Scientific school of Louis de Broglie and its role in the development of theoretical physics

ALEXANDRA SMYK

Moscow Automobile and Road State Technical University (MADI)
64, Leningradskii prospect, 125319 Moscow, Russia
afsmyk@mail.ru

L'Ecole de Louis de Broglie a été en son temps très nombreuse jusqu'à des centaines de membres. Elle a eu une grande influence dans le monde occidental.

Elle était une des principales branches de la tendance dominée par Einstein et rivalisait avec l'Ecole de Copenhague pour l'interprétation de la Mécanique quantique.

Avec Olivier Costa de Beauregard et Marie-Antoinette Tonnelat j'ai été un des derniers représentants de cette Ecole de de Broglie.

Il faut souligner toutefois que les deux tendances qui rivalisaient en mécanique quantique étaient d'accord sur un point essentiel : l'oeuvre collective de la mécanique quantique restera dans l'histoire comme le fondement de la microphysique moderne.

C'est pourquoi je suis particulièrement heureux et très fier de publier prochainement un livre commun qui sera signé du Professeur Harald Stumpf, un des plus proches collaborateurs et ami d'Heisenberg et de moi-même, Georges Lochak l'un des plus proches collaborateurs et ami de Louis de Broglie et son exécuteur testamentaire scientifique.

C'est dire combien le travail du Professeur Alexandra Smyk est particulièrement le bienvenu dans les Annales de la Fondation Louis de Broglie.

Georges Lochak

ABSTRACT. The article discusses the results of historical and scientific research of exploration activities of the prominent physicist of the twentieth century, Louis de Broglie. Observations are given as to the rise, existence and peculiar aspects of de Broglie scientific school activities, its role in the development of French theoretical physics, as well as its impact on the work of Russian physicists.

Introduction

The history of physics of the twentieth century is characterized by the formation and successful operation of scientific schools - research teams that have achieved results of planetary dimension. The notion of scientific school, according to Russian explorers of the history of science Y.A Khramov [1], V.P.Vizghin and A.V.Kessenikh [2,3], could be induced as research-on-research and historical idealization. Such an approach makes for an organic whole of scientific, educational, personal, psychological aspects of physics evolution along with effective collaboration of the scientific teams. The identifying features of any research on activities of a scientific school are scientific and educational aspects, the presence of certain research programs, specific evolution, its fate and fortunes.

The foreign scientific schools of J.J.Thomson, E.Rutherford, A. Sommerfeld, N.Bohr, M.Born are widely known and investigated. Their activity in 1910-1930-ies. was stimulated by the rapid development of non-classical physics. Since 1950s., foreign schools of this magnitude were disappearing, but in the USSR continued to successfully operate and maintain its value. Some leaders of the Russian scientific schools at one time underwent training at Western schools: Kapitsa considered himself a disciple of Rutherford and Landau – a follower of N. Bohr. The history of Russian scientific schools can boast the later school of theoretical physics in the Moscow University of People's Friendship. Professor Y.P. Terletsky was the head of that school. In 1957 he was trained in Paris by de Broglie. In actual fact modern historiography has hardly anything on scientific and educational activities of de Broglie and his scientific school.

The purpose of this article - to highlight certain aspects of the activities of the scientific school of Louis de Broglie, to show its role in the development of the French theoretical physics, as well as to pay attention to its international aspect that defined the direction of research of a number of Russian physicists.

Start up of educational activities of de Broglie

Low interest of modern historiography to the study of scientific and educational activities of de Broglie is largely due to the deep-seated prejudice of the scientific community. The misthought is that after the discovery of wave-particle duality in 1923 de Broglie did not made any substantial contribution to the development of modern physics, and his researches after 1924 are of no interest. The study of scientific works of L. de Broglie suggests that research and educational activities of de Broglie, as professor at the Sorbonne, contributed to the advancement and dissemination of the Copenhagen interpretation of quantum mechanics. He worked on issues such as the theory of light, thermodynamics of an isolated particle and wave mechanics, reinterpretation of wave mechanics and development of nonlinear wave equation [4].

The results of historical and scientific survey of Louis de Broglie role in the history of quantum mechanics confirm the following: the scientific team headed by de Broglie, which can be characterized as a scientific school, carried on activities for years [5]. This scientific school was marked first of all by the presence of a leader - Louis de Broglie, an outstanding scientist who identified the research envelope and specified research programs. And, secondly, by the disciples and the system of recruiting new ones through the university chair, as well as by the supervision of postgraduates and defense of a thesis.

Educational activity of de Broglie began in 1928. A prominent French mathematician Emile Borel, who was one of the originators of the Institute Henri Poincaré (IAP), invited de Broglie to take up a position as a professor at the Institute. From 1933 to 1962, Louis de Broglie was the head of the department of theoretical physics at the IAP, and left his post when he was 70 years old. IAP grew as a new Institute of the Faculty of Natural Sciences, University of Paris, which trained students and conducted research in the field of theoretical physics. In the 1930s. IAP was a center for the development of theoretical physics in France, and in some degree it was due to the activities of the scientific school of Louis de Broglie. Later E. Borel wrote: "de Broglie made of IAP one of the most important research centers in theoretical physics and in other related fields, he educated many followers" [6]. De Broglie himself grew up in keeping with the best l traditions of French scientific and philosophy schools (Descartes, Poincare, E.Meyerson) and in his scientific work developed these traditions, passing on "the torch of science" to his followers. His leadership was primarily related to the great discovery – wave-particle duality of matter. This was of great importance as

for understanding the physical nature of the world, as for the emergence of a new field of theoretical physics. And at that he had the necessary leadership qualities such as fresh ideas and cute mentality altogether, the span and diversity of interests, motivation and efficiency. De Broglie had the gift to express his ideas clearly and in plain words, and he had an unquestionable pedagogical skill.

Louis de Broglie loved his university duties, despite the fact that they took away his strength and a considerable part of his time. For 33 years, de Broglie was a brilliant lecturer, conscientious worker, persistently improving his lecture courses, as well as publishing them. In his popular scientific articles, he repeatedly discussed the origins of contradiction between the approach of a scientist and an educator: the mental talent of the first one is concentrated upon the discovery of the still unknown, while the educator is bound to be somewhat doctrinal in teaching process for he must follow a certain program. "The study certainly suggests perpetual anxiety, whereas teaching seeks to unabashed confidence, which is opposed to anxiety" - these were the thoughts of de Broglie, who remained a researcher, restless and challenging in heart, but having an air of an apparently confident Master who is absolutely certain about the facts he argues.

De Broglie taught courses on quantum mechanics and its applications, delved into issues such as the uncertainty principle, the theory of the magnetic electron, theory of measurement. According to his disciples de Broglie was an excellent lecturer on the theories of Heisenberg, Dirac, Pauli, nuclear physics and radioactivity. In 1930-1940-ies. de Broglie lectures were published as monographs and became widely known to physicists around the world. Among them are: "Introduction to Wave Mechanics", "magnetic electrons: the Dirac theory", "The New Physics and quanta", "A New Theory of Light", "Heisenberg uncertainty principle". Today these books represent the best exposition of the foundations of wave mechanics, quantum electrodynamics, physics of X-rays. All de Broglie monographs are the reflection of his thoughts about the nature, sources and ways of development of scientific knowledge, the genesis of scientific theories, about the impact of different philosophies on cognitive process. Einstein highly appreciated "a clear critical reasoning and philosophical approach", which are inherent qualities of de Broglie books.

In 1991, “The Annals of the Foundation Louis de Broglie” published a list of 241 theses, either supervised by de Broglie or examined by the board headed by de Broglie. The list gives an indication of the range of issues of modern theoretical physics tackled by his disciples. Here are just some of the topics of theses:

L. Goldstein "Quantum theory of inelastic collisions of electrons", 1932
A. Proca "The relativistic theory of the electron", 1933
S. Watanabe "Contribution to the study of the second law of thermodynamics in terms of wave mechanics", 1935
F. London "The new concept of superconductivity", 1937
L. Cartan "Prospects of ray optics and its application in mass spectrometry", 1938
M.A. Tonnelat "On the theory of the photon in a Riemannian space", 1941
O. Costa de Beauregard "Contribution to the study of the Dirac electron theory", 1943.
P. Chanson "Optical lens elements of proton microscope", 1946
P. Cüer "Contribution to the study and application of sensitive emulsions for problems in nuclear physics", 1947
Y. Angel "The behavior of ferrite materials in crossed magnetic fields", 1964
A. Gessous "Studies of relativistic thermodynamics", 1967

De Broglie Scientific seminar

The scientific school of de Broglie had the following mechanics: a scientific leader – professorial chair –seminar. For years the scientific and pedagogical activity of de Broglie remained unchanged in terms of his daily work. Every week de Broglie gave two lectures: the first on the basics of elementary quantum theory and relativity theory for students, and the second was dedicated to his own recent advances or to the original works of other scientists, published in various scientific reviews, which were of particular interest for him. Held the seminar under the supervision of Louis de Broglie was held every Tuesday afternoon in the IAP. According to his disciple G. Lochak, this seminar was "the number one scientific seminar throughout Paris for many years".

The first years of his seminar de Broglie described as an infancy. The period of scientific singleness of 1920 -1930 when he had no like-minded colleagues supporting his idea of phase electron wave, gradually dwindled. When de Broglie just started his seminar, he had only three followers : Andre Georges, Jean-Louis Destouches and Claude Magnan. There were very friendly relations among them. A.Georges later became a well-known French journalist and science writer, an editor, who published book series well-

known not in France only - "Science Today" and "The scientists of the world". Georges and de Broglie were very close friends, just like M. Besso and Einstein. J.L.Destouches who was an expert in the field of quantum mechanics, also studied philosophical problems of modern physics, such as the new rationalism. Alekandru Proca (1897-1955) stands out among the famous pupils of de Broglie. He defended his doctoral thesis in 1933 under the leadership of de Broglie, and in 1936 formulated the wave equation for particles with spin 1 and mass not equal to zero, which is known as Proca equation. This equation was obtained independently by de Broglie, almost at same time as Proca.

In the 1940s, Marie-Antoinette Tonnelat (1912-1980), Gerard Petiau, Olivier Costa de Beauregard (1911-2007) joined the seminar on a permanent basis first as undergraduates, then graduate students and members of a research team. There were working with de Broglie in different areas of theoretical physic. Student of de Broglie, M.-A.Tonnelat, explored questions of the gravitational field with the help of hypothetical particles - gravitons and developed a quantum theory of graviton particles with maximum spin 2. Developing the quantum theory of light Louis de Broglie coincidently established the wave equation describing the motion of a complex aggregate particle. He considered photon to be a composite particle formed by the merger of two Dirac particles with spin ½. Further to this work in 1950, in collaboration with Tonnelat he published an article in the "Comptes Rendus de l'Académie des Sciences" with the title "On the possibility of a complex structure for particles with spin 1".Then Tonnelat left quantum mechanics for a time and moved to Dublin. There she worked with E. Schrödinger on the problem of a unified field theory, and in the 1950s. returned to Paris. She published a book on the unitary theory of electromagnetism and gravity, became a professor at the Sorbonne and taught various disciplines of theoretical physics. Tonnelat originated the famous Paris seminar on the history of science, where physicists and philosophers held interdisciplinary discussions.

In the 1950s the de Broglie fusion technique was further developed by the work of other physicists. Similarly, Soviet physicist Frenkel considered the complexity of issues of particles with spin different from ½,. Fermi and Yang developed a theory of mesons with spin 1, as a fusion of two components with spin ½.

In the 1950s. young physicists - Andrade e Silva, Jean-Pierre Vigier, Georges Lochak, André Lichnerowicz joined the seminar and the group headed by de Broglie at the National Center for Scientific Research (CNRS). G. Lochak became a famous physicist. He developed the theory of the

leptonic magnetic monopole, which is a magneto-excited state of neutrino that could appear due to electromagnetic phenomena. In 1957 he worked with the Soviet nuclear physicists at the Joint Institute for Nuclear Research in Dubna. In the 1950s together with the young students, Louis de Broglie began to develop movement problems of singularities, which are solutions of nonlinear equations. During these years, he developed a new theory of quantum measurement, the dynamics of a particle with variable weight and the relativistic thermodynamics. Furthermore he formulated a concept of hidden thermodynamics of an isolated particle. "For twenty years I`ve been happily seeing with my own eyes the evolvement of a separate school around me and watching my present or former students, who have become teachers themselves, carrying out a number of important works out there, " - wrote de Broglie.

A research team as school is characterized by a special scientific atmosphere, style, or scientific ideology. All these features can be found in the scientific school of Louis de Broglie. It was working in the form of seminar, led de Broglie for many years. The seminar was a weekly session, where young and not so young theoretical physicists expressed their views. No one was likely to interrupt the speaker and ask questions until the end of the seminar. But there were after discussions and they proceeded without redundant passion. The great physicists of the twentieth century took part in the seminar and there were Born, Bloch, Brillouin, Darwin, Dirac, Einstein, Elsasser, Fermi, Fowler, Gamow, Heisenberg, Mott, Pauli, and many others. Russian physicists I.E.Tamm, D.D.Ivanenko, Ya.P.Terletsky, Y.P.Rybakov appeared at the seminar. For decades the seminar is an important forum for the French theoretical physicists who sought to keep abreast of the latest research. All theoretical studies which had been conducted in different research centers in France were reported at the seminar. Twenty years after the start of the seminar de Broglie wrote that up to fifty participants were involved in its work, and some of them sometimes had to stand, as there were no vacant seats.

The international aspect of the scientific school

De Broglie scientific school was distinguished itself by international cooperation. Physicists from different countries were trained at IAP, developing the ideas of de Broglie. There was a number of highly qualified physicists among them, and firs of all American physicist D. Bohm and Japanese Y.Takabayashi. De Broglie changed his attitude towards the

Copenhagen interpretation of quantum mechanics after the paper of Bohm, who made an attempt to construct a quantum theory with "hidden variables". They gave him a kind of impulse to return to the "theory of the double solution", left in 1927, when the probabilistic interpretation prevailed at the Solvay Congress. Together with Bohm, Vigier and Takabayashi de Broglie started to develop a nonlinear theory of subquantum field. The established theory of de Broglie-Bohm as a next step of the theory of "pilot wave", is now seen as an alternative (though rarely used) formulation of quantum mechanics. Takabayashi known for his works on the development of the theory of spin liquid, and his ideas are used in modern works on relativistic hydrodynamics. Among the foreign students of de Broglie there were a Portuguese Andrade e Silva, who developed the theory of measurement in quantum mechanics in cooperation with de Broglie; a Cambodian Thioun fruitfully worked with Andrade and Lochak. During long time cooperation this group wrote a lot of joint works. In particular, the idea of hidden thermodynamics of isolated particles was shaped. According to in the motion of a single particle there is a random element, due to its interaction with a hidden "subquantal environment." Thus, the quantum particle is reminiscent of colloidal particles showing Brownian motion due to collisions with invisible molecules of the medium. Takabayashi is known for his works on the development of the theory of spin liquid, his ideas are used in modern works on relativistic hydrodynamics.

With de Broglie direct involvement (he sent the first letters to the USSR Academy of Sciences, inviting for training). For the first time an exchange of French and Soviet physicists was organized to work in theoretical physics. G.Lochak was the first invited to the Soviet Union in 1956, and in 1957 professor Y.P.Terletsky came to IAP. It was Y.P.Terletsky who in the 1950s. drew attention to the rich possibilities of the nonlinear field theory to describe the structure of elementary particles. While developing the ideas of Einstein and de Broglie on the use for this purpose regular localized solutions of nonlinear field equations, Terletsky was actively looking for solutions subsequently called solitons. In particular, he initiated the first use of computers for numerical analysis of particle-like solutions in nonlinear models. The subsequent development of this area by his followers S.F.Shushurin, G.N.Shikin, Y.P. Rybakov to study the existence, stability and interaction of solitons has made a significant contribution to the development of modern physics of solitons. Creating in 1963 the Department of Theoretical Physics at the University of Peoples' Friendship, Y.P Terletsky from the beginning set up a good tradition of friendly relations with colleagues, students and graduate students. He has kept the spirit of the

scientific school of de Broglie where he happen to work. A number of his disciples (V.V.Kuryshkin, Y.P.Rybakov, N.V.Samsonenko) worked on the problems of the stability of the particles as localized structures in the framework of the nonlinear field theory. They were trained at the IAP, took part in the seminar of de Broglie, and published their article in the journal of the French Academy of Sciences upon his recommendations. "Sustainability issues in nonlinear field theory" (1965) was the subject of dissertation of Rybakov. He with many students from different countries subsequently developed methods for studying stability, existence and regularity of solutions of nonlinear field solutions. Rybakov and his disciples succeeded in implementing the idea of de Broglie that in a small neighborhood of the particle field equations are essentially nonlinear and corresponding localized solutions describe the structure of a particle as a soliton. Away from the center of the particle field decreases rapidly, leading to the linearization of the field equations. De Broglie thought that this linearization should lead the field equations to the known equations of quantum mechanics, which describes the state of the quantum particles as point objects.

Conclusion

In the study of the activities of a scientific school one might wonder why the name of one scientist is reasonably associated with a separate school, whereas another equal scientist has no such a school? To ask a question is much easier than to answer it. Why Einstein and Schrödinger had almost no disciples, while Bohr created and headed the unique Copenhagen School, Bourne – Gottingen and Sommerfeld – Munich one? One cannot give a straight answer to this question.. Historians of science understand research school as a special, unique system. This system reflects a complex range of social and creative relations between its scholars. Numerous components of this spectrum can be identified in the scientific and educational work of Louis de Broglie.

Acknowledgment

My acknowledgment to Sergei Abrakov for help in preparing this article.

References

[1] Khramov U.A. Scientific schools in physics, Kiev (1987)
[2] Vizgin V.P., Kessenikh A.V. Physical community of the USSR 1950-1960-ies.: The human resources and scientific schools // The scientific community of physicists of the USSR. 1950-1960-ies , Sankt -Petersburg (2007)
[3] Vizgin V.P. Sci-school approach to the history of Soviet physics / Institute for the History of Science and Technology. S.I.Vavilov. The Annual Scientific Conference (2013). V.1., Moscow (2013)
[4] Louis de Broglie. Selected research papers. T.1., Moscow (2010)
[5] Smyk A.F. From the de Broglie waves to the wave mechanics: monograph, Moscow (2013).
[6] Louis de Broglie. Physicien et penseur, Paris (1953)

(Manuscrit reçu le 16 février 2015)