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M.I. Baranov

AN ANTHOLOGY OF THE DISTINGUISHED ACHIEVEMENTS IN SCIENCE AND TECHNIQUE. PART 36: NOBEL PRIZE LAUREATES IN PHYSICS FOR 1995-1999

Purpose. Implementation of brief analytical review of the distinguished scientific achievements of the world scientists-physicists, awarded the Nobel Prize in physics for period 1995-1999. Methodology. Scientific methods of collection, analysis and analytical treatment of scientific and technical information of world level in area 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 bonuses on physics for period 1995-1999. Originality. Systematization is executed with exposition in the short concentrated form of the known scientific and technical materials, devoted opening of tau-lepton, experimental discovery of electronic neutrino, opening of superfluidity of liquid helium-3, creation of methods of cooling and «capture» of atoms by a laser ray, opening of new form of quantum liquid with excitations of fractional electric charge and clearing up of quantum structure of electroweak interactions of elementary particles scientists-physicists. Practical value. Popularization and deepening of scientific and technical knowledges for students, engineer and technical specialists and research workers in area of modern theoretical and experimental physics, extending their scientific range of interests and further development of scientific and technical progress in human society. References 25, figures 13.

Key words: **modern physics, achievements, tau-lepton, electronic neutrino, superfluidity of liquid helium-3, cooling and «capture» of atoms, quantum liquid with excitations of fractional electric charge, quantum structure of electroweak interactions of elementary particles, review**.

Приведен краткий аналитический обзор выдающихся научных достижений ученых мира, отмеченных Нобелевской премией по физике за период 1995-1999 гг. В число таких достижений вошли открытие тау-лептона, экспериментальное обнаружение электронного нейтрино, открытие сверхтекучести жидкого гелия-3, создание методов охлаждения и «пленения» атомов с помощью лазерного света, открытие новой формы квантовой жидкости с возбуждениями дробного электрического заряда и прояснение квантовой структуры электрослабых взаимодействий элементарных частиц. Библ. 25, рис. 13.

Ключевые слова: **современная физика, достижения, тау-лептон, электронное нейтрино, сверхтекучесть жидкого гелия-3, охлаждение и «пленение» атомов, квантовая жидкость с возбуждениями дробного электрического заряда, квантовая структура электрослабых взаимодействий элементарных частиц, обзор.**

Introduction. The Nobel Prize has been more than a century is one of the most prestigious international awards in the world. It is awarded by the Nobel Committee of the Royal Swedish Academy of Sciences for outstanding scientific research, revolutionary invention, a major contribution to culture and the development of human society [1]. Nobel Prize in physics, chemistry, physiology, medicine, literature and peace were established in accordance with the will-known Swedish engineer and inventor of dynamite Alfred Nobel (1833-1896) according to which for these purposes, and the financial support of Nobel laureates was created fund Nobel. They are handed to 1901 in the capital of Sweden – Stockholm (except for the Nobel Peace Prize award ceremony which takes place in the capital of Norway – Oslo). Traditionally, the annual awards ceremony for the winners of this prestigious award is held on the day of the death of A. Nobel – December 10th. Note that in 1968 by the Bank of Sweden Prize in Economics in memory of A. Nobel (Nobel Prize in Economics) was established [1]. The size of remuneration of the Nobel Prize, for example, in 2012, amounted to 8 million SEK (1.2 millon USD). Until 2012, this amount was considered the award of 10 million SEK. The Board of Directors of the Nobel Foundation in the summer of 2012 was forced to take a decision on the «cuts» monetary reward laureates for 20 % due to the need to «*preserve the fund's capital in the long term*» [1].

1. The discovery of the tau-lepton. According to the classification adopted in the physics of elementary particles tau-leptons are the third generation of microparticles [1, 2]. American experimental physicist Martin Lewis Perl (Fig. 1) working at Stanford heavy duty linear electron accelerator at energies up to 21 GeV with the length of the accelerator «tube» in 3200 m (USA) [3] in 1975 opened a new elementary particle tau-lepton (in other words, a «heavy» electron) [4]. This is an important discovery in high-energy physics and elementary particles confirmed the theory of «Big Bang» in the creation of the Universe [1, 5].

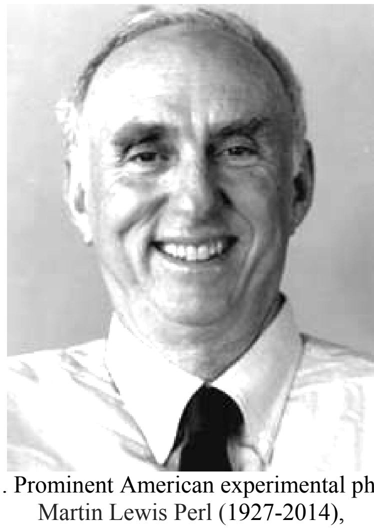

Fig. 1. Prominent American experimental physicist Martin Lewis Perl (1927-2014), Nobel Prize Laureate in physics for 1995

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For this fundamental scientific result M. Pearl in 1995 was awarded the Nobel Prize in Physics [4, 5]. This award he shared with other prominent American physicist Frederick Reines (Fig. 2) who discovered the neutrino [4, 6].

Fig. 2. Prominent American experimental physicist Frederick Reines (1918-1998), Nobel Prize Laureate in physics for 1995

2. The discovery of the neutrino. In 1930, an outstanding Austrian theoretical physicist Wolfgang Pauli (1900-1958) advanced the hypothesis of the existence of such «light» of elementary particles like the electron neutrino v_e according to the relevant [2] to the absolutely stable particles with no charge and rest mass [4 6]. Working in creative tandem with the renowned American experimental physicist at Los Alamos National Laboratory (New Mexico, United States) Clyde Cowan (1919-1974), F. Reines in 1956 to reverse the radioactive beta decay of atomic nuclei (β^+ − decay) on the experimental nuclear reactor found in the decay products of the electron neutrino v_e [6]. By the time of the award of F. Reines said Prize for 1995 K. Cowan was no longer alive. Therefore his name was not on the list of Nobel Prize winners (according to the current position of this award is only awarded to applicants living this prestigious award).

3. The discovery of superfluidity of liquid helium-3. In 1972, American physicist David Morris Lee (Fig. 3), working in the US as Professor at Cornell University, in collaboration with another Professor of this University Robert Coleman Richardson (Fig. 4) and graduate student Douglas Dean Osheroff (Fig. 5) have published research results opening at a temperature of about 0.001 K of superfluidity in the isotope helium ${}_2^3He$ − liquid helium-3 [7-9]. Recall that in 1937 the outstanding Soviet experimental physicist Peter Kapitsa (1894-1984), Head of the Institute for Physical Problems (IPhP) of the Academy of Sciences of the USSR (Moscow), with the absolute temperatures below 2.19 K was discovered a unique physical effect in the material – the phenomenon of superfluidity in the isotope helium ${}_2^4He$ − liquid helium-II [10]. For the «*basic inventions and discoveries in the field of low-temperature*» Academician of the Academy of Sciences of the USSR P.L. Kapitsa was awarded the Nobel Prize in physics for 1978 [4, 10]. Taking into account the fundamental nature of obtained by D.M. Li, R.C. Richardson, and D.D. Osheroff scientific results, in 1996 they were awarded the Nobel Prize in physics [4, 7-9]. The discovery of superfluidity of liquid helium-3 promoted promising fundamental and applied research in many fields of physics [4, 7].

Fig. 3. Prominent American experimental physicist David Morris Lee, born in 1931, Nobel Prize Laureate in physics for 1996

Fig. 4. Prominent American physicist Robert Coleman Richardson, (1937-2013), Nobel Prize Laureate in physics for 1996

Fig. 5. Prominent American experimental physicist Douglas Dean Osheroff, born in 1945, Nobel Prize Laureate in physics for 1996

4. Creation of methods to cool and «capture» of matter atoms. American Research Center of Bell Laboratories in the number of Nobel Prize winners take on today's leading position in the world [11]. In this well-known scientific centers in 1983 as head of the Department of quantum electronics future Nobel Laureate Steven Chu worked (Fig. 6). While addressing the supercooling and the «capture» of atoms using laser technology, in 1985. S. Chu and his colleagues William Daniel Phillips (Fig. 7), and Claude Cohen-Tannoudji (Fig. 8) achieved great success [11-15].

Fig. 6. Prominent American experimental physicist Steven Chu, born in 1948, Nobel Prize Laureate in physics for 1997

Fig. 7. Prominent American physicist William Daniel Phillips, born in 1948, Nobel Prize Laureate in physics for 1997

Fig. 8. Prominent French physicist Claude Cohen-Tannoudji, born in 1933, Nobel Prize Laureate in physics for 1997

It is well known that in the microcosm of the atom of matter the temperature measure (molecules) or particles their kinetic energy [2, 11]. A great contribution to this energy and, respectively, in the temperature gives the translational velocity of said microscopic objects. A smaller contribution of this indicator makes the frequency of natural oscillations [2, 11]. Therefore, the faster moving and more micro-object vary, so it will be «hot». By physicists it was found that at «minus» 270 °C (about 3 K) translational velocity substance atom is about 100 m/s [11]. T the ambient temperature («plus» 20 °C) atoms, this velocity value is close to 1000 m/s [2, 10, 16]. If we reduce the speed of 0.01 m/s, then the atom is virtually «frozen». This can be done by various physical methods. Studies conducted in the United States by S. Chu, W. Phillips, and C. Cohen-Tannoudji showed that the most convenient for this method is the method of laser cooling of atoms [11-15]. This group of physicists in the study using a laser beam of atomic processes have achieved the absolute temperature of the substance of the neutral atoms of the order of 10^{-6} K [11]. It is for this phenomenal achievement S. Chu, W.D. Phillips and C. Cohen-Tannoudji were awarded the Nobel Prize in physics for 1997 [4, 11-15]. Developed laser method of supercooling and the «capture» of the atoms in this way is currently used in the design of high-precision atomic clocks, as well as precise positioning and satellite navigation [13]. An important fact characterizing S. Chu like an unusual and talented person, is that S. Chu during the 2004-2008 biennium was the director of the world-famous Ernest Lawrence National Laboratory Lawrence (if the state is 4 thousand employees and an annual budget of 650 million US dollars) and is actively involved in alternative sources of energy (in particular biofuels, artificial photosynthesis and methods of generating electricity from solar radiation), and in the period 2009-2013 – Minister of Energy of the United States [12, 13].

5. Discovery of a new form of quantum fluid with fractional excitations of electric charge. The physical concept of «quantum fluid» was introduced in the period 1937-1941 by outstanding Soviet theoretical physicist Lev Davidovich Landau (1908-1968) is being developed at that time in the IPhP of the Academy of Sciences of the USSR (at the Academician of the Academy of Sciences of the USSR P.L. Kapitsa then worked fruitfully in the field of low-temperature physics and discovered experimentally in 1937 the phenomenon of superfluidity of liquid helium-II) the quantum theory of superfluidity of liquid helium-II [10, 17]. For a quantum fluid characteristic it is that it decisive role in the behavior of its microcomponent (constituent elements) are beginning to play the quantum effects. In this liquid, quantum uncertainty traces its origin (e.g., atoms) according to the Heisenberg uncertainty relation [2, 17] are starting to significantly exceed the current mutual distances between them. Therefore, the physical properties of these liquids will be determined solely by stochastic laws of quantum physics. In the period 1981-1982 research groups of Horst Ludwig Störmer (Fig. 9) and Daniel C. Tsui (Fig. 10) who studied «*the integer quantum Hall effect*» opened in 1980 by Klaus von Klitzing (born in 1943) at «helium» temperatures (till 1 K) and strong static magnetic fields (at magnetic flux density till 30 T) in the silicon field effect transistor and the award of the Nobel Prize in physics for 1985 [4, 18], using a two-dimensional ultra-pure gallium arsenide films at lower temperatures (below 1 K) and stronger permanent magnetic fields (for the magnetic flux density over 30 T) opened new «*fractional quantum Hall effect*» [18-20].

Fig. 9. Prominent German experimental physicist
Horst Ludwig Störmer, born in 1949,
Nobel Prize Laureate in physics for 1998

Fig. 10. Prominent American experimental physicist
Daniel C. Tsui, born in 1939,
Nobel Prize Laureate in physics for 1998.

For a better understanding of a difficult material should be noted that even in 1879 young American physicist Edwin Herbert Hall (1855-1938) exploring the flow of direct current strength along the I_H thin gold plate placed perpendicular to the lines of induction B_H external constant magnetic field discovered the phenomenon arises between the «free» edges of the plate electric potential difference or voltage U_H («*Hall effect*») [16]. As is known the cause of the rejection of U_H is drifting plates of electrons from the main direction of their drift to its «free» edges of the corresponding action on them in a magnetic field Lorentz force [2]. The value of U_H was directly proportional to the current I_H and B_H induction. In addition, the «Hall» R_H resistance equal to the ratio U_H/I_H

described by the relation of the form [18]: $R_H = B_H/(n_e e_0)$, where n_e is the average density of free electrons with the electric unit charge e_0=1.602·10^{-19} C in the material of the flat-plate conductor. That is why the Hall effect could be used for measuring the magnetic field, and determining the concentration of charge carriers (positive «holes») in conductors and semiconductors. E.H. Hall performed his experiments at room temperature (about 293 K) and the levels of magnetic induction B_H less than 1 T [18]. In the early 1980s by K. von Klitzing at the above-mentioned extreme conditions it was found that the «Hall» conductor resistance R_H (semiconductor) with increasing levels of exposure to it the magnetic induction B_H does not change continuously, but jumps, taking discrete (quantized) values $R_{Hi}=h/(ie_0^2)$, where i=1,2,3,.. are the integer quantum numbers i; h=6,626·10^{-34} J·s is the Planck constant [2]. Note that in this case the value of h/e_0^2 is approximately 26 Ω. According to the eminent German physicist Carl von Klitzing turned out that the «Hall» R_H resistance, regardless of the type of material under the action it ultralow temperatures and strong magnetic field is quantized. The experimentally discovered by K. von Klitzing «*integer quantum Hall effect*» was explained sequential filling of Landau levels (discrete energy levels of electrons in a magnetic field) with increasing magnetic induction level. In these experiments by H.L. Störmer and D.C. Tsui scientists have discovered new quantum leaps for the «Hall» resistance $R_{Hk}=h/(ke_0^2)$ which is three times higher than the largest R_{Hi} in earlier experiments by K. von Klitzing. The fundamental difference in this case was the fact that the value of k is the fractional value (1/3, etc.). In 1983, the American theoretical physicist Robert Betts Laughlin (Fig. 11) proposed a theoretical justification of this effect.

Fig. 11. Prominent American theoretical physicist
Robert Betts Laughlin, born in 1950,
Nobel Prize Laureate in physics for 1998

According to the theoretical substantiation by R.B. Laughlin of the open empirically by H.L. Störmer and D.C. Tsui «*fractional quantum Hall effect*» at the sufficiently low temperature and very strong magnetic field, a two-dimensional «electron gas» conductor (semiconductor) of the Fermi liquid becomes a kind of a new type of quantum fluid [18, 21]. Electrons with half-integer values of their spin are part of this «Laughlin» quantum fluid, and occurring in her excitement starting to behave like quasi-particles with integer spin (as bosons) [18-21]. «Laughlin» quantum liquid became a Bose liquid, for which it is possible Bose condensation, and hence the phenomenon of superfluidity and superconductivity. The latter phenomenon was made possible when driving in this particular quantum fluid is electrically charged. R.B. Laughlin in the proposed theory suggests that these quasi-particles in the quantum liquid are collective entities whose existence is ensured by long-range interaction between electrons and a strong magnetic field. According to R.B. Laughlin a composite quasi-particle (boson) in the «Laughlin» quantum liquid is a combination of an electron and three magnetic flux quanta [18, 21]. New «Laughlin» quantum liquid characterized by unusual physical properties added to it the electron is so energetically unfavorable for it, that it be born excitation with a fractional electric charge $e_0/3$ [18]. R.B. Laughlin first theoretically demonstrated that quasiparticles in condensed state of matter can have fractional electric charges. This theoretical approach by R.B. Laughlin allows individuals to explain the «*fractional quantum Hall effec*t» previously set by H.L. Störmer and D.C. Tsui. For the fundamentality and «*discovery of a new form of quantum fluid with fractional electric charge excitations*» H.L. Störmer, D.C. Tsui, and R.B. Laughlin was awarded Nobel Prize in physics for 1998 [4, 18-21]. It should be noted that despite the fact that fractional electric charge quasiparticles participating in the course of events «*the fractional quantum Hall effect*» in a kind of Bose condensate set and measured now, thanks to the outstanding achievements in electronics and metrology reliably talk about the direct supervision of the microparticles with charge is premature. However, the research results of the new Nobel Laureates allow us to state that there was an important event in the scientific world, which forces scientists to reconsider many of the provisions in our current understanding of the world around us.

6. Clarification of the quantum structure of electroweak interactions of elementary particles. In the 1960s, by prominent American Sheldon Lee Glashow (born 1932), Steven Weinberg (1933-1996) and Pakistani Abdus Salam (1926-1996) theoretical physicists, quantum theory of weak and electromagnetic interactions in microcosm has been developed using the principle of gauge invariance [22]. This theory was based on the fact that in the microcosm the weak and electromagnetic interactions are manifestations of a single electroweak interaction. The practical application of this theory to calculate the physical properties of elementary particles which it should predict had no good results [23]. In the 1970s to address the problem in the field of elementary particle physics actively involved physicists of the University of Utrecht (Netherlands), Martinus Veltman (Fig. 12) and Gerard Hooft (Fig. 13). They do a mathematical formulation of gauge theories and renormalization theory of so-called non-Abelian gauge theories which are the foundation of all modern physics of elementary particles [24]. Developed by these theoretical physicists mathematical apparatus and, based on a computer program showed that many of the most problematic aspects of a non-Abelian gauge theories – the theory of electroweak interactions in the process of mathematical calculations are compensated [22-24]. This program became the foundation for the difficult work of scientists to verify the different approaches to the renormalization theory, which would allow to obtain a reasonable prediction of particle physics.

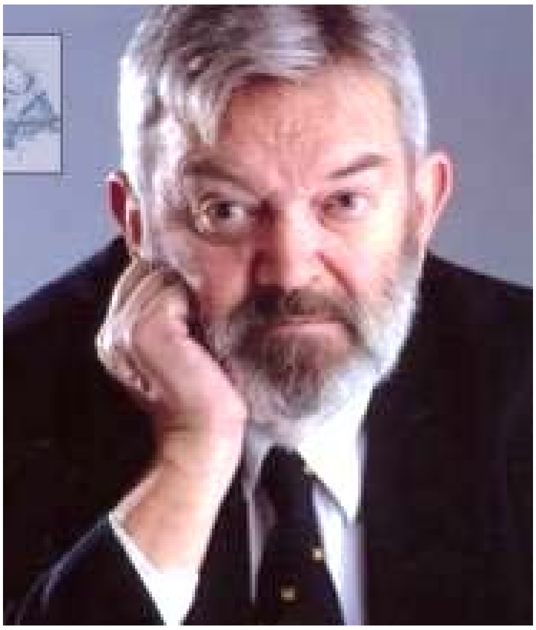

Fig. 12. Prominent Dutch theoretical physicist
Martinus Veltman, born in 1931,
Nobel Prize Laureate in physics for 1999

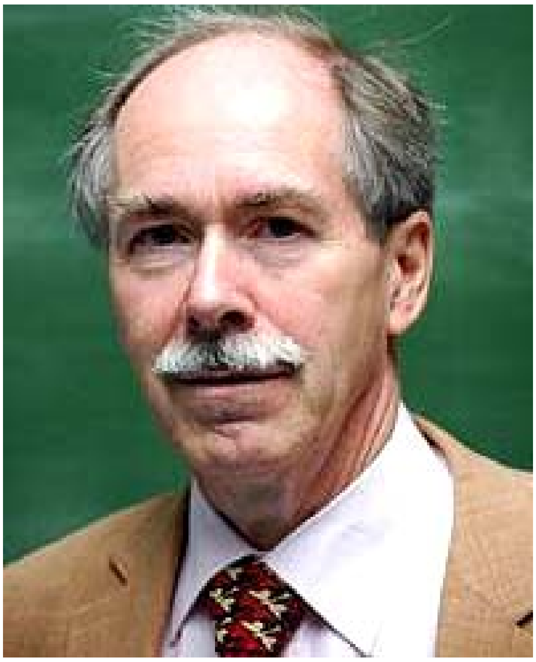

Fig. 13 Prominent Dutch theoretical physicist
Gerard Hooft, born in 1946,
Nobel Prize Laureate in physics for 1999

Developed by G. Hooft and M. Veltman new mathematical methods of renormalization of Yang-Mills fields as massless, and the weight was due to spontaneous symmetry violation in the microcosm of the laws, allowed to predict some effects of electroweak interactions of elementary particles [22-24]. So, in 1977, it based on these methods and theoretical approaches failed to predict the mass of the top quark, experimentally discovered in 1995 at the Enrico Fermi National Laboratory of Nuclear Research (USA) [22]. In addition, by using the proposed by G. Hooft and M. Veltman quantum theory of electroweak interactions were predicted mass of the intermediate vector bosons $W^{\pm}$ and Z^0 – two new elementary particles discovered thereafter experimentally at the Large Hadron Collider [3] at the European Center for Nuclear Research (CERN, Switzerland) [22, 24]. One of the Nobel Prize Laureates in physics in 1979, Sh.L. Glashow (the Prize «*for his fundamental contribution to the theory unifying weak and electromagnetic interactions*» in the field of elementary particle physics, he shared with his fellow physicists and collaborators S. Weinberg and A. Salam [4, 25]) on the scientific achievementsof M. Veltman and G. Hooft said the following [24]: «*... the theory of electroweak interactions cannot be engaged in earnest without computing innovations introduced by Veltman and Hooft*». In 1999 «*for clearing the quantum structure of electroweak interactions*» M. Veltman and G. Hooft were awarded [4, 22-25] Nobel Prize in physics. In subsequent years, M. Veltman and G. Hooft in the field of elementary particle theory fruitfully engaged in so-called «Higgs» problem associated with superheavy Higgs boson H^* which field is, according to physicists, generates mass of all existing in the microcosm particles [24].

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M.I. Baranov, Doctor of Technical Science, Chief Researcher,
Scientific-&-Research Planning-&-Design Institute «Molniya»
National Technical University «Kharkiv Polytechnic Institute»,
47, Shevchenko Str., Kharkiv, 61013, Ukraine,
phone +38 057 7076841, e-mail: eft@kpi.kharkov.ua

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