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Lev Yakovlevich Strum and the hypothesis of the existence of tachyons

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Contents

Abstract. It is argued that, historically, the concept of the existence of hypothetical superluminal particles called tachyons was preceded by the concept of a faster-than-light process. The latter concept, put forth by Lev Yakovlevich Strum (1890 – 1936) of the Soviet Union, contained within it the formulation of what later came to be known as the 'reinterpretation principle' of tachyon theory, a principle which proved instrumental in solving the problem of cause and effect in faster-than-light motions. L Ya Strum's results on this subject are briefly discussed, and his professional career is outlined.

1. Introduction

The physics community typically assumes that the concept of tachyons — hypothetical particles moving at superluminal velocities — was introduced in 1962 by O M Bilaniuk (1926–2009), V Deshpande, and E Sudarshan (born in 1931) [1] and was soon afterwards developed in the work of Ya P Terletskii (1912–1993) [2], G Feinberg (1933–1992) [3], and O M Bilaniuk and E Sudarshan [4]. In this context, earlier publications by E Wigner (1902–1995) [5], F R Tangherlini [6], and S Tanaka [7], who also discussed superluminal movement, are also cited. Very few people know, however, that this concept was first suggested as early as 1923 by the Soviet physicist Lev Yakovlevich Strum (1890–1936), although he never used the term 'tachyon'.

Lev Yakovlevich Strum
(11.11.1890 – 22.10.1936)

In 1936, L Ya Strum was arrested, imprisoned ('repressed' in the parlance of the times), and later executed; all his work was forgotten.

The objective of this report is to present L Ya Strum's brief scientific biography and the most interesting of his results. Note that some information about him was published even before his death in [8, 9], while recent research into his scientific biography was published in [10–16].

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L Ya Strum in his office at home, working. On the wall: photographs of science geniuses he worshipped — M Planck and A Einstein. This photograph was provided by L Ya Strum's daughter Elena, who now lives in Cologne, Germany (see Afterword).

2. The life and scientific activities of L Ya Strum

Lev Yakovlevich Strum was born on 11 November 1890 in the village of Melniki of the Chigirinsk district of Kiev province, and attended a gymnasium in the small town of Cherkassy. Having graduated from the gymnasium in 1908 with distinction (gold medal), he enrolled as a student in the Mathematics Department of Petersburg University. In 1914 (other sources state the year as 1913), L Ya Strum was awarded a PhD degree in mathematics; the title of his diploma work was 'Mathematical theory of X-rays'. However, his science supervisor, Professor I I Borgman (1849–1914),[1] died; due to having participated in a student rally in 1912 (after which he was arrested for two months), L Ya Strum was unable to find a job corresponding to his expertise and returned to Kiev, where he graduated from yet another school, the Polytechnic Institute.

In November 1921, L Ya Strum got a job as a researcher at the Ukrainian Academy of Sciences. In 1922, he started working at the Kiev Polytechnic Institute (KPI) in the research department headed by A G Goldman (1884–1971). In 1925, L Ya Strum began teaching physics and mathematics at the KPI. Incidentally, L Ya Strum conducted seminars of mathematics in a student group which included future Chief Designer Sergei Pavlovich Korolev. In the book [17, Ch. 10], we find the following lines: ''The seminars were led by Lev Yakovlevich Strum, a passionate man interested in many things. In addition to mathematics, he studied atomic physics and even published papers on the structure of nuclei. Strum noticed a young bright-eyed student [Korolev] and gave him his honors. In his report after exams, the pedantic mathematician wrote: 'The level of knowledge was chiefly determined in the most direct way, during the course of studies.... Some of the students, the most active, were given their honors without a regular exam....'' L Ya Strum conducted active research already during his first five years at the KPI. Between 1922 and 1926, he wrote almost 50 scientific reports and published 27 papers, 15 of these in science journals (6 of them published abroad) and 12 science-popularizing articles. In addition, he translated 9 research publications from foreign languages and published them. For instance, he translated into Russian Max Planck's monograph [18] and Ervin Schrödinger's groundbreaking paper on wave mechanics for the journal *Uspekhi Fizicheskikh Nauk* (*UFN*, which English version now is *Physics–Uspekhi*) [19]. He also wrote a large review paper on the Compton effect [20] for *Uspekhi Fizicheskikh Nauk* (*Physics–Uspekhi*) journal.

It was during those years that L Ya Strum came to understand in which fields he would do his research: relativity theory, quantum, atomic, and nuclear physics, thermodynamics, and physics methodology, and in all of them he obtained a number of important and interesting results.

L Ya Strum attended conferences on theoretical physics in Kharkov in 1930; a photograph of the participants of the first conference was published in a paper by V Ya Frenkel and

[1] I I Borgman's pupils included V F Mitkevich, B L Rozing, D A Rozhanskii, and D V Skobel'tsyn.

A D Chernin in *Priroda* (*Nature*, in Russian) magazine (1989) [21]. Now we can say with certainty that the third on the left in the second row, with his hat on, is L Ya Strum.

L Ya Strum also participated in the Second All-USSR Conference on Theoretical Physics which took place in Kharkov in May 1934. A review of the papers presented at this conference was published in *Uspekhi Fizicheskikh Nauk* (*Physics–Uspekhi*) journal [22] by one of its participants, Matvei Petrovich Bronstein, a talented theoretical physicist whose life ended in the same tragic way as the life of L Ya Strum [23]. M P Bronstein mentions [22] that more than a dozen reports were presented at the conference by such outstanding physicists as N Bohr, I E Tamm, L D Landau, G A Gamow, E M Lifshitz, V A Fock, and L Rosenfeld. The fact that a paper by L Ya Strum was also included in the program of the conference indicates that his reputation among physicists of the time was very high.

In 1925–1926, L Ya Strum made the acquaintance of academician Sergei Yurievich Semkovskii (1883–1937), one of the most respected Soviet philosophers, who actively studied the philosophy of natural sciences, including the relativity theory.[2] S Yu Semkovskii was one of those Soviet philosophers who supported Einstein's theory of relativity and was bold enough to face Einstein's critics. Communications between Strum and Semkovskii were concerned with the methodology of natural sciences; as a result of this, in 1926 L Ya Strum, in addition to his work at KPI, became a researcher at the Research Department of Marxism–Leninism. Alas, it was this acquaintance that later led to tragic consequences for L Ya Strum.

In 1927, L Ya Strum submitted and defended his DSc thesis, entitled 'Theory of quanta and X-ray radiation'. After the death of L I Kordysh (1878–1932),[3] he became Chair of Theoretical Physics at Kiev State University. Working independently of other researches, L Ya Strum established a number of regularities in progressively more complex nuclear structures, organized isotopes of atoms of various elements into sequences, and was able to predict the existence of theretofore discovered isotopes.

The work of the theoretician was interrupted in 1936. At that time, the USSR was the scene of numerous political trials. One of them was known as the trial of the "counter-revolutionary Trotskyist terrorist organization in Ukraine in 1936–1938" [27]. It appears that for L Ya Strum everything began with the arrest of S Yu Semkovskii on 3 March 1936. L Ya Strum was arrested on 23 March 1936. He was charged with being "an active member of the counter-revolutionary Trotskyist–Menshevist underground networks in Kiev and directly communicating with the underground center," and also of conducting Trotskyist propaganda in institutions where he worked. However, after his case was merged with those of a group of people arrested on similar charges, the charge grew to a yet more sinister one: that he "(a) is a member of a Trotsky–Zinoviev terrorist organization which on 1 December 1934 organized and carried out the despicable assassination of S M Kirov and prepared a number of terrorist acts against leaders of the Communist Party and the Soviet government, using the help of the Nazi German secret police (Gestapo); (b) was connected to Semkovskii and Rozanov, the leaders of the Trotskyist terrorist organization in Ukraine; (c) in 1934 personally transferred to Rozanov, a member of the leadership of the Trotskyist terrorist organization, Semkovskii's instructions on the need to organize a number of terrorist acts against the leaders of the Ukrainian Communist Party."

L Ya Strum was forced to plead guilty to all charges and was sentenced to execution by firing squad. The sentence was enforced on 22 October 1936 in the village of Bykovnya near Kiev [27]. In 1956, L Ya Strum was 'cleared of his crimes' ('rehabilitated' in the parlance of those times). Nevertheless, most of his research papers remained inaccessible and unknown to colleagues, mostly because his work was deliberately concealed; some of it was simply destroyed. The new chair, appointed after the death of L Ya Strum, was N Rozen,[4] who was famous for his collaboration with Einstein (1909–1995).

3. L Ya Strum's concept of superluminal particles

The possibility of exceeding the speed of light became the focus of L Ya Strum's studies in the framework of special relativity theory (SRT). While working on this topic, Strum tried to solve the following problems: the contradiction which arises in defining the concepts of 'earlier' and 'later' as one introduces the concept of superluminal speed, the problem of 'negative energy', and the problem of building a foundation for the concept of phase velocity in SRT.

His first report on this subject was presented at the Second Congress of the All-USSR Association of Physicists [34], which took place in Kiev in 1921. He later published a number of papers both in this country and abroad in foreign journals (some of these publications [35–38] were destroyed after L Ya Strum's death, while access to others was limited). While still a postgraduate student, L Ya Strum attempted to develop the theory of a process[5] [35, 36] that could propagate at a speed above the speed of light, c. In paper [38], L Ya Strum formulated a concept (later named the 'principle of reinterpretation' in paper [4]); this principle was a solution to the problem of causality relations in motions at superluminal velocities. Let us have a more detailed look at L Ya Strum's derivation.

In terms of geometry, the proof was conducted in the following manner (see Fig. 1). At a moment of time $t = 0$, a signal begins to propagate from the origin in both directions of the axis X of the system S at a superluminal velocity $V > c$. The lines A and A_1 plot the world lines of the light signals. System S′ moves relative to the system S at a velocity v less than the speed of light, $v < c$. Since the process we discuss here propagates at a superluminal velocity, the world line of this process in the figure lies below the world lines of light

[2] S Yu Semkovskii (real name Bronstein), a cousin of Leon Trotsky, was a member of the Central Committee of the Menshevik Party. It is interesting to note that the philosophical beliefs of Semkovskii were very severely criticized by Vladimir Lenin [24] ("for opportunism, eclecticism, and perversion of philosophical materialism") and by L D Landau [25] ("for his philosophical outlook on things concerning physics").

[3] L Ya Strum published a detailed *Personalia* (biography) on L I Kordysh [26].

[4] N Rozen was one of the co-authors of the widely known paper published in 1935 in *Physical Reviews* [28]; its Russian translation was edited by V A Fock and published in 1936 in *Uspekhi Fizicheskikh Nauk* (*Physics–Uspekhi*) journal [30] with an introduction by V A Fock and a concluding response paper by N Bohr. In the modern physics literature, this paper is known as the Einstein–Podolskii–Rosen paradox (see, e.g., [31–33]).

[5] It is important that it was a theory of a process, not of an object.

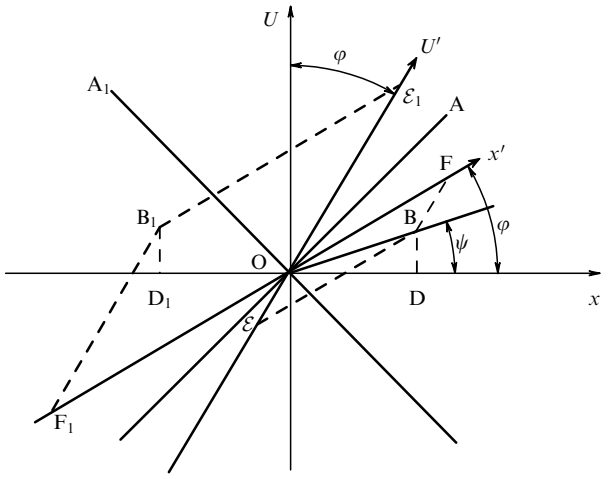

Figure 1. Spacetime diagram given in L Ya Strum's papers [34–38].

signals. The dashed curve passing through point B is the world line of the process considered here. We take two points, B and B_1, and define for both the moments of arrival of the signal in them for a moving reference frame and for one at rest. The points $\mathcal{E}$ and $\mathcal{E}_1$ correspond to the times of registration of a signal in the moving reference frame. The points D and D_1 correspond to the points of recording of the signal in the reference frame at rest, while the points F and F_1 are in the moving frame.

Therefore, in the system S,

$$\mathrm{OD} = x\,, \quad \mathrm{BD} = U = ct\,, \quad \mathrm{OD}_1 = -x_1\,, \quad \mathrm{B_1D_1} = u_1 = ct_1\,,$$

$$\tan\varphi = \frac{v}{c}\,, \quad \tan\psi = \frac{U}{x} = \frac{c}{V}\,, \quad \angle\mathrm{XOA} = \frac{\pi}{4}\,.$$

For the superluminal velocity of propagation of a signal $V > c$, angle $\psi < \pi/4$, and the point B lies within an angle XOA, that is, in the 'intermediate space' [38]. When $v > c^2/V \geqslant v/c > c/V$, that is, for $\tan\varphi > \tan\psi$, the point B lies within the angle $\angle\mathrm{XOX}'$ and, therefore, has negative time coordinate $U' = ct_1$.

In the system S′,

$$x' = \mathrm{OF} > 0\,, \quad ct' = \mathrm{O}\mathcal{E} < 0\,,$$

$$x'_1 = \mathrm{OF}_1 < 0\,, \quad ct'_1 = \mathrm{O}\mathcal{E}_1 > 0\,.$$

As L Ya Strum remarked, these formulas are exceptional "not only in that the time coordinate is negative but also in that the time coordinate is negative only in system S′ while in the other system, S, this coordinate is positive. This shows that for processes propagating at a velocity above that of light, system S allows such velocity of rectilinear and uniform motion of another system S′ relative to S at which the time in system S′ runs for such processes in a direction opposite to the flow of time in system S... . We thus find that relativity theory yields new consequences not yet discovered. First, the possibility of the existence of velocities exceeding the speed of light does not contradict special relativity theory. Second... under certain conditions the concepts 'later' and 'earlier' can change places" [34, 38] .

This argument, made by L Ya Strum in the 1920s, was later voiced in a paper by O Bilaniuk and E Sudarshan [4] (see also their earlier paper written together with V Deshpade [1]).[6] Having introduced the concept of a 'negative energy particle', the authors of [4] note: "...the reverse sequence of events is observed when the point B lies below the axis x. It is striking that this occurs precisely under the same conditions at which the product $v\omega$ [v is the tachyon velocity relative to system S, ω is the velocity of motion of system S′ relative to S] becomes greater than c^2. ...The interpretation of this coincidence of sign changes is the key to a consistent non-contradictory theory of superluminal particles." This principle, named the principle of the reinterpretation in [4], states that "negative energy particles, first absorbed and then emitted, are emitted and absorbed in the reverse order" [4].

The concept of phase velocity used in SRT also results in velocities exceeding the speed of light. However, the phase velocities exceeding c cannot be used to transfer signals, and, as L Mandelstam pointed out, "...[relativity theory] can be falsified only if nature will show us processes of the *signal type* that propagate faster than light" [49, p. 209; 50, p. 194].

Further attempts were made to build a foundation for the correspondence of the phase velocity to kinematics in relativity theory [34, 38]. The derivation suggested by L Ya Strum can be presented on the basis of the following arguments. Let us consider the formula of addition of velocity $V' = (V - v)/(1 - Vv/c^2)$, where v is the speed of the system S′ relative to S; V and V' are the velocities of the processes in systems S and S′, respectively.

It is assumed that V transfers the phase velocity of the wave which corresponds to the motion of the material body at velocity ω in system S, i.e., $V = c^2/\omega$. Therefore, the scientist makes an assumption on the possible proof of V' being the phase velocity of the wave which corresponds to the motion of the same body in a system S′.

Therefore, on the one hand, when we substituted $V = c^2/\omega$ into the formula for the addition of velocities, we obtained $V' = (c^2 - v\omega)/(\omega - v)$. On the other hand, the velocity ω in the system S corresponds to velocity in the system S′: $\omega' = (\omega - v)/(1 - \omega v/c^2)$. This velocity corresponds to the phase velocity $c^2/\omega' = (c^2 - v\omega)/(\omega - v)$ equal to V'.

L Ya Strum wrote: "If $V < c^2/v$, i.e., $\omega > v$, then the body which moves in the system S at a velocity ω advances on the system S′, and in this case V and V' are directed identically in both systems. If $V = c^2/v$, i.e., $\omega = v$, then $V' = \infty$. However, in the latter case, if the velocities v and ω are equal, then the body is at rest relative to the system S′, and the phase velocity of the material point at rest is infinitely large, because in this case the process of oscillations $\Phi = \Phi_0 \sin 2\pi v_0 t_0$ is periodical in time but not periodical in space. If $V > c^2/v$, i.e., $\omega < v$, then the directions V and V' in both systems are opposing to one another. However, with $\omega < v$, the velocity of the motion of the body relative to the system S′ becomes negative and then the velocity corresponding to the phase velocity of the wave[7] is directed to the system S′ in the same way [37].

Note that in 1940 this issue was also discussed by E Wigner (1902–1995) [5].

[6] It is of interest to remark that the space–time diagram in [4] is practically identical to the corresponding diagram in L Ya Strum's papers [34–38] (see Fig. 1).

[7] The expression used in L Ya Strum's paper [37] published in German was 'velocity of the phase wave'; it is quite clear from the context, however, that what he meant was 'the phase velocity of the wave'.

4. Conclusion

Nearly 90 years separate us from the days when L Ya Strum published his seminal papers, and an enormous number of publications have been devoted in this period to various aspects of the existence of tachyons: original papers, reviews, and monographs. However, tachyons have not yet been detected. Only on one occasion was there an experimental indication of the reality of tachyons [39, 40]. In these papers, A A Tyapkin (1926–2003) and his colleagues were recording the Vavilov–Cherenkov radiation by relativistic ions of lead at the CERN accelerator. They also detected some Vavilov–Cherenkov radiation corresponding to particles moving at a velocity exceeding the speed of light. However, later work has neither confirmed nor falsified the results of [39, 40]. The theoretical foundation of this phenomenon was discussed in [41].

It should be noted that, in addition to hypothetical tachyons, very real superluminal objects exist, such as light spots which can move at a velocity exceeding that of light [42–44]. We can also consider a real problem that is more interesting in terms of physics: the motion of a particle through a medium with a reflective index $n > 1$. In this medium, the speed of light is lower than the speed of light in a vacuum, and the superluminal motion does not contradict the relativity theory. Observation over such a superluminal object has some curious specific features. It was thus pointed out in [45] that, when approached by a superluminal object, the observer will not see it because it moves faster than its electromagnetic field. The observer begins to see the superluminal body only after it has swished by. Moreover, the observer detects two images of this body moving in opposite directions. One of the images moves in the same direction as the body itself, while the other moves in the opposite direction. This pattern resembles the one given in Strum's work, but the author of [45] did not need to consider the Lorenz transformation, since the analysis is conducted in the same reference frame. Questions related to superluminal motion are also discussed in papers [46, 47].

5. Afterword

This article had already been submitted for publication and announced on the *Uspekhi Fizicheskikh Nauk* (*Physics–Uspekhi*) website (www.ufn.ru) when one of its authors, G B Malykin, was contacted by L Ya Strum's daughter, Elena Lvovna. She kindly offered to add to this publication some photographs of her father with which she had never parted — whether in exile during the hectic wartime evacuation from Kiev, or when departing to Germany. She and her son Aleksandr Gultiaev also gave us additional information on the fate of L Ya Strum's family:

"After Lev Yakovlevich's arrest, the life of his close relatives became nearly unbearable. In 1937, his wife, Gilda-Albertina Isaakovna Iofan-Strum (1895–1969), was exiled to Shenkursk, a town in the Archangelsk region. In exile, she worked as a pediatrician for some years but was arrested in 1944 and spent eight years in a labor camp. Released from prison in 1953 but denied the right to live in large cities, she worked as a doctor in Stary Oskol, a town in the Belgorod region; once all charges against her were quashed (by way of 'rehabilitation') and she reached retirement age, she joined her daughter in Leningrad in 1956.

"L Ya Strum's daughter Elena Lvovna Strum (born 23 May, 1923) managed, despite enormous obstacles, to follow in her father's footsteps by pursuing a career as a researcher. This was very difficult for a daughter of 'an enemy of the people', which she became at the age of 13. After staying with her mother in exile for a short while, she returned in 1938 to Kiev, thus probably avoiding forced removal to an orphanage. While still a school girl, Elena Lvovna was able to stand up to insistent pressure from the authorities to renounce her 'repressed' parents. Having graduated from school in 1941, she was evacuated to Kazan. In Kazan she combined working in a hospital laboratory with studying in the Chemistry Department of Kazan University (she was rejected by the Physics Department). In 1944, she moved with the hospital (which followed the westward advance of the front line) to Kiev, where she continued working and studying at the university. In 1946, having practically nowhere to live in her native city of Kiev, she moved to Leningrad to live with her brother and graduated from Leningrad University in 1948. In 1948–1951, Elena Lvovna worked in Leningrad at the Rechargeable Batteries Institute; despite having practically completed her PhD thesis, she was fired in 1951 when the issue of her 'repressed' parents surfaced again. In 1953 she was given a job in the Laboratory of Semiconductors (organized by A F Ioffe in Leningrad and later transformed into IPAN — the Institute of Semiconductors of the USSR Academy of Sciences). At IPAN she worked as a researcher in an interdisciplinary field between chemistry and physics, studying semiconductor crystals and films, and received her PhD in 1961. From 1964 and until her retirement in 1978, she worked at the Kiev Institute of Semiconductors of the Academy of Sciences of Ukraine as senior researcher, continuing her studies of semiconductor films. In 1993, she emigrated to Germany and now lives in Cologne.

"Lev Yakovlevich's only grandson, the son of E L Strum, Aleksandr Petrovich Gultyaev (born 10.01.1956), also became a scientist. His father, Piotr Vasilievich Gultiaev (1914–1970), was also a physicist, also in semiconductors. A P Gultiaev graduated from the Moscow Institute of Physics and Technology (MIPT) in 1978 and got his PhD in 1986. At present, he is studying RNA structures; he works in the Netherlands at Leiden University and the Medical Center in Rotterdam."

The information on L Ya Strum given in this paper and his last publications quoted in the bibliography below, as well as a detailed study of his scientific biography published recently in [48], support the hope that the name of the highly talented physicist Lev Yakovlevich Strum will take its proper place in the history of science in our country.

Acknowledgments

The authors are grateful to M S Aksent'eva and B M Bolotovskii[8] for a number of useful remarks, which made it possible to improve the content of this paper, and to F R Tangherlini for help in locating a number of L Ya Strum's papers destroyed in the USSR at the end of 1930s.

[8] In his review of this paper, B M Bolotovskii proposed, amongst other things, the following fascinating hypothesis: "Interestingly, the name of the protagonist of the widely popular novel by Vasily Grossman, *Life and Fate*, is Strum. Some critics have voiced the opinion that this character was modeled on Igor Evgenievich Tamm. However, the facts presented in this paper make one think that in his novel, Vasily Grossman brought the real man, the physicist Strum, back from oblivion." (*Editor's note*.)

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