LETTERS TO PROGRESS IN PHYSICS

On the Astronomical Observations of Instant Transmission of Signals from Stars and Their Explanation in the Framework of General Relativity

Dmitri Rabounski and Larissa Borissova

Puschino, Moscow Region, Russia. E-mail: rabounski@yahoo.com; lborissova@yahoo.com

This article discusses the astronomical observations of instant transmission of signals from stars (long-range action), performed in 1977–1979 by Prof. N. A. Kozyrev. It is shown that stopping physically observable time, which is a necessary condition for instant transmission of a signal, is impossible in the Minkowski space (which is the space-time of Special Relativity) due to its geometric structure, i.e., the very structure of the Minkowski space does not allow long-range action. On the other hand, this is possible in the space-time of General Relativity due to the presence of the gravitational field potential or the rotation of space (due to the non-orthogonality of time lines to the three-dimensional spatial section), or both of these factors presented together. Thus, Kozyrev's astronomical observations of instant transmission of signals from stars (long-range action) find their explanation in the space-time of General Relativity.

1 Experimental results

Nikolai A. Kozyrev (1908, St. Petersburg — 1983, ibid.) was one of the most productive astronomers of the 20th century, best known due to his discovery of volcanism on the Moon in 1958 [1] and the atmosphere of Mercury in 1963 [2]. For the discovery of lunar volcanism, Kozyrev was awarded the gold medal of the International Academy of Astronautics, encrusted with seven diamonds in the form of stars of the constellation Ursa Major (Paris, 1969). Prof. Kozyrev worked at the Pulkovo Astronomical Observatory near St. Petersburg. Read about him in the *Encyclopaedia Britannica* [3] and in a detailed biography for his 100th birthday [4].

In addition to his studies in astronomy, Kozyrev in 1958 introduced the "causal or asymmetrical mechanics" [5] that takes the physical properties of time into account. Continuing this research, he described his many years of experimental research on this topic [6, 7]. In particular, Kozyrev arrived at the conclusion about the possibility of astronomical observations using the physical properties of time [8].

The apotheosis of this research were the astronomical observations using the 50-inch reflecting telescope of the Crimean Astronomical Observatory, during which in 1977–1979 Kozyrev registered the effect of long-range action, i.e., the instant transmission of signals from stars [9, 10].* His astronomical observations were then reproduced and successfully confirmed in 1989 [11, 12] by a group of scientists, headed by Irène A. Eganova and Michael M. Lavrent'ev from the Sobolev Institute of Mathematics (Novosibirsk).

Since the original two papers [9, 10] in which Kozyrev reported the instant transmission of signals from stars were published in Russian, and the reports [11, 12] confirming his results are only short communications from the USSR Academy of Sciences (in English), we must first explain the details of Kozyrev's astronomical observations.

Based on his previous research into the causal or asymmetric mechanics [5], Kozyrev concluded that time has different speeds at different points of space depending on the active processes of destruction or creation (increase or decrease in the level of entropy) at these points.† Kozyrev considered the field of distribution of time speeds around active processes of destruction or creation as one of the physical properties of time, which he called the *field of time density* [6, 7]. By this he meant that time is not just the fourth coordinate of space-time, but a real physical field, the non-uniformity of which can affect physical bodies and the processes occurring in them. Therefore, Kozyrev concluded, around any star there must be a field of time speeds (a field of time density) due to the active processes of destruction (loss of organization of stellar substance) occurring in it.

Since time does not spread, Kozyrev reasoned, but appears instantly throughout the entire three-dimensional space of the Universe (which is an instant three-dimensional section of space-time at the moment of observation), therefore the organization lost by stars can be transmitted from them by the field of time density instantly over any distance. The effect of this transmission must decrease inversely proportional to the square of the distance between the points of departure (a star) and arrival (a detector), i.e., inversely proportional to the area of a sphere as it should be in a space of three dimensions.

As a result, Kozyrev expected that the field of time den-

*In these papers, Prof. Kozyrev, who usually did not have co-authors in publications, had added the name of his laboratory engineer Victor V. Nassonov (1931–1986) in recognition of his many years of assistance.

†This is similar to how, in the space-time of General Relativity, the intervals of physically observable time are shortened (compared to the intervals of time in unperturbed space) depending on the potential of the gravitational field that fills the space and on the speed of rotation of the space itself.

sity created by any star can instantly initiate microprocesses of creation (organization) in a physical detector placed at the focus of a reflector telescope.*

This idea was confirmed by the astronomical observations performed by him in 1977–1979 (with the assistance of his laboratory engineer Nassonov) on the 50-inch reflecting telescope of the Crimean Astronomical Observatory [9, 10].

As a detector, Kozyrev used a metal-film resistor built into a Wheatstone bridge (and later — a thermocouple) installed in the focal plane of the telescope directly behind the narrow slit usually intended for a spectrograph, parallel to the slit. The slit was sawn in a 1-cm thick aluminum plate. Its width was 0.25 mm = 2″ in the sky. To increase the angular resolution of the observations, the slit (and detector) were oriented perpendicular to the daily motion of the celestial sphere. The detector and the entire measuring system were reliably isolated by a 1-cm thick aluminum case from external temperature influences, as well as from the influences of various processes in the telescope tower and beyond, so that random fluctuations from external influences registered by the detector were rare and did not affect the planned astronomical observations. The light from the observed astronomical objects was reliably shielded by a shutter made of black dense cardboard used in the packs of photographic plates, installed together with a thin glass plate in front of the slit (the thin glass plate covered the slit to prevent air circulation from the telescope into the measuring system).

Once the telescope was pointed at a point in the sky in front of a star, close to its visible position, Kozyrev slowed down the telescope's guiding mechanism slightly, causing the slit (and detector) installed in the focal plane of the telescope to slowly "scan" the sky in front of the visible star toward it along the right ascension.

Kozyrev proposed this method of observation, because his target was the true position of the visible stars at the moment of observation, which could be registered by the detector only in the case of instant transmission of signals through the field of time density. Whereas the visible position of a star in the sky is in the past, at the moment of time when the star emitted the light signal that we see in the form of its visible image. In other words, the visible position of a star "lags" relative to its true position in the sky, which is ahead of it, by the angular distance travelled by the star in the sky (due to its own motion relative to other stars) until the light emitted by the star reached an observer on the Earth and thereby created the visible image of the star.

The true position of a star can be calculated relative to its visible position, knowing the tangential velocity of the star relative to the Solar System (and the Earth) and the distance to the star, calculated based on its trigonometric parallax†. These data, obtained through astrometric observations over the past two centuries, can be found in astronomical catalogues and yearbooks.

The first series of astronomical observations according to the mentioned "scanning" method was performed by Kozyrev and Nassonov in October 1977. They immediately found that the detector responded reliably to the true position of the observed stars. The results were published in the paper [9].

In addition, the detector also responded to the visible position of the stars (where they are visible in the sky), despite the fact that it was reliably shielded from their light (see above). The difference in angular distance between the true and visible positions of the stars measured using the detector $\Delta\alpha_{\rm ob}$ and $\Delta\alpha_{\rm c}$ calculated from astronomical catalogues (both along the right ascension α) was in the range of 1″ to 4″, which is comparable to the slit in front of the detector (it selected 2″ on the celestial sphere, see above).

Table 1 shows the results of these astronomical observations. In Table 1, in addition to $\Delta\alpha_{\rm ob}$ and $\Delta\alpha_{\rm c}$ explained above, $\Delta\alpha_{\odot}$ is the angular distance between the true and visible positions of the stars, corrected for the value A_α of their annual aberration‡ along the right ascension

$$\Delta\alpha_{\odot} = \Delta\alpha - A_\alpha\,,$$

and the parallax π of each star is calculated based on its own annual angular displacement μ_α with respect to other stars and the celestial coordinates along the right ascension

$$\pi = 3.26\,\frac{\mu_\alpha}{\Delta\alpha_{\odot}}\,.$$

Besides the stars, they observed Jupiter, Mars, and Venus. Jupiter showed no effect on the detector. Mars showed the same effect as Venus (see Table 1).

An anomaly was the star ι Per, for which the observations yielded an abnormally large value of $\Delta\alpha_{\rm ob} - \Delta\alpha_{\rm c} = +28''$ that most likely corresponded to another faint object located near this star.

The value of $\Delta\alpha_{\odot} = \Delta\alpha - A$ and the parallax π calculated from the measured distances $\Delta\alpha_{\rm ob}$ for three stars having small unknown parallaxes are given in square brackets.

It is interesting that the detector responded to both the true and visible positions of the stars even when the telescope's main mirror was covered by a shutter that reliably screened the light. In this case, the magnitude of the registered effect was weakened to the same extent for both the true and visible positions of the stars. "Consequently, the influence of the visible image [in this experiment] is not related to the light, but only coincides with its direction" — Kozyrev wrote [9].

*Since the glass of lenses, like any amorphous material, should absorb this effect, a refractor telescope is not applicable for this task.

†This is the very small angle at which the radius of the Earth's orbit is seen from the star. If you measure the position of a star relative to other stars in the sky several times during one year, when the Earth is at different points in its orbit around the Sun, the star will appear slightly offset relative to the other stars. Half of this apparent angular displacement of the star over the course of a year is called its trigonometric parallax.

‡Annual stellar aberration A is the observed displacement of stars from their actual positions on the celestial sphere, caused by the Earth's motion along its orbit around the Sun.

Star	Stellar magnitude	Spectral class	π	μ_α	$\Delta\alpha_\odot$	A_α	$\Delta\alpha_c$	$\Delta\alpha_{ob}$	$\Delta\alpha_{ob}-\Delta\alpha_c$	Reg. magnitude (in scale divisions)		Date of observation
										vis. pos.	true pos.	
ε And	4.52	G_5	0″.031 ± 5	−0″.232	−24″ ± 4	−17″	−41″ ± 4	−38″ −43″	+3″ −2″	5 2	6 4	21 October 1977 22 October 1977
η Cas	3.64	F_8	0″.182 ± 5	+1″.101	+19″ ± 0	−18″	+1″ ± 0	0	−1″	6	6	21 October 1977
o Cet	2.0 – 10.1	M_{5e}	0″.013 ± 5	−0″.009	−4″ ± 0	−19″	−23″ ± 0	−26″ −21″ −27″	−3″ +2″ −4″	0.2 0.8 0.0	1.3 1.2 10	23 October 1977 23 October 1977 20 October 1977
ρ Per	3.3 – 4.1	M_3	0″.008 ± 16 [0″.0040]	+0″.132	 [102″]	−16″ −16″ −17″		+80″ +85″ +88″		 0.0	 1.2	12 October 1977 13 October 1977 21 October 1977
ι Per	4.17	G_0	0″.084 ± 15	+1″.266	+48″ ± 2	−17″	+31″ ± 2	+59″ +59″	+28″? +28″?	10.0 1.1	13.2 1.8	22 October 1977 23 October 1977
α Tau	1.1	K_5	0″.048 ± 4	+0″.069	+5″ ± 0	−12″	−7″ ± 0	−5″	+2″	—	15 30	13 October 1977 8 October 1977
o^2 Eri	4.5	K_0	0.200	−2″.225	−35″	−13″	−48″ ± 0	−50″	−2″	—	5	13 October 1977
α CMa	−1.58	A_0	0″.375 ± 4	−0″.537	−5″	−2″	−7″ ± 0	−5″	+2″	—	20	12 October 1977
α Ori	0.0 – 1.2	M_0	0″.005 ± 4 [0″.0067]	+0″.027	[+12″]	−12″		0″		1.5	1.5	27 October 1977
ξ Gem	3.4	F_5	0″.051 ± 6	−0″.111	−7″ ± 1	−9″	−16″ ± 1	−19″	−3″	0.8	2.2	27 October 1977
β Gem	1.21	K_0	0″.093 ± 5	−0″.623	−21″ ± 1	+4″	−17″ ± 1	−20″	−3″	3	3	19 October 1977
α CMi	0.48	F_5	0″.288 ± 5	−0″.707	−8″ ± 0	−4″	−12″ ± 0	−12″	0″	1.3	5.5	27 October 1977
Venus						—	+36″	+37″ +38″	+1″ +2″	8 8	5 8	18 October 1977 22 October 1977
α Lyr	0.14	A_0	0″.123	+0″.200	+5″ ± 0	−2″	+3″ ± 0	+5″	+2″	4.8	6	20 October 1977
θ Peg	3.70	A_2	0″.042 ± 5	+0″.0272	+21″ ± 2	−9″	+12″ ± 2	+14″	+2″	0.0	0.7	22 October 1977
ξ^2 Aqr	4.42	F_2	0″.013 ± 5	+0″.204	+50″ ± 13	−11″	+39″ ± 13	+40″ +43″	+1″ +4″	 0.3	0.6 0.7	23 October 1977 23 October 1977
β Peg	2.1 – 3.0	M_0	0″.015 ± 5	+0″.188	+39″ ± 13	−14″	+25″ ± 13	+26″	+1″	0.0	0.0	20 October 1977
ψ Peg	4.75	M_0	0″.003 ± 5 [0″.0042]	−0″.039	[−27″]	−16″		−43″		0.3	0.5	23 October 1977

Table 1: Results of the first series of Kozyrev's astronomical observations, in which he registered the instant transmission of signals from stars. October, 1977. Quoted from the original publication [9].

Star	Stellar magnitude	Spectral class	π	μ_α	$\Delta\alpha_\odot$	Date of observation
β Tri	3.08	A_5	$0''.012$	$+0''.150$	$+39''$	12 October 1977
λ Tau	3.8 – 4.1	B_3	$-0''.009$	$-0''.006$	?	23 October 1977
α Tau	1.1	K_5	$0''.048$	$+0''.069$	+5	22 and 23 October 1977
γ Psc	3.85	K_0	$0''.025$	$+0''.756$	+95	22 October 1977
ω Psc	4.03	F_5	$0''.012$	$+0''.147$	+15	22 October 1977

Table 2: Four stars that had no effect on the detector, and also the star α Tauri, whose effect was found to be variable. October, 1977. Quoted from the original publication [9].

Four of the observed stars had no effect on the detector, most likely due to the low sensitivity of the signal registering system used in the observations. They are listed in Table 2.

In addition, Kozyrev concluded that the star α Tau most likely emits a variable time density. This explained the fact that, as is seen from Table 1 and Table 2, this star produced a very strong effect on October 8, then its influence on the detector halved on October 13, and there was no influence on October 22 and 23.

In the second series of the astronomical observations, Kozyrev and Nassonov increased the sensitivity of the signal registering system by almost one order of magnitude, and also extended the area of the sky subject to "scanning" near each observed star. The latter was due to the fact that, as Kozyrev reasoned, since the detector responded to the signals transmitted instantly through the field of time density from the true position of the star (where it is at the present moment of time) and from its visible position in the past (along the trajectory of the light coming from it), then the field of time density should also instantly transmit the signals coming from the star and along the "reverse trajectory of light", along which the position of the Earth at the present moment of time is visible from the star located in the future.

In other words, the detector must respond to the signals transmitted instantly through the field of time density from three points in the sky associated with each observed star:

1. The visible (past) position of the star, where it was in the past when it emitted the light signal that we see at present as its visible image in the sky;
2. The true position of the star, where it actually is at the present moment of time;
3. The position of the star in the future, symmetric to its visible position in the past with respect to its true position in the sky.

The signals coming instantly through the field of time density from the first position of a star (its visible position in the past) indicate that the star not only exists at the present moment of time, but in fact continues to exist as a real object in the past. Whereas the third position of the star (in the future) makes it possible to instantly observe the future of the star as an already existing reality.

This second series of the astronomical observations was performed during the spring and autumn of 1978, and also in May 1979, using the same 50-inch reflecting telescope. The results were published in the paper [10]. They are shown here in Table 3, where $\Delta_1\alpha_{\rm ob}$ means the observed angular distance between the true position of the star (where it is at the present moment of time) and its visible position (in the past), while $\Delta_2\alpha_{\rm ob}$ is the observed distance between the symmetrical position of the star in the future and its visible position (theoretically, it should be $\Delta_2\alpha_{\rm ob} = 2\Delta_1\alpha_{\rm ob}$).

The detector responded to all three mentioned positions of each observed star (except only ι Persei).

As previously in 1977, in the first series of the observations, ι Persei showed an anomaly: the detector did not respond to its true position (in the middle between its positions in the past and in the future), but reliably detected its position in the future $\Delta_2\alpha_{\rm ob} = +59''$. Most likely this star has variable activity and was weakened during the season of these observations.

Since the values of the stellar aberration A differ in spring and autumn (due to the Earth moving in different directions in its orbit), the values of A for α Lyrae differ greatly in spring and autumn (A even changes its sign). This also led to a corresponding change in the sign of the measured values of $\Delta_1\alpha_{\rm ob}$ and $\Delta_2\alpha_{\rm ob}$, in full agreement with the theory.

In addition to the stars, the aforementioned "scanning" method of astronomical observations was also used to observe extended astronomical objects: the globular cluster M2 in Aquarius, the globular cluster M13 in Hercules, and the galaxy M31 (Andromeda Nebula). Since these are not point-like objects (unlike stars) and they are not uniform, then scanning each one creates three non-uniform profiles of it, corresponding to its past, present and future, which are superimposed on each other. As a result, in the scan of each of the extended astronomical objects, the hills of maximum influence on the detector were split into three peaks corresponding to the past, present and future. These scanned profiles, which were non-uniform in structure, also showed a decrease in the

Star	Stellar magnitude	Spectral class	π	μ_α	$\Delta\alpha_\odot$	A_α	$\Delta\alpha_c$	$\Delta_1\alpha_{ob}$	$\Delta_2\alpha_{ob}$	Date of observation
10 UMa	4.1	F_5	$0''.071\pm5$	$-0''.436$	$-20''$	$-9''$	$-29''\pm1$	$-28''$	$-57''$	13 April 1978
α Leo	1.3	B_8	$0''.039\pm7$	$-0''.248$	$-20''$	$-12''$ $-4''$	$-32''\pm4$ $-24''\pm4$	$-35''$ $-26''$	$-70''$ $-50''$	7 April 1978 8 May 1979
γ Boo	3.0	F_0	$0''.016\pm7$	$-0''.115$	$-23''$	$-20''$	$-43''\pm7$	$-50''$	$-97''$	24 April 1978
ε Boo	2.7	K_0	$0''.013\pm7$	$-0''.049$	$-12''$	$-20''$	$-32''\pm6$	$-35''$	$-67''$	13 May 1979
α Lyr	0.14	A_0	$0''.123\pm5$	$+0''.200$	$+5''$	$-2''$ $-18''$	$+3''\pm0$ $-13''\pm0$	$+5''$ $-12''$	 $-23''$	20 October 1977 14 May 1979
ι Per	4.2	G_0	$0''.084\pm5$	$+1''.266$	$+48''$	$-17''$	$+31''\pm2$	no	$+59''$	22–23 October 1977
τ Per	4.1	G_8, A_5	$0''.012\pm5$	$0''.000$	0	$-20''$	$+20''\pm0$	$-27''$	$-46''$	3 November 1978
ξ^2 Aqr	4.4	F_2	$0''.013\pm5$	$+0''.204$	$+50''$	$-11''$	$+39''\pm13$	$+42''$ $+38''$	 $+80''$	23 October 1977 29 October 1978
β Peg	2.1 – 3.0	M_0	$0''.015\pm5$	$+0''.188$	$+39''$	$-14''$	$+25''\pm13$	$+26''$ $+35''$	 $+60''$	20 October 1977 29 October 1978

Table 3: Results of the second series of Kozyrev's astronomical observations. The detector responded to three positions of each observed star (except ι Persei): its position in the past (visible position), in the present (its true position), and in the future symmetrical to its visible position in the past. Spring and autumn 1978, and also May 1979. The values of $\Delta_1\alpha_{ob}$ measured in the first series of the astronomical observations (October 1977, see Table 1) are given as a reference. Quoted from the original publication [10].

Star	π	μ_α	$\Delta\alpha_\odot$	A_α	$\Delta\alpha_c$	$\Delta\alpha_{ob}$
β Peg	$0''.015\pm5$	$0''.217$	$47''.16$	$+33''.52$	$+13''.6$	$+12''.6\pm1''.3$
β And	$0''.043\pm5$	$0''.220$	$16''.72$	$+41''.58$	$-24''.9$	$-25''.4\pm1''.7$
δ And	$0''.024\pm6$	$0''.162$	$22''.00$	$+39''.51$	$-17''.5$	$-20''.2\pm2''.5$

Table 4: Results of the testing astronomical observations conducted by Eganova and Lavrent'ev. 13 October 1989. Quoted from the original publication [11].

magnitude of the effect near the centre of each extended astronomical object: Kozyrev explained this by the supposition that where the stellar density is very high, there is a strong absorption of the field of time density [10].

It should be noted that although we unfortunately were not personally acquainted with Prof. Kozyrev (we read these publications already after his death), one of the authors of this paper, Dmitri Rabounski, visited Victor Nassonov twice at his apartment in St. Petersburg in 1985 shortly before his sudden death (at that time, Nassonov headed a laboratory at an industrial company). Nassonov demonstrated the recordings of an automatic recorder used in the last series of the astronomical observations (instead of the pointer galvanometer used at the initial stage). The recorded tapes clearly indicated three peaks of the signals, recorded for each of the observed stars and corresponding to its successive positions in the past, present and future on the celestial sphere.

It is no wonder that other scientists also took notice of these astronomical observations. In 1989, Irène A. Eganova and Michael M. Lavrent'ev, Director of the Sobolev Institute of Mathematics (Novosibirsk) and a Fellow of the USSR Academy of Sciences, decided to reproduce Kozyrev's astronomical observations. Their collaborators at the Institute in Novosibirsk reproduced Kozyrev's experimental setup, then Eganova and Lavrent'ev, together with their research group, performed testing astronomical observations according to Kozyrev's method on the same 50-inch reflecting telescope of the Crimean Astronomical Observatory. To be more confident in the result, they scanned the area of the sky near each observed star not only in one direction (as Kozyrev did), but also in two directions (there and back). Excerpts from their testing observations of the stars β Pegasi, β Andromedae and δ Andromedae are shown in Table 4, quoted from their first short report [11].

In their second short report [12], Eganova and Lavrent'ev reported the registration of signals coming from the true position of the Sun preceding the visible one by $2°4'.6$ (four visible diameters of the Sun) — the angular distance travelled by the Sun in 8.3 minutes, during which the light emitted by it reaches the Earth. The detector was installed in the focal plane of a small 4-inch reflecting telescope, the main mirror of which was reliably shielded from the light coming from the Sun, and the signal registering system was protected from solar thermal effects. The detector in one series of the observations was a metal-film resistor built into a Wheatstone bridge as before. According to the records of scanning the near-solar space, the resistor responded to both the true and visible positions of the Sun, as when observing the stars. In the second series, it was a container with Escherichia coli bacteria in the state of anabiosis, which they exposed to the true position of the Sun for 3 minutes, while a control container with bacteria of the same brood remained in the laboratory. It was found that after exposure to the true position of the Sun, the number of viable cells increased by 1.2 – 3 times (depending on the specific brood).

"Not a single fact was found that contradicted Kozyrev's observations, however, further research is required to confirm his conclusions regarding the properties of the observed effect" — they concluded [11].*

Indeed, one cannot but agree with this conclusion. Yes, the effect discovered by Prof. Kozyrev was weak and his astronomical observations were difficult to reproduce. On the other hand, this was not a single unique experiment. The discovered effect was registered on many stars over several years and was confirmed by astronomical observations of an independent group of scientists.

We must therefore carefully search for a theoretical basis that could explain the instant transmission of signals in the framework of modern theoretical physics. A theory of this effect could determine the key physical factors of this process, and, accordingly, determine methods for enhancing these factors in order to create a new industrial technology of communication and transport.

This was one of the reasons why we started our own theoretical research on this topic in the mid-1980s and why we are now writing this article.

2 Theoretical explanation

In fact, Kozyrev's astronomical observations showed that signals from each star in the real space-time are instantly transmitted to the observer from its three positions in the sky: its visible position in the past (along the trajectory of light), its true position at the moment of observation and its position in the future (along the "reverse trajectory of light").

Kozyrev originally believed [13] that the results of his astronomical observations could be interpreted in the framework of the four-dimensional Minkowski space (which is the space-time of Special Relativity). He proceeded from the fact that the four-dimensional metric (four-dimensional distance between two adjacent points) in the Minkowski space is expressed in the form

$$ds^2 = c^2dt^2 - dx^2 - dy^2 - dz^2 = c^2dt^2\left(1 - \frac{\mathrm{v}^2}{c^2}\right),$$

where v is the velocity of a signal in the three-dimensional space. Kozyrev argued that the four-dimensional distance in the Minkowski space, say, between a star and an observer, is zero $ds = 0$ along three world lines. The line $dt = 0$, coinciding with the three-dimensional space of the observer, indicates the true position of the star, where we would see it if light travelled instantly. The line $\mathrm{v} = +c$ indicates the position of the star in the past, when it emitted the light signal that we see as its image in the sky. The line $\mathrm{v} = -c$ indicates the position of the star in the future, symmetrical to its visible position in the past (with respect to its true position), when the light signal emitted from the Earth reaches it.

However, this statement by Kozyrev does not correspond to the geometry of the Minkowski space (Kozyrev was an outstanding astronomer of the 20th century, but was not familiar with Riemannian geometry). Below we show why and how the instant transmission of signals is explained in the space-time of General Relativity.

Definition: *Instant transmission of a signal* means that the interval of physically observable time, registered by the observer between the sending of the signal and its arrival, is zero. In other words, the physically observable time of an instantly transmitted signal, registered by the observer, stops.

Physically observable quantities in the four-dimensional pseudo-Riemannian space (the space-time of General Relativity, a particular case of which is the Minkowski space) are defined as the projections of four-dimensional generally covariant quantities onto the three-dimensional spatial section and the time line associated with an observer. Such physically observable projections are invariant throughout the observer's spatial section (his observable three-dimensional space), depend on its geometric and physical properties, and are, therefore, called *chronometric invariants* [14–17].

Thus, the interval of physically observable time $d\tau$ registered by an observer is the projection of the four-dimensional displacement vector x^α $(\alpha = 0, 1, 2, 3)$ onto his time line

$$d\tau = \sqrt{g_{00}}\, dt - \frac{1}{c^2}\, v_i\, dx^i,$$

where dt is the interval of coordinate time, which would be counted by the observer in the absence of disturbing factors, the time (zero) component g_{00} of the fundamental metric tensor $g_{\alpha\beta}$ is expressed with the potential w of the gravitational field that fills the space of the observer

$$\sqrt{g_{00}} = 1 - \frac{\mathrm{w}}{c^2}\,, \qquad \mathrm{w} = c^2\left(1 - \sqrt{g_{00}}\right),$$

*Their reports [11, 12] were published in the short communications from the USSR Academy of Sciences, known as *Doklady Akademii Nauk SSSR*, which is a highly influential and prestigious scientific journal, intended only for the Academy Fellows (or for the communications personally recommended by them) and published in English since 1956.

and v_i is the three-dimensional vector of the linear velocity of rotation of the observer's space

$$v_i = -\frac{c\,g_{0i}}{\sqrt{g_{00}}}\,, \qquad v^i = -c\,g^{0i}\sqrt{g_{00}}\,,$$

which is caused by $g_{0i} \neq 0$ (meaning that the observer's spatial section is non-orthogonal to his time line) and therefore it cannot be eliminated by coordinate transformations along the spatial section of the observer.

The physically observable three-dimensional interval $d\sigma$ is determined as

$$d\sigma^2 = h_{ik}\,dx^i dx^k,$$

where

$$h_{ik} = -g_{ik} + \frac{1}{c^2}\,v_i v_k\,, \quad h^{ik} = -g^{ik}, \quad h^i_k = \delta^i_k$$

is the physically observable three-dimensional metric tensor, which is the projection of the fundamental metric tensor $g_{\alpha\beta}$ onto the spatial section of the observer and possesses all its properties throughout his spatial section (three-dimensional observable space). Thus, the square of the four-dimensional (space-time) interval $ds^2 = g_{\alpha\beta}\,dx^\alpha dx^\beta$ expressed in terms of physically observable quantities has the form

$$ds^2 = c^2 d\tau^2 - d\sigma^2.$$

In the Minkowski space, as is seen from the Minkowski metric that above, $g_{00} = 1$ that means the absence of gravitational fields (the gravitational potential is $\mathrm{w} = 0$), and also $g_{0i} = 0$ meaning that the three-dimensional space (spatial section) is everywhere orthogonal to the time lines piercing it, and, hence, it does not rotate ($v_i = 0$). Therefore, the interval of physically observable time $d\tau$, which is registered by an observer in the Minkowski space, is always

$$d\tau = dt\,.$$

This fact, in particular, means that in the Minkowski space (the space-time of Special Relativity) there are *no geometric or physical disturbing factors* that could cause stopping physically observable time. In such a space, the concept of stopping time is essentially absent: according to the geometry of the Minkowski space, the physically observable time coordinate registered by the observer is $dx^0 = cd\tau = cdt$, i.e., it changes absolutely uniformly throughout the space along the directrices of the light cone of the observer at a speed equal to $\pm c$ (the plus sign takes place when counting time into the future, and the minus sign — when counting time into the past). The physically observable time interval in the Minkowski space is zero $dx^0 = cdt = 0$ only at the space-time point, where the vertices of the light cones of his past and future converge (i.e., only at the point of his observation), but not along any three-dimensional path between him and another object in space (say, a star). Consequently:

> Since stopping physically observable time in the Minkowski space is in principle impossible due to the fact that its geometric structure does not contain disturbing factors that could stop time, the geometric structure of the Minkowski space itself does not allow instant transmission of a signal.

On the other hand, despite the error in Kozyrev's theoretical explanation [13], the results of his astronomical observations indicate that instant transmission of signals from stars is an ordinary phenomenon in the real space-time.

Another case — the space-time of General Relativity, because it allows all conceivable disturbing factors characteristic of pseudo-Riemannian spaces due to their Riemannian geometry.

We considered the conditions for stopping physically observable time in the space-time of General Relativity in our works on the theory of non-quantum teleportation, which we began in the late 1980s and continue to this day. Everything that follows is based on the theoretical background, published in 2001 in our research monograph [18], and then — in our subsequent papers [19–21].

Derive the *physical conditions that stop observable time*. From the definition of the interval of physically observable time $d\tau$ in the space-time of General Relativity (see above), we obtain that the physically observable time stops for an observed object ($d\tau = 0$) under the physical conditions

$$\mathrm{w} + v_i u^i = c^2,$$

determining the necessary combination of the potential w of the gravitational field that fills the space, the linear velocity v_i with which the space rotates, and also the coordinate velocity $u^i = \frac{dx^i}{dt}$ of the object with respect to the observer.

These physical conditions at first glance seem exotic for a regular laboratory: an extremely strong gravitational potential and speeds close to the speed of light. However, these conditions that stop observable time are realized inside every physical body in the range from elementary particles to planets and stars. And we will now show why.

Since every physical body possesses mass, its gravitational field has a breaking at a distance from its barycentre, which is equal to its gravitational radius $r_g = 2GM/c^2$ calculated for its mass M. For instance, at $r = r_g$ from the barycentre, the zero (time) component g_{00} of the fundamental metric tensor of the Schwarzschild mass-point metric

$$ds^2 = \left(1 - \frac{r_g}{r}\right) c^2 dt^2 - \frac{dr^2}{1 - \frac{r_g}{r}} - r^2 \left(d\theta^2 + \sin^2\theta\, d\varphi^2\right),$$

which describes the space of a massive spherical body approximated by a material point, is zero

$$g_{00} = 1 - \frac{r_g}{r} = 0\,.$$

Therefore, the potential of the gravitational field of every physical body on a spherical surface of the radius r_g around its barycentre is

$$\mathrm{w} = c^2 \left(1 - \sqrt{g_{00}}\right) = c^2,$$

which is the same in the space of a rotating massive spherical body, because the component g_{00} has the same formula for these two spaces. You can see this from the space metric of a massive spherical body that rotates along its equatorial coordinate axis φ with a constant angular velocity $\omega = const$, which was introduced and proved in [22]

$$ds^2 = \left(1 - \frac{r_g}{r}\right) c^2 dt^2 - 2\,\omega r^2 \sin^2\theta \sqrt{1 - \frac{r_g}{r}}\, dt\, d\varphi - \\ - \frac{dr^2}{1 - \frac{r_g}{r}} - r^2 \left(d\theta^2 + \sin^2\theta\, d\varphi^2\right).$$

Such a tiny spherical surface, we concluded in our previous paper [23], exists around the barycentre deep inside absolutely every physical body simply because physical bodies possess mass.

The condition $\mathrm{w} = c^2$ means stopping physically observable time $d\tau = 0$, which is also the condition for instant transmission of signals, if the body does not rotate ($v_i = 0$). This means that the condition for instant transmission of signals ($d\tau = 0$) is satisfied on the spherical surface $r = r_g$ around the barycentre of every non-rotating body. For rotating bodies, $d\tau = 0$ is satisfied under $\mathrm{w} + v_i u^i = c^2$ (see above). Therefore, since $d\tau = 0$ in this case is satisfied at a lower value of the gravitational potential w due to the second term caused by the rotation of space, the condition for instant transmission of signals is satisfied inside every rotating body on a sphere enveloping its barycentre slightly above the radius r_g.

Thus, we arrive at the conclusion:

> According to General Relativity, the condition of instant transmission of signals is satisfied on a tiny spherical surface of the gravitational radius (for non-rotating bodies) or slightly above it (for rotating bodies), existing around the barycentre deep inside absolutely every physical body in the range from elementary particles to planets and stars.

The path along which signals can be instantly transmitted in the pseudo-Riemannian space is determined by the condition of instant signal transmission ($d\tau = 0$) and is described by the obvious equation

$$\tau = const\,,$$

which describes trajectories along the three-dimensional spatial section of the observer (his observable three-dimensional real physical space), which is generally non-uniform, curved, rotating and deformable. Along such trajectories, neither the four-dimensional (space-time) interval ds nor the physically observable three-dimensional interval $d\sigma$ between the points of departure and arrival of the instantly transmitted signal are not equal to zero

$$c^2 d\tau^2 = 0\,, \qquad ds^2 = c^2 d\tau^2 - d\sigma^2 = -d\sigma^2 \neq 0\,.$$

The resulting equation of trajectories for instant signal transmission, together with the previous conclusion about the location of the conditions for stopping observable time, lead us to the conclusion:

> The spherical surfaces, enveloping the barycentres of all physical bodies at their gravitational radius (for non-rotating bodies) and slightly above it (for rotating bodies), on which physically observable time stops, are all connected to each other by trajectories of stopping observable time. Signals, instantly transmitted along these trajectories, instantly connect all physical bodies in the Universe.
>
> Trajectories of this type instantly connect any observer with stars and indicate the middle (true) position of stars, which was registered in Kozyrev's astronomical observations.

Note that, as we have already mentioned above, this type of trajectories for signals do not take place in the Minkowski space of Special Relativity (where there is no disturbing factors that could cause stopping observable time). Such trajectories take place only in the space-time of General Relativity (since it allows all disturbing factors that are conceivable due to its Riemannian geometry).

Let us now find the trajectories that indicate the instant transmission of signals from the visible (past) position of stars and their position in the future (symmetrical to their visible position) in Kozyrev's astronomical observations. Presumably, these should be trajectories on the surface of the light cone: on its half (for signals coming to the observer from the visible position of the star in the past) and on the upper half (for signals coming from the symmetrical position of the star in the future). Therefore, we will first check this assumption by considering the light cone equation.

The light cone equation is the equation of trajectories lying on the surface of the light cone in the four-dimensional pseudo-Riemannian space (which is the space-time of General Relativity). It is determined according to the definition of the light cone by the condition

$$ds^2 = c^2 d\tau^2 - d\sigma^2 = 0\,, \qquad c^2 d\tau^2 = d\sigma^2 \neq 0\,,$$

which means that the four-dimensional intervals on its surface (i.e., along its directrices) are zero, while the intervals of physically observable time and the physically observable three-dimensional spatial intervals are equal to each other, but not equal to zero. Substituting the definitions of $d\tau$ and $d\sigma$ (see above) into the light cone condition $c^2 d\tau^2 = d\sigma^2$ and reducing similar terms, we obtain the light cone equation in the pseudo-Riemannian space

$$g_{00}\, c^2 dt^2 - 2\sqrt{g_{00}}\, v_i\, dx^i dt + g_{ik}\, dx^i dx^k = 0\,.$$

In the Minkowski space metric (see it in the very beginning), we have $g_{00} = 1$, $g_{0i} = 0$ (and, hence, $v_i = 0$), and also $g_{ik} = -1$. Substituting these values into the general formula of the light cone equation above, and since $dt \neq 0$ (as we have already explained, observable time cannot be stopped in the Minkowski space, because its geometric structure does not contain disturbing factors that could stop time), we obtain the light cone equation in the Minkowski space

$$\left(1 + \frac{1}{c^2}\, g_{ik}\, u^i u^k\right) dt^2 = 0\,, \qquad dt \neq 0\,,$$

where $u^i = \frac{dx^i}{dt}$ is the coordinate velocity of a signal. Because $g_{00} = 1$ and $v_i = 0$ in the Minkowski space, ($v_i = 0$), we have

$$d\tau = \sqrt{g_{00}}\, dt - \frac{1}{c^2}\, v_i\, dx^i = dt\,,$$

$$h_{ik} = -g_{ik} + \frac{1}{c^2}\, v_i v_k = -g_{ik}\,,$$

and, therefore, the square of the physically observable velocity of the signal $\mathrm{v}^i = \frac{dx^i}{d\tau}$ has the form $\mathrm{v}^2 = h_{ik}\,\mathrm{v}^i \mathrm{v}^k = -g_{ik}\, u^i u^k$. As a result, the light cone equation in the Minkowski space has the form

$$\left(1 - \frac{\mathrm{v}^2}{c^2}\right) dt^2 = 0\,, \qquad dt \neq 0\,,$$

which means

$$\mathrm{v}^i = \pm\, c^i\,, \qquad \mathrm{v}^2 = -g_{ik}\, c^i c^k = c^2 = inv,$$

where the plus sign refers to signals travelling into the future, and the minus sign — if signals travel into the past. Therefore, we conclude:

> Signals on the surface of the light cone in the Minkowski space (which is the space-time of Special Relativity) are not transmitted instantly. They travel with the same (constant) physically observable velocity equal to the velocity of light.

Let us turn back to the above general formula of the light cone equation in the pseudo-Riemannian space (which allows all disturbing factors that are conceivable due to its Riemannian geometry). It can be easily transformed using the definition of $d\tau$ to the form

$$\left(1 - \frac{\mathrm{v}^2}{c^2}\right) d\tau^2 = 0\,,$$

which differs from the above formula of the Minkowski space in the disturbing factors $g_{00} \neq 1$, $g_{0i} \neq 0$ (and, hence, $v_i \neq 0$) and $g_{ik} \neq -1$ that are characteristic of the pseudo-Riemannian space metric and manifested, in particular, in the physically observable time interval $d\tau$, the physically observable velocity of signals v^i and the physically observable metric tensor h_{ik} determining $\mathrm{v}^2 = h_{ik}\,\mathrm{v}^i \mathrm{v}^k$.

This condition is satisfied, since $d\tau \neq 0$ on the surface of the light cone*, only if the observable velocity of signals is

$$\mathrm{v}^i = \pm\, c^i,$$

$$\mathrm{v}^2 = h_{ik}\, c^i c^k = \left(-g_{ik} + \frac{1}{c^2}\, v_i v_k\right) c^i c^k = c^2 = inv,$$

where the plus sign means their travel into the future, and the minus sign — their travel into the past. This means:

> Signals are not transmitted instantly on the surface of the light cone in the pseudo-Riemannian space (which is the space-time of General Relativity), but travel with the velocity of light, the physically observable three-dimensional vector of which depends on the disturbing factors characteristic of the pseudo-Riemannian space, while its square remains invariant. Their trajectories coincide with the trajectories travelled by light signals in the Minkowski space in the absence of the disturbing factors, i.e., when the non-uniform, curved, rotating and deformable light cone of the pseudo-Riemannian space has became the straight and uniform light cone of the Minkowski space.

In other words,

> Neither the straight and uniform light cone in the Minkowski space of Special Relativity nor the disturbed light cone in the pseudo-Riemannian space of General Relativity are home of the instantly transmitted signals that indicated the visible and future positions of stars in Kozyrev's astronomical observations.

We therefore consider trajectories, along which a stronger condition is satisfied than the aforementioned light cone condition ($ds^2 = c^2 d\tau^2 - d\sigma^2 = 0$, $c^2 d\tau^2 = d\sigma^2 \neq 0$). This is the condition

$$ds^2 = c^2 d\tau^2 - d\sigma^2 = 0\,, \qquad c^2 d\tau^2 = d\sigma^2 = 0\,.$$

Since along such trajectories the four-dimensional interval ds, the physically observable time interval $d\tau$ and the physically observable three-dimensional spatial interval $d\sigma$ are zero, i.e., all these intervals degenerate along such trajectories, we called their home space a *fully degenerate space*, or in other words — a *zero-space* [18–21].

In particular, since trajectories in the zero-space associated with the pseudo-Riemannian space of General Relativity

*Except for a single space-time point, which is the location of the observer himself (at this point, the vertices of the light cones of his past and future converge). In this case, the point of signal emission and the location of the observer coincide and, therefore, the observable time interval between the emission of the signal and its arrival is always $d\tau = 0$.

is a fully degenerate (ultimate) version of trajectories on the surface of the light cone, the zero-space is in fact a *fully degenerate light cone*.

Since from the point of view of a regular observer $d\tau = 0$ is everywhere in the zero-space (which is a fully degenerate light cone), then the motion of signals along their trajectories in the zero-space is observed by him as an instant transmission of these signals in his observable (non-degenerate) space along trajectories on the surface of the regular light cone.

In confirmation of what has been said, we transform the light cone equation to a form that takes into account the physical conditions of full degeneration $\mathrm{w} + v_i u^i = c^2$, which are also the physical conditions that stop observable time ($d\tau = 0$, see above). The resulting form of the light cone equation

$$\left\{\left[1 - \frac{1}{c^2}\left(\mathrm{w} + v_i u^i\right)\right]^2 - \frac{u^2}{c^2}\right\} dt^2 = 0\,, \qquad dt \neq 0$$

is satisfied at every point on the surface of the light cone. Here $u^i = \frac{dx^i}{dt}$ is the signal's coordinate velocity (for which we have $u^2 = -g_{ik}\,u^i u^k$), and dt is the coordinate time interval (it never becomes zero, see explanation above). Under the conditions of full degeneration $\mathrm{w} + v_i u^i = c^2$, when observable time stops ($d\tau = 0$) from the point of view of an external observer, the above light cone equation transforms into the *degenerate light cone equation* that is also the *zero-space equation*

$$\left(1 - \frac{u^2}{c^2}\right) dt^2 = 0\,, \qquad dt \neq 0\,,$$

meaning that signals travel in the zero-space with the coordinate velocity of light, while they are observed as instantly transmitted signals by an external observer, whose home is the regular (non-degenerate) space-time.

In particular, the above means the following. Since the zero-space is a fully degenerate (ultimate) version of the light cone, signals can enter the zero-space and return back from there at any point on the surface of the light cone if the physical conditions for full degeneration are somehow realized at that point. For example:

> Let us say that at the point of emission of a signal towards an observer at the moment of its emission the physical conditions of full degeneration are somehow realized, and these conditions are also realized in the receiving device of the observer. Then the observer will register that the signal has disappeared at the emission point and was instantly received by his receiver, while the visible path along which the signal was instantly transmitted is the trajectory of light signals between him and the emission point (despite the fact that the signal itself was transmitted along a trajectory lying in the fully degenerate zero-space).
>
> Such trajectories, instantly connecting any observer with stars, indicate the visible (past) position of stars and their position in the future (symmetrical to their visible position), which was registered in Kozyrev's astronomical observations.

Thus, all three positions of stars, which were indicated by instantly transmitted signals in Kozyrev's astronomical observations, have been explained in the pseudo-Riemannian space (space-time) of General Relativity. In the Minkowski space, which is the space-time of Special Relativity, Kozyrev's results have no explanation, because the Minkowski space does not contain disturbing factors that could stop time or fully degenerate the entire space-time.

3 Conclusion

In this article we discussed the phenomenon of instant transmission of signals from stars (long-range action), discovered in the astronomical observations performed in 1977–1979 by Prof. N. A. Kozyrev [9,10], then — reproduced and confirmed in 1989 by a group of scientists, headed by I. A. Eganova and M. M. Lavrent'ev [11, 12]. We also gave our own theoretical explanation to Kozyrev's observed results in the framework of General Relativity.

We have shown that the geometric structure of the Minkowski space (which is the space-time of Special Relativity) does not contain disturbing factors that could stop time. And, since stopping physically observable time along the trajectory of a signal between the points of its emission and arrival is a necessary condition for its instant transmission, signals cannot be transmitted instantly in the space-time of Special Relativity.

On the other hand, we have shown that observable time can be stopped in the pseudo-Riemannian space (space-time) of General Relativity, since it allows all disturbing factors that are conceivable due to its Riemannian geometry. Such factors are the gravitational field potential or the rotation of space (due to the non-orthogonality of the three-dimensional spatial section to time lines), or both of these factors presented together.

We have shown that the condition of stopping physically observable time is satisfied on a tiny spherical surface of the gravitational radius (for non-rotating bodies) or slightly above it (for rotating bodies), existing around the barycentre deep inside absolutely every physical body in the range from elementary particles to planets and stars. These spherical surfaces, enveloping the barycentres of all physical bodies are all connected to each other by trajectories of stopping observable time. Signals, instantly transmitted along these trajectories, instantly connect all physically bodies in the Universe. Such trajectories instantly connect any observer with stars and indicate the *middle* (*true*) *position of stars*, which was registered in Kozyrev's astronomical observations.

We have also considered a fully degenerate (ultimate) version of trajectories on the surface of the light cone, along which physically observable time stops and, therefore, signals travel instantly. Such trajectories make up a fully degenerate light cone associated with the pseudo-Riemannian space, which we called the zero-space. The motion of signals along such trajectories (i.e., in the zero-space) is observed by a regular external observer as their instant transmission in his observable (non-degenerate) space along trajectories of light. Once the conditions of full degeneration are somehow realized at the point of emission of a signal towards an observer and these conditions are also realized in his receiving device (receiver), then he will register that the signal has travelled instantly from the emission point to him along the trajectory of light signals (while it travelled along a trajectory lying in the fully degenerate zero-space). Such fully degenerate trajectories also instantly connect any observer with stars. They indicate the *visible* (*past*) *position of stars* and *their position in the future* (symmetrical to their visible position), registered in Kozyrev's astronomical observations.

This is how Kozyrev's astronomical observations of instant transmission of signals from stars are explained in the framework of General Relativity.

These results illustrate that, according to General Relativity, all physical bodies in the Universe, including you and us, exist not only at the present moment in time, but are multidimensional objects, the past, present and future of which are an existing reality.

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