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AN ANTHOLOGY OF THE DISTINGUISHED ACHIEVEMENTS IN SCIENCE AND TECHNIQUE. PART 39: NOBEL PRIZE LAUREATES IN PHYSICS FOR 2011-2015

Purpose. Implementation of brief analytical review of the distinguished scientific achievements of the world scientists-physicists, awarded the Nobel Prize on physics for the period 2011-2015. Methodology. Scientific methods of collection, analysis and analytical treatment of scientific and technical information of world level in area of astrophysics, physics of elementary particles, physics of high energies, of modern theoretical and experimental physics. Results. The brief analytical review of the scientific openings and distinguished achievements of scientists-physicists is resulted in area of modern physical and technical problems which were marked the Nobel Prizes on physics for the period 2011-2015. Originality. Systematization is executed with exposition in the short concentrated form of the known scientific and technical materials, devoted opening of acceleration of expansion of Universe, creation of breach technologies of manipulation the quantum systems, theoretical discovery of mechanism of origin of mass of under-atomic particles, invention of effective power sources of light − blue light-emitting diodes and opening of neutrino oscillations. Practical value. Popularization and deepening of scientific and technical knowledges for students, engineers and technical specialists and research workers in area of modern theoretical and experimental physics, extending their scientific range of interests and cooperation in further development of scientific and technical progress in human society. References 17, figures 14.

Key words: **modern physics, distinguished achievements, speed-up expansion of Universe, technologies of manipulation of the quantum systems, mechanism of origin of the masses of under-atomic particles, energy saving sources of light, blue light-emitting diodes, neutrino oscillations**..

Приведен краткий аналитический обзор выдающихся научных достижений ученых мира, отмеченных Нобелевской премией по физике за период 2011-2015 гг. В число таких достижений вошли открытие ускорения расширения Вселенной, создание прорывных технологий манипулирования квантовыми системами, теоретическое обнаружение механизма происхождения массы субатомных частиц, изобретение энергоэффективных источников света − синих светодиодов и открытие нейтринных осцилляций. Библ. 17, рис. 14.

Ключевые слова: **современная физика, достижения, ускоренное расширение Вселенной, технологии манипулирования квантовыми системами, механизм происхождения массы субатомных частиц, энергосберегающие источники света, синие светодиоды, нейтринные осцилляции.**

Introduction. Physics in the will of the famous Swedish engineer-inventor and businessman Alfred Nobel (1833-1896) was mentioned in the first of five fields of scientific knowledge and social movements (physics, chemistry, medicine, literature and the struggle for peace between nations), which should In the near future to establish awards for outstanding scientific research, revolutionary inventions, a major contribution to the culture and development of human society [1]. Note that the first Nobel Prize in physics was awarded to the German Wilhelm Roentgen (1845-1923) in 1901 *«for the discovery of X-rays»* [2]. From 1901 to 2011, the Nobel Prize in physics was awarded to 190 scientists around the world. At the same time, 58 times the Prize was awarded to two or three researchers simultaneously (according to the existing position in the authors' team of applicants there should be no more than three scientists) [1]. American John Bardin (1908-1991) has so far been the only scientist awarded in this group of scientists Nobel Prize in Physics twice - in 1956 (*«for the study of semiconductors and the discovery of transistor effect»*) and in 1972 (*«for the development of the theory of superconductivity»*) [2, 3]. Women scientists became Nobel Prize Laureates in physics only twice - the Frenchwoman of Polish descent Maria Sklodowska-Curie (1867-1934) in 1903 (*«for the study of the phenomenon of radioactivity»*) and the American Maria Geppert-Mayer (1906-1972) in 1963 (*«for the creation of a shell model of the nucleus»*) [2].

1. The discovery of the acceleration of the expansion of the Universe. The Laureates of the Nobel Prize for Physics in 2011 were the Americans Saul Perlmutter (Fig. 1), Adam Riess (Fig. 2) and Brian Schmidt (Fig. 3) *«for the discovery of the acceleration of the expansion of the Universe by observing distant supernovas»* [1]. Their fundamental conclusion about the accelerated expansion of the universe with time was obtained in the course of very fine and accurate observations of supernova stars conducted by S. Perlmutter from the University of California (Berkeley, USA), A. Riess from the Space Telescope Science Institute (Baltimore, USA) and B. Schmidt from the famous Mount Stromlo Observatory at the Australian National University [1].

Fig. 1. Prominent American physicist-astronomer Saul Perlmutter, born in 1959, Nobel Prize Laureate in physics for 2011

S. Perlmutter, A. Riess and B. Schmidt carried out their many years astronomical observations using exclusively supernovae of type I*a* located in the distant galaxies of our Universe. For these observations, they used several large telescopes, including a 3.6-meter telescope type NTT (New Technology Telescope) and a 8.2-meter telescope type VLT from the world-famous South American observatory La Silla (ESO, Chile) [1]. Fig. 4 shows a series of photos of the 1995K supernova made by the Laureates on April 3, 1995, using a 3.6-meter NTT telescope [1]. Based on the analysis of such images, they made a scientific discovery, awarded such a high Prize.

Fig. 2. Prominent American physicist-astronomer Adam G. Riess, born in 1969, Nobel Prize Laureate in physics for 2011

Fig. 3. Prominent Australian-American physicist-astronomer Brian P. Schmidt, born in 1967, Nobel Prize Laureate in physics for 2011

It is believed that the accelerated expansion of the universe is due to the presence of «dark» energy («black holes») in it [1, 4]. The origin of this energy in outer space and its nature for scientists are still deeply mysterious phenomena. In the scientific world, it is common to believe that this discovery, accomplished by astronomical physicists, is one of the few recent truly great scientific discoveries in physics and astronomy [1]. It can have serious worldview significance for mankind. Here we should note that the fundamental discovery made earlier on the basis of astronomical observations by the famous American astronomer Edwin Powell Hubble (1889-1953) about the expansion of the universe remained practically beyond the «field of vision» of the Nobel Committee at the Royal Swedish Academy of Sciences [1]. An interesting fact is that E.P. Hubble once led the movement of numerous scientists for the establishment of the Nobel Prize in astronomy. It should be noted that this movement did not have much success, but it apparently influenced the members of the Nobel Committee in a certain way, who nevertheless made the decision that the world's astronomers could receive the Nobel Prize in physics [1, 2].

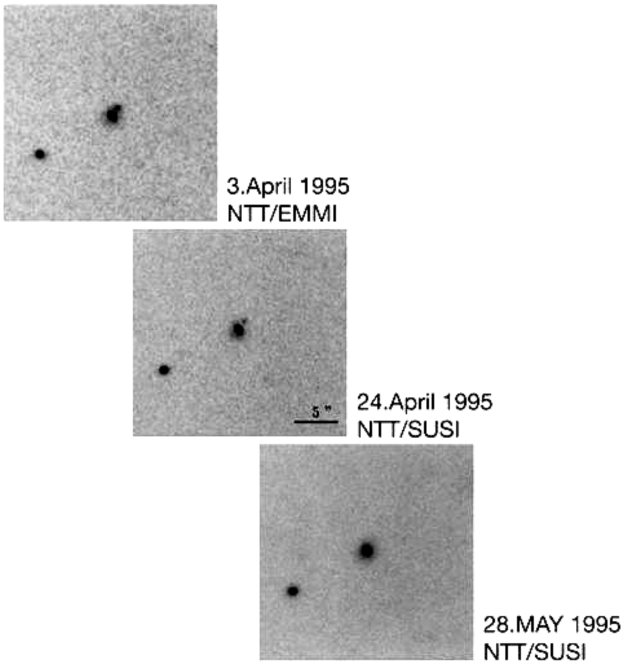

Fig. 4. A series of astronomical images of a very distant supernova in our Universe, which has an international registration number 1995K [1]

Recall that for 111 years of awarding the Nobel Prizes (for the period 1901-2011), astronomical scientists were awarded 11 times this prestigious award [1].

2. The discovery of a method for measuring microparticles and quantum systems without destroying them. Nobel Prize winners in physics in 2012 were Frenchman Serge Haroche (Fig. 5) and American David Wineland (Fig. 6) working in the field of quantum physics, *«for the advanced discoveries of experimental methods that make it possible to measure individual quantum systems»* [5]. S. Haroche and D. Wineland laid the scientific basis for a new generation of experiments in quantum physics that allow «to directly observe individual quantum particles without destroying them.» S. Haroche and D. Vineland carried out their quantum experiments independently of each other. These scientists managed to develop original physic-engineering solutions for manipulating individual quantum microparticles without destroying their quantum-mechanical nature. Many experimental physicists believed that such studies were simply impossible. The American physicist used the method of ion «traps», manipulating ions with the help of quasiparticles-photons (quanta of an electromagnetic field or light that do not have a rest mass [6]). His French counterpart, on the other hand, measured the quanta of light, directing the flow of atoms of matter through a photon «trap» [5].

D. Wineland taught specialists to trap microparticles that carry an electric charge (for example, atoms and ions), and also to monitor and measure their state with the help of light quanta [5].

Fig. 5.Prominent French experimental physicist Serge Haroche, born in 1944, Nobel Prize Laureate in physics for 2012

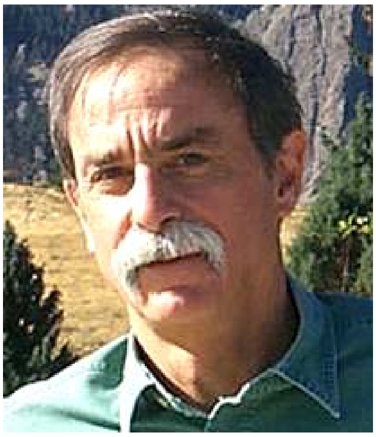

Fig. 6. Prominent American experimental physicist David J. Wineland, born in 1944, Nobel Prize Laureate in physics for 2012

S. Haroche developed an opposite scientific approach that allows you to understand the physical wonders of the quantum world. He came up with a way to control and measure the properties of «captured» photons with the help of atoms trapped in the «trap» [5]. In this case, S. Haroche and his colleagues used «Rydberg» atoms in their experiments, which are more than a thousand times larger than ordinary atoms of matter [6]. They sent them to a photon «trap» with a strictly defined rate, causing them to communicate with the microwave photons (quanta of light) present there. Because of this interaction, the quantum energy state of the «Rydberg» atoms themselves, named after the famous Swedish physicist J.R. Rydberg (1854-1919) [2, 7], while changing. Measurement of the state of these atoms occurred at the output of the specified «trap». As a result, physicists received information about photons trapped in the trap, without destroying them. Like everything, at first glance, it's easy! And behind this apparent simplicity lies the many years of painstaking work of many physicists, connected with high-precision measurements at the atomic level. The described method, as it turned out, can be used to calculate the number of photons trapped in the trap. Subsequently, the physics laureates, based on these achievements, have learned to track changes in the quantum state of an individual photon in real time [5, 8]. Thanks to their research, it became possible to create in the future superhigh-precision clocks and superfast high-speed quantum computers. If a quantum computer with a large volume of information qubits is created in the foreseeable future, its computing power is expected to be truly enormous, which will lead to a real information and technological breakthrough in the world.

3. Theoretical detection of the mechanism of origin of the mass of subatomic particles. The Nobel Prize in physics for 2013 was awarded to two theoretical physicists, the Belgian Francois Englert (Fig. 7) and the British Peter Higgs (Fig. 8) [9].

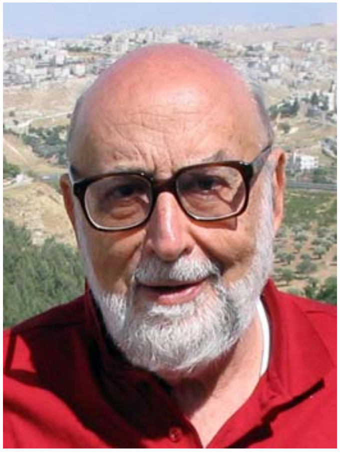

Fig. 7. Prominent Belgian theoretical physicist Francois Englert, born in 1932, Nobel Prize Laureate in physics for 2013

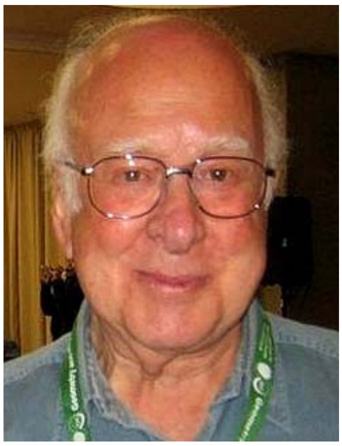

Fig. 8. Prominent British theoretical physicist Peter Higgs, born in 1929, Nobel Prize Laureate in physics for 2013

This Prize F. Engert and P. Higgs were awarded *«for the theoretical detection of the mechanism that helps to understand the origin of the mass of subatomic particles,* *recently confirmed by the discovery of the predicted elementary particle in experiments on the ATLAS and CMS detectors of the Large Hadron Collider at CERN»* [9]. It is important to note that these physicists were given this prestigious and highly paid (USD 1.2 million for two [5]) Prize not for the prediction of the «Higgs» boson experimentally discovered in 2012 at the largest accelerating electrophysical installation in the world - Large Hadron Collider (LHC) at the European Center for Nuclear Research (CERN), located near Geneva (Switzerland) [3], but for the very «Higgs» mechanism, whose «echo» is the «Higgs» boson. The history of constructing theories of weak and strong interactions of microparticles in the field of elementary particle physics and high-energy physics is quite complex, requires special consideration and is not particularly interesting for us now. Undoubtedly, it is interesting in terms of the scientific priority for not one dozen theoretical physicists who have put their heads and hands on the creation of such theories and the development of a «Higgs» mechanism (for example, R. Braut, Ch. Yang, R. Mills, G. Guralnik, K. Hagen, T. Kibble and others) [9].

The role of the boson, first mentioned explicitly (in the form of a new massive spinless particle) in the theoretical work of P. Higgs (1964), as a convenient «echo» for the experimental mechanism of interaction in the microworld, was truly realized by physicists only in 1970th years [9]. Here to him (this boson), as well as to the very mechanism of interaction of elementary particles for ever, and a convenient and brief, but not quite fair epithet «Higgs». It was after the theory of electroweak interactions was constructed that relied, among other things, on this mechanism, and also after it was shown that this theory is renormalizable (self-consistent and suitable for calculations) and there arose a mass interest among physicists towards properties and to Search for the Higgs boson [9].

Theoretical physicists began to calculate the processes of birth and decay of this boson, and experimental physicists began to search for it in nuclear reaction products at all the largest colliders in the world (for example, in Europe at the electron-positron LEP accelerator with energy up to 104 GeV at CERN and in the USA at a giant proton-antiproton accelerator «Tevatron» with an energy of up to 1 TeV at the E. Fermi National Laboratory for Nuclear Research [3]). There were years of observations, and no one could find the required boson. The overwhelming majority of the world's leading physicists based on accumulated scientific data by the beginning of the 21st century convinced themselves that the Higgs boson should exist. They lacked the final touch - the direct discovery of the «Higgs» boson in the experiment. And now, at the super-powerful proton collider LHC at CERN, actually launched in 2009, the Higgs boson in 2012 was experimentally discovered. This important scientific event happened almost 50 years after the theoretical discovery of this elementary particle [9].

What is the essence of the «Higgs» mechanism and why does the «Higgs» boson answer the microcosm? According to [9], the «Higgs» mechanism for relativistic theories of the interaction of elementary particles is based on the idea that when a massless scalar particle «contacts» a massless carrier of interaction, a carrier particle with mass (some unknown massive boson) is born. To approach historical truth in the issue of the birth in physics of elementary particles of this idea, formulated by P. Higgs only in 1964, we note that in 1963 prominent American physicist, Nobel Prize Laureate in physics for 1936 (*«for the discovery in cosmic rays of the positron»* [2]) Karl Anderson (1905-1991), published a similar idea with reference to the nonrelativistic theory of the interaction of microparticles [9]. Therefore, the author of the above-mentioned scientific idea, which later became the basis of the «Higgs» mechanism of particle interaction, probably should be considered the US physicist K. Anderson.

As for the possible liability for the inexperienced reader of the Higgs boson for the mass of all the particles in our Universe, it is immediately necessary to say unambiguously that this boson does not give anybody and nothing in nature [9]. It turns out that the mass of particles is given by a «Higgs» field. The «Higgs» boson is only a microscopic «ripple» and a kind of energy perturbation of this «Higgs» field [9]. In addition, the Higgs field gives mass only to electrons, muons and some other heavy particles [6, 9]. The mass of protons and neutrons that make up the nuclei of all chemical elements from the periodic system of elements of D.I. Mendeleyev [3, 6] and the mass numbers A determining them and, correspondingly, up to 99 %, the mass of any substance, determine completely different physical mechanisms [9]. In this connection, the «Higgs» field corresponds approximately to 1 % of the mass of the surrounding matter [9]. The «black holes» present in space, as well as the undiscovered particles of «dark» matter [4] and, possibly, neutrinos also receive their mass due to other physical sources [9]. At present, in physics of elementary particles on the universal level of communication between scientists, it is considered that the «Higgs» boson is nothing, and the «Higgs» field is everything [9]. It is not yet possible to obtain and investigate this field without the boson in question. Therefore, the «Higgs» boson should help mankind to know the properties and origin of the «Higgs» field. And for this, numerous experiments are required at the Large Hadron Collider LHC, accompanied by the birth and decay of the Higgs boson. Statistical processing of the results obtained in these processes should «shed» light on its nature and the nature of the «Higgs» field. At present, physicists believe that the «Higgs» field does not generate gravity associated with the total energy of the physical body. The «Higgs» field can translate some of the energy of the physical body into rest energy (in its mass). However, it does not influence the gravitational interaction of bodies [9].

4. The invention of blue LEDs – energy-saving light sources. In 2014, three Japanese experimental physicists, Isamu Akasaki (Fig. 9), Hiroshi Amano (Fig. 10) and Shuji Nakamura (Fig. 11) received the Nobel Prize in physics *«for the creation of a new energy efficient and environmentally friendly light source - blue light-emitting diodes"* [10-13]. Note that before 1990, world manufacturers of LEDs could only produce red, yellow and green diodes. It is known that only a combination of blue, green and red colors can give a pure white color. Therefore, the current problem in the physics and technology of semiconductors for the world's leading manufacturers of LED products was the one that was associated with the invention of light-emitting diodes giving a bright blue color [10].

Fig. 9. Prominent Japanese experimental physicist Isamu Akasaki, born in 1929, Nobel Prize Laureate in physics for 2014

Fig. 10. Prominent Japanese experimental physicist Hiroshi Amano, born in 1960, Nobel Prize Laureate in physics for 2014

Fig. 11. Prominent Japanese experimental physicist Shuji Nakamura, born in 1954, Nobel Prize Laureate in physics for 2014

Fundamental and applied physical and technical investigations of I. Akasaki, H. Amano and Sh. Nakamura showed that one of the promising semiconductor compounds on the basis of which it is possible to create such light emitters can be gallium nitride GaN [10-13]. In the early 1990s, these Japanese physicists based on GaN gallium nitride created both double-layered and multilayer heterostructures with *p-n* junctions of conductivity that provide the creation and industrial production of blue-light-emitting diodes [10-13]. This scientific and technical event was a major breakthrough in the field of world light technologies.

In 1993, Nichia Chemical Industries Corporation (NCI) (Tokushima, Japan) was the first in the world to start the industrial production of blue LEDs [10]. These LEDs made it possible to manufacture new energy-saving white sources. The invention of I. Akasaki, H. Amano and Sh. Nakamura of blue LEDs, which are necessary for obtaining all shades of light in LED devices, was a real technological revolution for outdoor LED video screens [10].

Sh. Nakamura became famous not only for the invention of blue LEDs of high brightness, but also for the NCI Corporation in 2005 win in a lawsuit to pay him a fee based on the results of the introduction of his patents worth about 9 million USD (the largest Japanese bonus!) [13].

5. Discovery of neutrino oscillations. The Nobel Prize in physics for the year 2015 was awarded to two experimental physicists: Canadian Arthur Bruce McDonald (Fig. 12) and Japanese Takaaki Kajita (Fig. 13) *«for the discovery of neutrino oscillations, which shows that neutrinos have a mass»* [14]. These scientists led the two leading scientific groups SNO (Sudbury Neutrino Observatory, Canada) and Super-Kamiokande (Japan), engaged in the study of the easiest, most mysterious and subtle instrumentation detectors - neutrinos [6, 7]. These particles, which interact extremely weakly with matter, belong to leptons [6]. They arise in the beta decay of atomic nuclei and the decays of elementary particles and are characterized by spin $S_\nu=\pm 1/2$ [6, 7]. Their measurements have shown that neutrinos come in three varieties: electronic ν_e, muonic ν_μ and tau-neutrino ν_τ [6, 14].

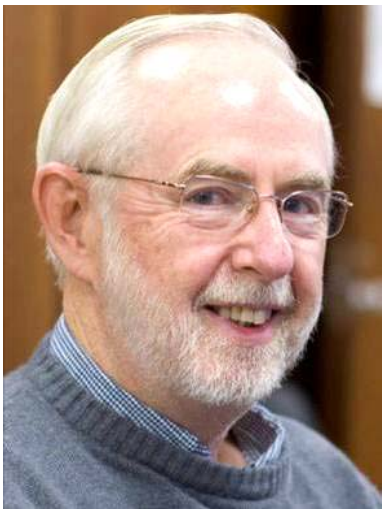

Fig. 12. Prominent Canadian experimental physicist Arthur Bruce McDonald, born in 1943, Nobel Prize Laureate in physics for 2015

Fig. 13. Prominent Japanese experimental physicist
Takaaki Kajita, born in 1959,
Nobel Prize Laureate in physics for 2015

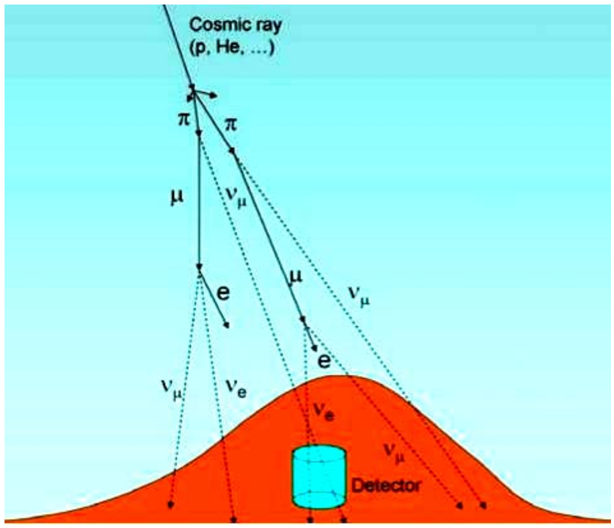

Fig. 14. Schematic representation of the processes of «birth» of muonic and electronic neutrinos in the Earth's atmosphere [12]

Moreover, these three kinds of neutrinos are not separated from each other in the microworld and, accordingly, in the macrocosm. They are able to mutually oscillate - spontaneously turn «on the fly» into each other. It was for the proof of the reality of this physical effect (neutrino oscillations) that the Nobel Prize for the past year was awarded to these scientist-physicists. Experimental demonstration of this fact in the field of elementary particle physics and measurement of parameters of neutrino oscillations using cosmic rays contributed to the active development of neutrino physics and the progress in this scientific area of our knowledge. Mutual transformations of neutrinos in the Earth's atmosphere (Fig. 14) are due to their very small masses at distances of a few (tens of) kilometers - a purely quantum effect [14, 15]. Note that the main milestones in the field of neutrino physics prior to the studies we are considering are A.B. McDonald and T. Kajita became [2, 14]: achievements awarded the Nobel Prize in physics for 1988 (*«for the discovery of muon neutrinos»*), for 1995 *(«for the discovery of electronic neutrinos"*) and for 2002 (*«for the discovery of solar neutrinos»*). Despite this, before the discovery of A.B. McDonald and T. Kajita, neither neutrino masses nor their oscillation parameters were known to physicists [2].

Fig. 14 schematically shows the processes of «birth» during the passage of high-energy cosmic rays (mainly the proton flux p) through the earth's atmosphere of pions (π), muons (μ), electrons (e), muonic ν_μ and electronic ν_e neutrinos, measured Deeply located underground in the mines by detectors (detector) [14]. In the course of the measurements, it was established that after the course of the series shown in Fig. 14 decays to the Earth neutrinos penetrate in the ratio $\nu_\mu/\nu_e \approx 1.2/1$.

Estimated calculation data, performed by theoretical physicists in 1991, indicated that for the reduced ratio of muonic ν_μ and electronic ν_e neutrinos, an equality of the form $\nu_\mu/\nu_e \approx 2/1$ [14-16].

The reason for the discrepancies in the ν_μ/ν_e ratio for physicists was at that time unknown and incomprehensible. In 1998, at an international conference on astrophysics, T. Kajita, on behalf of the collaboration of Japanese scientists Super-Kamiokande, a report was made, from the results of which it emerged that in underground neutrino detectors from above (from the nearest Earth's surface) and from below (from a remote opposite terrestrial surface) Numerous quantities of muonic neutrinos ν_μ arrive at the Earth. The neutrino detector Super-Kamiokande was a large underground cistern located in an old mine inside the mountain and filled with ultrapure ordinary water [16]. The internal walls of the detector were completely covered with sensitive photomultipliers, which registered light flashes from nuclear events that flowed inside its working substance-water. The energy cosmic neutrino (with an energy of the order of 100 MeV) of the electron or muonic variety, colliding with the atomic nucleus of water, turns into an electron e or a muon μ that flies forward at a high speed and emits light due to the Vavilov-Cherenkov effect [6, 14-16]. Due to this, the neutrino detector Super-Kamiokande not only detected a neutrino bombarding it, but also determined their sort, energy and direction of arrival to the Earth. Recall that the substance of our planet for neutrinos is almost completely «transparent» [14]. Therefore, on the basis of the experimental data obtained by Japanese physicists, an important conclusion was drawn that on a thousand-kilometer path through the solid crust, semi-liquid mantle and liquid core of the Earth [17], an essential part of the muon neutrinos ν_μ penetrating our planet from the opposite location of the side detectors Turn into other types of neutrinos [14]. Moreover, not in the electronic neutrinos ν_e measured by the detectors, but in the unmetered by them, the tau-neutrino ν_τ. Analogous results in the part of neutrino oscillations (with respect to electronic ν_e, muon ν_μ and tau-neutrino ν_τ coming from the Sun) in the period 2001-2002 were obtained by the collaboration of Canadian scientists SNO with the help of underground neutrino detectors of elementary particles, the capacitances of which were filled with heavy water, whose nuclei (deuterons) contained a weakly bound system of proton and neutron [14, 15]. At the energy of several neutrons of SNO neutrons acting on the detectors, the deuterons of their heavy water decay into protons and neutrons. By highlighting gamma quanta in neutrino detectors that accompany the capture of deuterium nuclei by the produced neutrons, physicists have judged the nuclear transformations taking place in them. So physicists from the Super-Kamiokande and SNO collaborations obtained irrefutable experimental evidence in favor of the existence of neutrino oscillations [14]. These experimental results also confirmed the validity of the «solar model» developed by theoretical physicists, describing the thermonuclear reactions that are taking place inside our luminaries and the «born» fluxes of solar neutrinos that pervade space and penetrate outer space and the planet Earth.

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