AST Publishing House, – 2018. – 256 p. (rus).

11. Alpher R. A. et al. The origin of the chemical elements // Phys. Rev. – 1948. – No 73 (7). P. – 73-74.