
doi: <https://doi.org/10.15407/knit2017.03.064>

UDC 530.12:531.514

Ya. S. Yatskiv¹, I. B. Vavilova¹, O. A. Romanets², V. S. Savchuk²

¹ Main Astronomical Observatory of the NAS of Ukraine, Kyiv, Ukraine

² Oles Honchar National University of Dnipropetrovsk, Dnipro, Ukraine

SOME LITTLE-KNOWN FACTS AND EVENTS FROM THE HISTORY OF GRAVITATIONAL WAVE RESEARCH IN UKRAINE

The paper deals with the history of gravitational wave research in Ukraine and describes two little-known facts and events. Our first comment is concerned with a short period of Dr. Nathan Rosen's life in Kyiv and his scientific activity at the Institute of Physics of the Academy of Sciences of the UkrSSR in 1936–1938 years. At that time, he has published several papers, which promoted the first steps in the creation of modern theories in the fields of gravity and quantum physics. These papers, including "Plane-polarized waves in the General Theory of Relativity", have been issued in the "Ukrainian Physical Notes" ("Ukrainski Fizychni Zapysky"), which was not widely accessed. We quote also some letters from correspondence of N. Rosen and A. Einstein in period. The second comment refers to the history of gravitational wave experimental research in Kyiv, which were initiated in 1970s by Prof. Aleksey Z. Petrov at the Institute of Theoretical Physics of the Academy of Sciences of the UkrSSR. We describe briefly the development of the detector of high-frequency gravitational waves (the Weber type antenna) as well as results obtained by K. A. Pyragas's group.

Keywords: *gravitational waves, detectors of gravitational waves; history of physics: Nathan Rosen.*

INTRODUCTION

In the paper "High-Frequency Gravitational Wave research and application to exoplanet studies" by Robert M. L. Baker, Jr. ([2], see this issue, pp. 47–63) the history of gravitational wave (GW) research was discussed. The author has also mentioned the GW research in Ukraine. We would like to shed more light on some little-known facts of these studies in Ukraine and give two comments.

The first comment is concerned with a short period of Dr. Nathan Rosen's life in Kyiv and his scientific activity at the Institute of Physics of the Academy of Sciences of the UkrSSR¹ in 1936–1938 years. At that

time, he has published several papers which promoted the first steps in the creation of modern theories in the fields of gravity and quantum physics. These papers have been issued in the little-known journal "Ukrainian Physical Notes" ("Ukrainski Fizychni Zapysky"), which was not widely accessed. Therefore, we briefly describe some Rosen's results as well as highlight excerpts from the letters between Nathan Rosen and Albert Einstein, which have been saved at "The Albert Einstein Archives" in Israel. This correspondence was first brought to the notice of a wide scientific commu-

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¹ UkrSSR – Ukrainian Soviet Socialist Republic, one of the constituent republics of the former Soviet Union from its inception in 1922 to its breakup in 1991.

nity by Olena A. Shcherbak and Varpholomei S. Savchuk [23, 24].

The second comment is related to the history of GW experimental research in Kyiv, which were initiated in 1970s by Prof. Aleksey Z. Petrov at the Institute of Theoretical Physics of the Academy of Sciences of the UkrSSR. The development of the Weber type antenna for this purpose was described briefly in the book “General Relativity Theory: Tests through Time” by Yatskiv Ya.S., Alexandrov A.N., Vavilova I.B., Zhdanov V.I., Kudrya Yu.N., Parnovsky S.L., Fedorova O.V., Khmil S.V., namely, in the Chapter “World lines in the relativistic space-time of Ukraine” [34]. The history and present-day state of GW research are discussed in the books by Alexandrov A.N., Vavilova I.B., Zhdanov V.I., Zhuk A.I., Kudrya, Yu.N., Parnovsky S.L., Fedorova E.V., Yatskiv Ya.S. “General Relativity Theory: Recognition through Time” ([1], in Russian) and “General Relativity: Horizons for Tests” ([35], in Ukrainian). They contain a theoretical basis of the General Relativity, its experimental tests and applications. The monographs address scientists, post-graduated students, and students specialized in the natural sciences as well as everyone who takes interest in the General Relativity.

LIFE AND SCIENTIFIC ACTIVITY OF NATHAN ROSEN IN KYIV (1936–1938 years)

Nathan Rosen (March 22, 1909, New York, USA – December 18, 1995, Haifa, Israel) was an American-Israeli foremost theoretical physicist. He received a bachelor's degree in electromechanical engineering (1929), a master's degree in physics (1931), and Ph.D. in physics (1932) from the Massachusetts Institute of Technology. During his student time, Nathan Rosen has published several papers, among them “The Neutron,” in which he provided the first reliable calculation of the structure of the atomic nucleus a year before their discovery by James Chadwick. Besides of hydrogen molecule, he developed a lifelong interest also in wave functions and their application to the gravitation physics.

The first acquaintance with Albert Einstein took place when N. Rosen wrote a master's thesis. He came to Princeton to be engaged in molecular physics and was interested on A. Einstein's opinion re-



Nathan ROSEN, an American-Israeli foremost theoretical physicist

garding his dissertation. After the meeting of these scientists, a fruitful cooperation has begun between them. As a result, in 1934, after a short research fellowship at the University of Michigan, Nathan Rosen became Albert Einstein's assistant at the Institute for Advanced Study in Princeton and continued in that position until 1936 (see, [12], and “Nathan Rosen” in Wikipedia). Just in these years, two famous papers have been published, namely “The Particle Problem in the General Theory of Relativity” [9] and “Can quantum-mechanical description of physical reality be considered complete?” [8].

The first paper [9] was written together with Albert Einstein. Using Einstein's field equations, the authors found the mathematical solution of nontrivial problem by merging the models of a black hole and a white hole (a black hole moving backward in time). Later this theoretical solution was named as the Einstein–Rosen bridge or space-time wormhole, which connects distant areas in hypothetic universe. In 1962, John A. Wheeler and Robert W. Fuller showed that this type of wormholes is unstable. It is believed that the Einstein–Rosen bridge is a theory of Nathan Rosen.

The second paper [8] was written jointly with Albert Einstein and Boris Podolsky, a fellow student to Einstein. Namely Rosen pointed out the peculiarities

of Einstein's research involving the entangled wave functions. The effects described in the paper were labeled later as the "Einstein-Podolsky-Rosen paradox" that raises hackles with physicists until now ². *"It advanced a "thought experiment" to show the wrong-headedness of the quantum theory, which many scientists of the time found highly unpalatable. Einstein deemed it something akin to magic. The paper pointed out conceptual problems that the authors had with the theory and what they saw as its paradoxical and contradictory aspects... The paper drew a sharp response from Niels Bohr, and quantum theory has since been widely accepted. Scientists use it as a primary tool to predict the interactions of atoms, molecules, elementary particles and radiation; it plays a role in virtually all the chemical and physical reactions that control our lives and the world around us" [22].*

Despite of these remarkable results during the research fellowship at the Institute for Advanced Study, Nathan Rosen could not find a job at a time of the Great Depression, and Einstein gave advice to him to continue a scientific career abroad. So, in 1936, at the personal request of A. Einstein in his correspondence with Vyacheslav Molotov [16], the Chairman of the Council of People's Commissars of the USSR in 1930—1941, Nathan Rosen came to the Soviet Union.

During the two-year stay in Kyiv from 1936 to 1938, Nathan Rosen was a head of the department of theoretical physics of the Institute of Physics of the Academy of Sciences of the UkrSSR as well as he has lectured at the department of theoretical physics of the Kyiv University [34, 23]. At that time, he has published three papers on gravity theory and quan-

tum physics in the "Ukrainian Physical Notes" (in Ukrainian language), which are not well known even now, and had a correspondence with A. Einstein.

This correspondence between Rosen and Einstein had both scientific and private sense and could be a source of additional information on Rosen's life in Kyiv.

In the first letter to A. Einstein (February 26, 1937), after discussion of the problems of theoretical physics, Nathan Rosen writes that *"I am working at the Physical Institute of the Ukrainian Academy of Sciences, doing research, and I also lecture at the University of Kiev. I am always very busy — there is so much to be done! But, although I haven't the leisure that I had in Princeton, I have other, more important, thing. I have the feeling that I am useful and needed (and without such a feeling life is not worth very much). And — at any rate, up to the present — in order to get my bread. I have not had to win the favor of little men in high positions. So, all in all, I am still grateful to you for your help in arranging for me to come here» [27].*

We see from this letter that N. Rosen was overfilled with desire to work in Ukraine as long as possible. He came to Kyiv with his wife, and their son was born here. He wrote with enthusiasm about the Soviet system and even discussed an opportunity to find work at the University of Dnipropetrovsk for one of Princeton's chemists. But he could not find a responsible soviet person who would be entrusted with this scientist: *"the authorities are cautions because of their experiences with foreign spies and wreckers" [28].*

A year later, we read (March 24, 1938): *«As you see, we are still in Kiev. And we still feel very enthusiastic about the Soviet Union... Perhaps I shall have occasion to speak with you in person next summer» [29].* But his plans have been changed gradually: first of all, his family moved to America. His last letter from Ukraine (July 31, 1938) was already very different from the first letters: *«When I last wrote to you, I was expecting to come to America this summer for a visit. Since then my plans have changed. In a few weeks, I am coming back to U.S. to remain there. This I am doing in spite of the fact that I am very pleased with what I have seen of the Soviet Union and very much enjoy living in it. The reason for this step is mainly that I am dissatisfied with my own work and my ability. I feel that I am not accomplishing as much as I ought to. My conscience does not permit me to remain here. Hence, I am returning to*

² The tests of the Einstein-Podolsky-Rosen paradox conducted at the end of the XX century have led to the concept of the "quantum teleportation" (see, for example, [3, 5, 11, 25]), i.e. obtaining the information on the state of one of the particles that are in the "quantum confinement", when determining the state of the second particle. It is worthily to mention that the first successful teleportation of the quantum state of particles onto the Earth orbit was realized by using the Chinese satellite "Micius" (QUESS) in 2017 [16]. For the first time a link of the transcontinental connection, the encryption key for which was distributed using methods of quantum cryptography, took place on September 29, 2017 (https://en.wikipedia.org/wiki/Quantum_Experiments_at_Space_Scale).

the States and shall look for some kind of job not requiring research work. If I find it then I shall work on research in my spare time without feeling any responsibility» [30]. *“An impression arises that N. Rosen knew about the perusal of his correspondence and tried to make A. Einstein know the true reasons of his departure from the USSR. One may suppose that A. Einstein, who knew N. Rosen well, could guess why “conscience” did not allow him to stay more in the USSR”* [24]. The reason was resulted from “a purge of the Soviet scientists”. Many of them had already been condemned or shot dead. Even Alexander G. Goldman, Director of the Institute of Physics where Rosen has worked, was arrested by the organs of the NKVD³ of the UkrSSR on January 22, 1938. So, considering these circumstances, a decision of Nathan Rosen to go out from the USSR has helped him to escape the inevitable repressions.

In 1936–1939, Nathan Rosen published several papers, three of them were issued, as we already noted, in the “Ukrainian Physical Notes” [17–19].

The paper [17] was devoted to the consideration of plane-polarized waves in the General Relativity Theory. At the end of this paper there was a note that this work is a continuation of research “On the gravitational waves”, the results of which have been published in the “Journal of the Franklin Institution” in 1937 [10]. Rosen has written to Einstein (May 6, 1937): *«About the work I sent you – I thought over carefully your remarks in connection with it and I read the improved version in the Journal of Franklin Institute but I am not yet satisfied. Our original problem was the question of plane waves (where plane is in the sense of a Euclidean space into which the space considered goes over in the absence of the waves). True there was an error in our reasoning. In the published paper, the error is avoided – but at the cost of avoiding the problem. The question is raised: are there plane waves? And the answer is given: yes, there are cylindrical waves. For this reason it seems to me that the original problem needs further investigation. It seems to me that from the point of view of the original problem what I wrote in the paper I sent you is not incorrect but is perhaps incomplete. I think one can show that for all plane waves of*

the type under discussion there are no solutions which are free from singularities everywhere and for all time» [28]. So, Rosen has outlined that the nonlinearities of such a kind, whatever small they were, in the equations of gravitational perturbation would inevitably lead to the change of the tensor sign, which, in its turn, would make the solution proposed out of sense: *“the limit, mentioned above, of plane waves with finite amplitudes does not obviously exist in the general theory of relativity”* [17].

In 1957, I. Robinson and G. Bondi obtained such generalizations of a weak plane-polarized wave using the same approach, and also pointed out to this singularity, but they noticed that it can be eliminated by coordinate transformation (see, for example, [4]). It's generally accepted that they first obtained this result. As a fact, this result was obtained by N. Rosen yet in 1937, and only that this paper was published in the journal, which was not practically accessible to foreign physicists, and, moreover, in Ukrainian language without translation, it was virtually unknown to the world scientific community. Nevertheless, a conclusion can be drawn that N. Rosen's work [17]⁴ was among the first which concerned the creation of the model of gravitational waves. We can add that Nathan Rosen has returned later, in 1950-ies, to the problem of gravitational waves and their properties. For example, in 1993 he and K.S. Virbhadra published the paper “Energy and momentum of cylindrical gravitational waves”, where they write in abstract: *“It was found many years ago [20] that in cylindrical polar coordinates the energy and momentum densities of gravitational waves, calculated with the help of a pseudo-tensor, vanish. However, using Cartesian coordinates, one finds them to be finite and reasonable”* [21].

In 1938 yet one paper was issued by Rosen written together with the Ukrainian physicist G. Ilkevich. It was devoted to the quantum physics, namely, corrections to the Thomas-Fermi model to obtain a coincidence of theoretical results with experiments for light elements [19]. Another paper “Elementary particles in the field theory” [18] was concerned with problem of the existence of an electron in classical field theo-

³ The People's Commissariat for Internal Affairs (abbreviated NKVD, Narodnyi Komissariat Vnutrennikh Del)

⁴ The detailed analysis of the N. Rosen's work [17] is made by Shcherbak O.A. and Savchuk V.S. [24].

ry. It was shown that the classical theory of a field without expansion does not imply the existence of elementary particles. Rosen has proposed to introduce new "functions of matter", similar to the wave functions of quantum theory. The solution of an equation based on the use of "functions of matter" allows the existence of solution for electron, but it means that the mass of the electron must be negative. To avoid this problem, Rosen suggested that this difficulty can be eliminated by quantization. This paper was issued already in 1939, when Nathan Rosen came back from Ukraine to the US.

After return to the United States, Rosen has lectured at the University of North Carolina at Chapel Hill from 1941 to 1952. *"In 1953, after permanently moving to Israel, he joined the Technion in Haifa, Israel. During this time Rosen was advisor to Asher Peres. He was President of the Ben-Gurion University of the Negev in the 1970s and commuted between the two institutions from his home in Haifa. Additionally, Nathan Rosen helped found the Israel Academy of Sciences and Humanities, the Physical Society of Israel (serving as president from 1955–1957), and the International Society on General Relativity and Gravitation (president in 1974–1977). He was very active in encouraging the founding of higher educational institutions in Israel"* [22].

A BRIEF HISTORY OF DEVELOPMENT OF THE WEBER TYPE GRAVITATIONAL WAVE DETECTOR IN KYIV, IN 1970s

At the end of 1970s Aleksey Zinovievich Petrov, member of the Academy of Sciences of the UkrSSR, Chairman of the Gravity Society of the Sci.-Tech. Council of the Ministry for Higher Education of the USSR in 1962–1972, who worked at the Institute for Theoretical Physics of the Academy of Sciences of the UkrSSR (hereafter – ITP), has initiated the experimental GW research. He proposed a work on the creation of a unique device – the Weber type antenna – for monitoring of gravitational waves from powerful extragalactic sources. Being an outstanding physicist-theorist, the author of the classification of gravitational field by three types ("Petrov types") [13, 14], he was aware of the need for an experimental confirmation of the main principles of the Gen-

eral Relativity. Consequently, the development of the Kyiv detector (Weber bar) and the observation of gravitational waves were conducted with the support and in close contact with the well-known scientist Vladimir B. Braginsky, who has previously begun to construct a similar detector in Moscow. The ITP Scientific Council approved a decision to create a special experimental laboratory and gave a start to the production of unique equipment, including vacuum chamber, which was made at the E.O. Paton Electric Welding Institute in Kyiv. General management of works in this laboratory was carried out by, Kazimir A. Pyragas [36], while a principal development of "Weber bar" was guided by A.M. Sviridov.

"As far as till now there are scientists who do not understand why it was necessary to carry out a deliberate "zero" experiment in Kyiv, we give some explanation. We recall that the history of gravitational wave observations began with the "supposed discovery" of gravitational signals by Weber, whose authority was and is very high. But observed signal magnitude was very large that was in contradiction with the General Relativity Theory. Therefore, it was important to either refute or strongly confirm the Weber's results. In a positive case, it would be a matter of discovery, which may require a substantial revision of many theoretical paradigms. By this reason, experiments on the discovery of gravitational waves have roused and still are of great interest among the gravitationalists around the world" ([34], pp. 227–229).

A premature death of A.Z. Petrov made significant changes of the plans for theoretical and experimental gravitational studies in Ukraine. Some of his followers, including employees of the experimental laboratory, have passed to the Ukrainian Center for Standardization and Metrology of the State Committee of Statistics of the USSR. For example, in 1972, K. Pyragas said at the meeting of the Gravity Society in Moscow devoted to the memory of A.Z. Petrov: *"Aleksei Zinovievich assigned great expectations to his work on the modeling of gravitational fields. Recently, he showed a great interest in experiments in the field of gravity. He wanted to derive a solution to the problem – the information of the language of general relativity to the language of the experimental physicist. Alexei Zinovievich did not manage to complete this cycle of work. Part of this work will be completed by his students.*

He also placed great hopes on solving the problem of energy and quantizing gravity. He tried to help the experimental groups in our country. Now in Kyiv there is an experimental group that is working on testing the Weber experiment together with Vladimir Borisovich Braginsky. Aleksei Zinovievich himself was going to give a theoretical justification for Weber's experiments. He believed to work on the processing of his results. It's all left unfinished. In addition, Alexei Zinovievich had unpublished work on the influence of the structure of the Sun on gravitational effects and on observations in the General Relativity Theory. His employees in Kyiv were engaged in group theory, the Cauchy problem and groups of motion of certain spaces..." ([31], pp. 42–45).

It is worth noting that at the very beginning of attempts to detect gravitational waves, prof. A.S. Davydov, the ITP Director in 1973–1988, expressed his reasonable doubts about the possibility of success in this project with the planned equipment. Nevertheless, this group – K.A. Pyragas, A.M. Sviridov, V.A. Kopylov, S.S. Zhovmir, I.T. Zhuk, L.N. Blagoveschenskaya, later on Yu.A. Opanasyuk and A.N. Alexandrov – had spent a lot of time in attempts to detect gravitational waves using the constructed Weber bar (Fig. 1, 2), which was installed at a basement of the “Feofaniya” hotel in Kyiv (see, for example, a paper “Hunting for heavy rays” in the advertising journal “Science and Society”, 1980, No. 1).

A key task of the Kyiv group was to set up and verify the presence of gravitational signals at least at the same level as J. Weber [32, 33]. They have analyzed main types of GW antennas and results of previous GW experiments as well as developed own technique for registration of the high-frequency component of gravity field and constructed the gravitational detector of Weber type.

We will quote hereafter certain fragments from the final report [15] of K.A. Pyragas's group, since they are little known to the scientific community.

“The main part of this detector, gravitational antenna, had the parameters as follows: an aluminum cylinder with a mass of 1100 kg, a length of 150 cm, the resonance frequency of the fundamental vibration mode is 1617 Hz, the quality factor is 2.5×10^5 ; the antenna is equipped with a capacitive sensor of small displacements. The sensitivity of the detector is limited, basically, by the Brownian oscillations of the cylinder of the

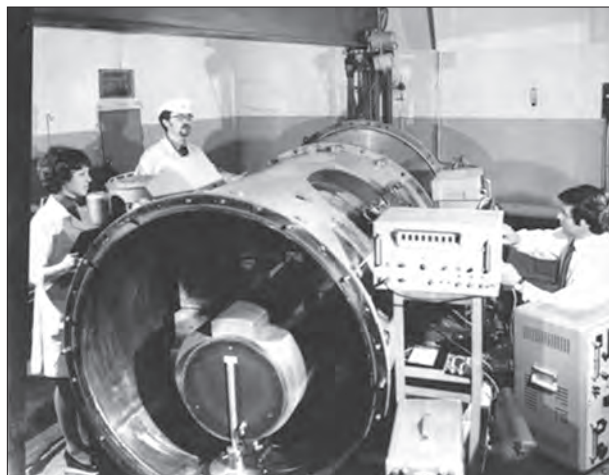


Fig. 1. The Weber type detector of gravitational waves developed at the Institute of Theoretical Physics of the AS UkrSSR and later at the Ukrainian Center for Standardization and Metrology of the State Committee of Statistics of the USSR. Kyiv, 1970s (photo from [15])



Fig. 2. From left to right: M.N. Polozov, V.A. Kopylov, A.M. Sviridov, Yu. S. Vladimirov, and K. A. Pyragas. The author of the picture “Diogenes climbed out of his barrel trying to hear the gravitational signals” on the detector's casing is I.T. Zhuk (photo from [31])

gravitational antenna, the mean square of the amplitude of these oscillations (σ_{br}) at a temperature of $\approx 300^\circ \text{K}$ is $5,9 \times 10^{-14} \text{ cm}$. The detector has operated at this temperature of 18.5 days during a session”. After recording the oscillation's amplitudes of the cylinder and their statistical processing, they obtained that the detector's output signal was well approximated by the Rayleigh distribution, i.e. due to the thermal noise of

the cylinder. On Nov 5, 1976 they “detected a single burst of non-thermal origin with an amplitude of $13 \pm 16 \sigma_{br}$ and a duration of $t \leq 2s$...” ([15], p.3) Their results were of importance for fundamental physics (gravitational radiation), metrology (measurements of ultra-small displacements), statistical radio physics (thermal fluctuations in narrow-band systems)”. The K.A. Pyragas’s group when summing up has also written that “the most powerful source of gravitational radiation near Earth should have a space origin and be expected at 100 Hz–100 KHz, i.e. from supernova burst or collapse of stars with a weak optical detectability. Such bursts could take place one time per year in our Galaxy and able to trigger multiple broadband outbursts at 1–100 KHz, duration from $10^{-3}s$ to 1s, $F = 10^{10} \text{ erg/cm}^2\text{s}$ and amplitude $h = 2 \times 10^{-19} - 10^{-17}$ as well as such outbursts, for example, in the Virgo cluster, one time per month with $F = 10 - 10^4 \text{ erg/cm}^2\text{s}$ and amplitude $h = 2 \times 10^{-22} - 10^{-20}$. The sensitivity of the Weber detector was $2 \times 10^4 \text{ erg/cm}^2\text{s}$ ” ([15], p. 24). It allowed them to conclude that “one signal per month could be detected near limit sensitivity of detector as well as less frequent strong signals, two orders of magnitude greater than the limit sensitivity”.

So, the GW detectors that should have started work simultaneously with Kyiv’s detectors – in St. Petersburg and in Moscow – have not worked yet. By this reason the result obtained with Kyiv’s detector could not be confirmed as well as be compared with results by Weber (due to political situation of the end of 1970-ties). In 1980, before the Moscow Olympiad, the experiment in Kyiv was cancelled, and the experimental laboratory was disbanded. As for the V.B. Braginsky’s idea “to organize a broad program of GW research in the Soviet Union, it was eventually encountered lacks of funds and of the necessary technological base” ([34], pp. 227-228).

We can conclude that a task to construct the Weber type antenna for detecting high-frequency gravitational waves was completed by K.A. Pyragas’s group [15]. The result of the measurements was rather negative, as in many other groups. Nevertheless, the first attempts to detect gravitational waves around the world gave a powerful impetus to technological research in order to create the next generation of GW detectors, e.g. the Laser Interferometer Gravitational-Wave Observatory (LIGO).

INSTEAD OF CONCLUSION

On October, 3, 2017, the Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017 with one half to Rainer Weiss (LIGO/VIRGO Collaboration) and the other half jointly to Barry C. Barish (LIGO/VIRGO Collaboration) and Kip S. Thorne (LIGO/VIRGO Collaboration) “for decisive contributions to the LIGO detector and the observation of gravitational waves”. In view of the special importance of this discovery, we will quote below the press release of the Nobel Committee on this occasion, which is titled as the “Gravitational waves finally captured”:

“On 14 September 2015, the universe’s gravitational waves were observed for the very first time. The waves, which were predicted by Albert Einstein a hundred years ago, came from a collision between two black holes. It took 1.3 billion years for the waves to arrive at the LIGO detector in the USA.

The signal was extremely weak when it reached Earth, but is already promising a revolution in astrophysics. Gravitational waves are an entirely new way of observing the most violent events in space and testing the limits of our knowledge.

LIGO, the Laser Interferometer Gravitational-Wave Observatory, is a collaborative project with over one thousand researchers from more than twenty countries. Together, they have realized a vision that is almost fifty years old. The 2017 Nobel Laureates have, with their enthusiasm and determination, each been invaluable to the success of LIGO. Pioneers Rainer Weiss and Kip S. Thorne, together with Barry C. Barish, the scientist and leader who brought the project to completion, ensured that four decades of effort led to gravitational waves finally being observed.

In the mid-1970s, Rainer Weiss had already analyzed possible sources of background noise that would disturb measurements, and had also designed a detector, a laser-based interferometer, which would overcome this noise. Early on, both Kip Thorne and Rainer Weiss were firmly convinced that gravitational waves could be detected and bring about a revolution in our knowledge of the universe.

Gravitational waves spread at the speed of light, filling the universe, as Albert Einstein described in his general theory of relativity. They are always created when a mass accelerates, like when an ice-skater

pirouettes or a pair of black holes rotate around each other. Einstein was convinced it would never be possible to measure them. The LIGO project's achievement was using a pair of gigantic laser interferometers to measure a change thousands of times smaller than an atomic nucleus, as the gravitational wave passed the Earth.

So far all sorts of electromagnetic radiation and particles, such as cosmic rays or neutrinos, have been used to explore the universe. However, gravitational waves are direct testimony to disruptions in space-time itself. This is something completely new and different, opening up unseen worlds. A wealth of discoveries awaits those who succeed in capturing the waves and interpreting their message” (https://www.nobelprize.org/nobel_prizes/physics/laureates/2017/press.html).

Acknowledgements. Romanets O.A. and Savchuk V.S. express their sincere thanks to the “Albert Einstein Archives” of the Jewish National and University Library (Jerusalem), and personally to Barbara Wolff, for the kindly provided materials. The authors thank Milentij Golovnya for his help in acquaintance with the archive of the State Enterprise “Ukrmetrstandart”.

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Received 09.10.17

Я. С. Яцків¹, І. Б. Вавилова¹,
О. А. Романець², В. С. Савчук²

¹ Головна астрономічна обсерваторія
НАН України, Київ, Україна

² Дніпропетровський національний університет
імені Олеся Гончара, Дніпро, Україна

МАЛОВІДОМІ ФАКТИ І ПОДІЇ З ІСТОРІЇ ДОСЛІДЖЕНЬ ГРАВІТАЦІЙНИХ ХВИЛЬ В УКРАЇНІ

Описуються два маловідомих факти і події з історії досліджень гравітаційних хвиль в Україні. Перший з них стосується періоду життя Натана Розена в Києві та його наукової діяльності в Інституті фізики Академії наук УРСР у 1936–1938 роках. У той час він опублікував кілька праць, які сприяли створенню сучасних теорій в області гравітації і квантової фізики. Ці роботи, зокрема «Плоскополяризовані хвилі в загальній теорії відносності», були видані

в журналі «Українські фізичні записки», до якого не було тоді широкого доступу. Ми цитуємо також деякі листи із переписки Н. Розена і А. Ейнштейна в цей період. Другий коментар пов'язаний з історією експериментальних досліджень гравітаційних хвиль, які були ініційовані в 1970-х роках у Києві академіком АН УРСР О.З. Петровим в Інституті теоретичної фізики АН УРСР. Ми коротко описуємо історію створення детектора високочастотних гравітаційних хвиль (антени веберівського типу), а також результати, отримані групою дослідників під керівництвом К.А. Пирагаса.

Ключові слова: гравітаційні хвилі, детектори гравітаційних хвиль; історія науки: Натан Розен.

Я. С. Яцків¹, І. Б. Вавилова¹,
Е. А. Романець², В. С. Савчук

¹ Главная астрономическая обсерватория
НАН Украины, Киев, Украина

² Днепропетровский национальный университет имени
Олеся Гончара, Днепро, Украина

МАЛОИЗВЕСТНЫЕ ФАКТЫ И СОБЫТИЯ ИЗ ИСТОРИИ ИССЛЕДОВАНИЙ ГРАВИТАЦИОННЫХ ВОЛН В УКРАИНЕ

Рассматриваются два малоизвестных факта и события из истории исследований гравитационных волн в Украине. Первый из них касается периода жизни Натана Розена в Киеве и его научной деятельности в Институте физики Академии наук УССР в 1936–1938 годах. В то время он опубликовал несколько работ, которые способствовали созданию современных теорий в области гравитации и квантовой физики. Эти работы, в том числе «Плоскополяризованные волны в общей теории относительности», были изданы в журнале «Украинские физические записки», к которому тогда не было широкого доступа. Мы цитируем также некоторые письма из переписки Н. Розена и А. Эйнштейна в этот период. Второй комментарий связан с историей экспериментальных исследований гравитационных волн, которые были инициированы в 1970-х годах в Киеве академиком АН УССР Алексеем З. Петровым в Институте теоретической физики АН УССР. Мы кратко описываем историю создания детектора высокочастотных гравитационных волн (антенны веберовского типа), а также результаты, полученные группой исследователей под руководством К.А. Пирагаса.

Ключевые слова: гравитационные волны, детекторы гравитационных волн; история науки: Натан Розен.