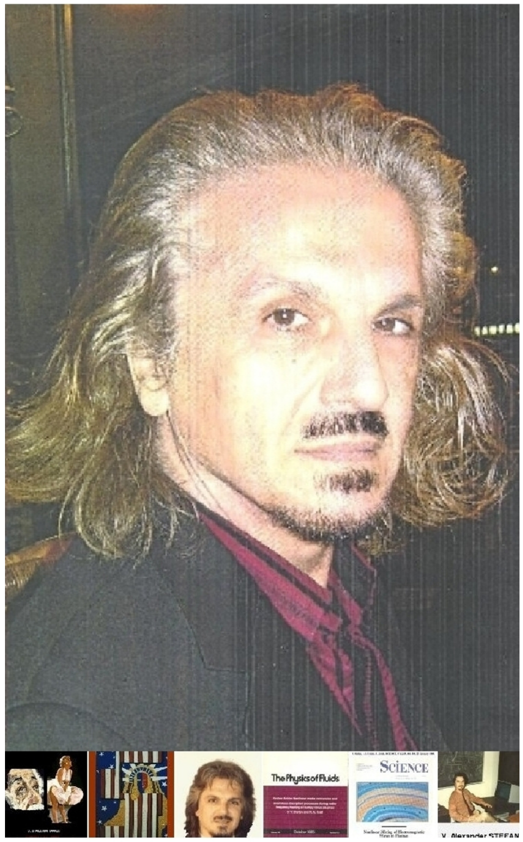
The Master of the Multiverse



A Biography of Vladislav Alexander Stefan

The Master of the Multiverse

A Biography of Vladislav Alexander Stefan

Compiled and Edited by the Editors
of the Stefan University Press

S-U-Press Editors and V. Alexander Stefan
Stefan University
La Jolla, California, USA

Published by the Stefan University Press, La Jolla, CA 92037

Library of Congress Cataloging-in-Publication Data

The master of the multiverse : biography of V. Alexander Stefan.
p. cm.
Includes index.
ISBN 978-1-889545-78-3 (hardcover : acid-free paper) 1. Stefan, V. 2. Physicists--Serbia and Montenegro--Biography. 3. Physicists--Russia (Federation)--Biography. 4. Physicists--United States--Biography.
QC16.S783M37 2008
530.092--dc22
[B]
2008035180

In recognition of the importance of preserving what has been written, it is a policy of the Stefan University Press to have books of enduring value, published in the United States, printed on acid-free paper to meet the guidelines for performance and durability of the Committee on production guidelines for book longevity of the Council on Library Resources.

Printed in the United States of America. The Stefan University Press, La Jolla, California 92037.

CONTENTS

Appendix I
Works, (1973-1977), in Philosophy of Physics and Mathematics

V. Alexander Stefan

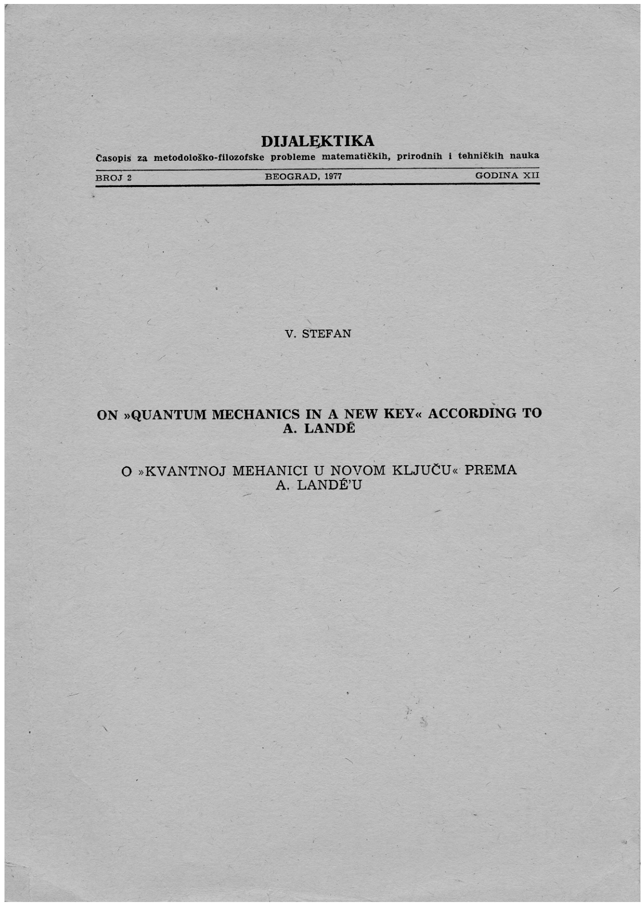
On Quantum Mechanics in a New Key According to A. Landé

Solving the "Quantum Ridle," Einstein's "Pet Idea" [1] [2]

---

[1] V. Stefan, On "Quantum Mechanics in a New Key" According to A. Landé, Dialectica, (Belgrade), No.2, Year XII, (1977).

[2] English editing by Carolyn Kilkka Todorovich.



DIJALEKTIKA
Časopis za metodološko-filozofske probleme matematičkih, prirodnih i tehničkih nauka
BROJ 2 BEOGRAD, 1977 GODINA XII

V. STEFAN

ON »QUANTUM MECHANICS IN A NEW KEY« ACCORDING TO A. LANDÉ

O »KVANTNOJ MEHANICI U NOVOM KLJUČU« PREMA A. LANDÉ'U

DIJALEKTIKA

Časopis za metodološko-filozofske probleme matematičkih, prirodnih i tehničkih nauka

BROJ 2 BEOGRAD, 1977 GODINA XII

DISKUSIJA I KRITIKA

V. STEFAN

ON »QUANTUM MECHANICS IN A NEW KEY« ACCORDING TO A. LANDÉ

A historical scheme is purposely constructed in order to show the roots of A. Lande's work. His entire work on problems of »quantum riddle« and dual nature of a microobject is presented in such a manner to be easy to derive his main gnoseologic-methodological view-points. Besides that some pro et contra remarks are given concerning dualistic theory and solution of »quantum riddle« as well as for Lande's general opinions about fundamental problems of contemporary physics.

Setting forth of the hypothesis on quantum of energy by M. Planck (1900) practically marked the beginning of the quantum era. Not much later (1905) A. Einstein used this hypothesis in the form of the relation $\Delta E = h\nu$ in order to explain the photoelectric effect. Besides using the idea of quantum, he was extremely interested in its essence. As seen from his correspondence[1] with Sommerfeld, the »Quantum riddle«so affected his thoughts that he called the idea of its solution his »pet idea«. Even in his later years, he carefully followed all endeavors towards the discovery of what lies beyond the quantum. Until 1923 when L. de Broglie set forth the hypothesis that every particle in motion corresponds to a wave with wavelength

$$\lambda = \frac{h}{p} \tag{1}$$

endeavors to find the essence of the quantal properties were directed towards seeking the gaps in Lioville's theorem of classical statistical physics. On the other hand, many were pragmatists about the quantum riddle, as was Sommerfeld, for example. He discouraged his students, among whom was A. Landé, from dealing with the hopeless question of quantum and encouraged them to consider quantum something fundamental and to direct their efforts towards seeking the consequences of quantum postulates. Besides connecting the very strange selectivity of the linear momentum with natural selectivity of wave length and thus approaching the solution of the quantum riddle, the de Broglie relation undoubtedly represents the most productive heuristic principle in modern physics, for later through the works of Heisenberg, Schrödinger, Born, Dirac and others the entire structure of contemporary quantum mechanics was built. From that time on, the dual picture of microobject through various interpretations of the wave Ψ function has been adopted by more and more physicists. Thus, today that concept is broadly accepted in research on the microdomain. Gradually, Einstein's riddle has been forgotten and the entire quantum mechanics has taken on the character of a pragmatically directed science — first accepting the selection rules as fundamental and then seeking the consequences.

The scheme presented above has been purposely constructed in order to serve as an explanation of the historical roots of A. Landé's work. In this context it should be added that already in 1926, after the hypothesis on matter wave, A. Einstein wrote very sceptically to A. Sommerfeld, »Did we now relly come closer to the solution of the riddle?« and that in 1923 W. Duane set forth the selection rule for change of the linear momentum. To Einstein's above question, Landé answers negatively and considers the fact that Duane's principale was ignored to be the cause of today's absurd situation in quantum mechanics that on the basis of some new logic we must be compelled to conceive the microobject as a unity of inherently exclusive concepts, such as »wave« and »particle«. His attitude in regard to the given historical scheme is that the whole structure of quantum mechanics in its contemporary form could be evaluated on the basis of nonquantal principles and t hat the experiment on electron difraction as the main fulcrum of the dualistic conception, can be explained purely corpuscularily by Duane's selection rule.

As has already been implicitly presented, two spheres of action have been met in the works of A. Landé — the first, which relates to the essence of the quantum selection rules, embodied in Einstein's wish »if I only knew which little screw the Lord applies here« and the other directed towards exceeding the quantum dualism. As taken together, these represent »Quantum Mechanics in a New Key«.

In many books dealing with the fundamentals of quantum physics, Schrodinger's operator rule in symbolic form

$$p = \frac{h}{2\pi i}\,\frac{\partial}{\partial q} \tag{2}$$

and Born-Jordan's commutational rule also in symbolic form

$$pq - qp = \frac{h}{2\pi i} \tag{3}$$

appear as fundamental relations from which the entire structure of quantum mechanics arises. Such an approach is evidently a consequence of conceiving the selection rules as fundamental, for the above relations are nothing other than a result of quantinizing in the microdomain, expressed by Planck's selection rule for energy change

$$\Delta E = h\nu \tag{4}$$

and Sommerfeld's selection rule for change of angular momentum

$$\Delta p_{\varphi} = \frac{h}{2\pi} \tag{5}$$

74

In contrast to such an approach, A. Landé, in many[2—8] of his works on this topic, directs attention to that which exists beyond the quantum. His aim is to show that quantum mechanics, created inductively by the works of Heisenberg, Born, Schrödinger and others, may be taken as a deductive consequence not only of quantum rules (2), (3) etc. but also of nonquantal principles such as symmetry, correspondance and covariance, in that manner entering into the domain beyond the quantum and thus offering an answer to the »quantum riddle«.

Quantum riddle

A. Landé emphasizes the statistical base in constructing the theory at the very beginning[2] taking into consideration the micro-system (limiting it, for the sake of simplicity but without loss of generality, to discrete eigen-values) and investigating it by means of the A-meter, B-meter, etc., setting forth as the basis the concept of probability for transition from one state to another.

Let us assume that through the test of »A« (which can have values of A_1, A_2, $A_3 \ldots A_n$; for the sake of simplicity we assume that the multiplicity of observable »A« is definite, i.e. »n«) we have found its value A_α. According to the probability principle, the result of measurement by »B« meter cannot be certain. Constantly starting from the same initial state »A«, for »B« observable we can get B_1, B_2, ... etc., i.e. experimentally determine the statistical frequency of individual transitions $A_\alpha \to B_\beta$ which we shall denote by $P(A_\alpha \to B_\beta)$ and name the probability of transition. It is evident that the summation rule exists:

$$\sum_\beta P(A_\alpha \to B_\beta) = 1 \tag{6}$$

On the basis of reaffirmability of a test results (representing the basis of every theory), which states zero probability so that in successive tests we find first A_α and then $A_{\alpha'}$, we have

$$P(A_\alpha \to A_{\alpha'}) = \delta_{\alpha\alpha'} \tag{7}$$

where $\delta_{\alpha\alpha'}$ is the Cronecker symbol.

Now symmetry is postulated (rather, two-way symmetry) for the probabilities of transition, which is analogous with classical reversibility on the basis of time inversion. We write

$$P_{\alpha\beta} = P(A_\alpha \to B_\beta) = P(B_\beta \to A_\alpha) = P_{\beta\alpha} \tag{8}$$

The next step in constructing Landé's theory is seeking the theorem by which all probabilities of transition could be connected. By far the most convenient, due to its simplicity, is the ordinary law of summation of products of probabilities in the form

$$P_{\alpha\gamma} = \sum P_{\alpha\beta} P_{\beta\gamma} \tag{9}$$

We easily see that this law cannot be general, for it is inherently contradictory. It is obvious that it is not valid in the case of $P_{\alpha\alpha'}$ nor must the probability of direct transition from A_α to C_γ always be equal to the sum of the transition probabilities to C_γ through the intermediary states B_β (this is only valid in the case that all probabilities are equal as, for example, with the throwing of dice). In order to reach the generality of the above law in the microdomain, it is necessary to make a modification, through the following form[2]:

The general theorem of connection between three sets of quantities $P_{\alpha\beta}$, $P_{\beta\gamma}$ and $P_{\gamma\alpha}$ should be such that it gives the ordinarö law of summation of probability products in the average and at the same time avoids inconsistency including $P_{\alpha\alpha'}=\delta_{\alpha\alpha'}$ as a special case.

In order to construct the desired P-theorem, with every quantity $P_{\alpha\beta}$ Landé corresponds the auxiliary quantity $\Psi_{\alpha\beta}$ and looks for the connection between these two quantities so that for $\Psi_{\alpha\gamma}$

$$\Psi_{\alpha\gamma}=\sum_\beta \Psi_{\alpha\beta}\,\Psi_{\beta\gamma}, \quad \Psi_{\alpha\alpha'}=\delta_{\alpha\alpha'} \tag{10}$$

is valid. For the connection between $\Psi_{\alpha\beta}$ and $P_{\alpha\beta}$ through (6), (7), (8), (9), (10) he gets

$$P_{\alpha\beta}=\Psi_{\alpha\beta}\cdot\Psi_{\beta\alpha}=P_{\beta\alpha} \tag{11}$$

For the case that Ψ is real, positive or negative, it follows that

$$\Psi_{\alpha\beta}=\Psi_{\beta\alpha}, \quad P_{\alpha\beta}=(\Psi_{\alpha\beta})^2 \tag{12}$$

and for the case that Ψ is complex

$$\Psi_{\alpha\beta}=\Psi^*_{\beta\alpha}, \quad P_{\alpha\beta}=|\Psi_{\alpha\beta}|^2 \tag{13}$$

We can see that the given quantity $\Psi_{\alpha\beta}$ entirely determines $P_{\alpha\beta}$, but that the given quantity $P_{\alpha\beta}$ determines the corresponding quantity $\Psi_{\alpha\beta}$ only up to a »+« or »—« sign, for the real $\Psi_{\alpha\beta}$, and up to a phase factor in the case that the $\Psi_{\alpha\beta}$ is Hermitian. In the latter case we have

$$\Psi_{\alpha\beta}=(P_{\alpha\beta})^{\frac{1}{2}}\; exp\,(i\,\Phi_{\alpha\beta}) \tag{14}$$

It is easy to show that the demand of the correspondance postulate, that (9) equals (10) in average, is satisfied by using both (12) and (14). Relation (10) in quantum mechanics is usually called the interference theorem and is primarily attained through the generalization of quantum postulates. The theorem of interference is often thought to be something mysterious which takes place in the microdomain and to be a sign of the impossibility of returning to the fundamentals of classical physics. A. Landé's idea about arriving at this theorem on the basis of general considerations dates back to 1955 and was completed with the introduction of the correspondance postulate[2], which represents a novelty in his work and at the same time fills the gap in his structure of quantum mechanics.

As we have seen in the former presentation, $\Psi_{\alpha\beta}$ can be real, positive or negative, or a Hermitian complex quantity although in

76

quantum mechanics it appears to be only a complex quantity. The next step is proof that on the basis of the covariance postulate, the Ψ function must necessarily be complex with which the construction of quantum mechanics would be completed, with the complex Ψ function as the central quantity, on the basis of nonquantal postulates.

The covariance postulate, i.e., demand that only the differences of conjugate quantities appear in physics, Landé uses in the following form: [2]

Any observable $T(q)$ defined as a function of the linear coordinate »q« in respect to the arbitrary zero point must have transition values (matrix elements)

$$T_{pp'} = \int \Psi_{pq}\, T(q)\, \Psi_{qp'}\, dq \qquad (15)$$

so as to depend only on the differences $(p—p')$. Also, any observable $S(p)$ defined as a function of the linear momentum »p« in respect to the arbitrary zero point must have a matrix elements

$$S_{qq'} = \int \Psi_{qp}\, S(p)\, \Psi_{pq'}\, dp \qquad (16)$$

so as to depend only on the difference of the linear coordinates $(q—q')$.

The same covariance he also postulated for conjugate pairs φ (angle) and p_φ and E and t (time). Since the above demand is valid for any function $T(q)$, then it also must be valid for the Delta function $D(q)=\delta(q—q')$ Then from (15) follows

$$D_{pp'} = \Psi_{pq_0}\, \Psi_{q_0 p'} \qquad (17)$$

It is evident that the condition that the above product is dependent on $(p—p')$ is satisfied by the complex function

$$\Psi_{pq} = a(q)\, exp\, [i\, \alpha(q) \cdot p] = \Psi^*_{qp} \qquad (18)$$

Using the same method as above in the case of function $S(p)$ we have

$$\Psi_{qp} = b(p)\, exp\, [i\, \beta(p) \cdot q] = \Psi^*_{pq} \qquad (19)$$

where $a(q)$ and $b(p)$ are arbitrary functions while $\alpha(q)$ and $\beta(p)$ must be real functions. Comparing (18) and (19) we get

$$\Psi_{pq} = C\ exp\ (ipq/c_1) \equiv < q/p > \qquad (20)$$

where we take $h/2\pi$ for constant »c_1« as the action constant. Function (20) is periodical with the wavelength $\lambda = h/p$ where »p« depends on the chosen reference point, so that λ cannot have any physical sense. In the same manner Landé also gets

$$\Psi_{Et} = C\ exp\ (2\, \pi\, i\, E\, t/h) \qquad (21)$$

$$\Psi_{p\varphi y} = C\ exp\ (2\, \pi\, i\, p\, y/h) \qquad (22)$$

Dualistic theory

In reference to the problem of quantum dualism, it is undoubtedly one of the most fundamental and complex questions of contemporary theoretical physics, its gnoseology and methodology. The main questions in this system of problems are related to the appearance of quantum duality and its meaning. Along with questions on the basic nature of the physical legality of phenomena, the above questions represent the core of the system of problems regarding the structure of physical reality in quantum mechanics. Both groups of questions are concentrated on the problem of interpreting Ψ functions, which can be and is interpreted as corpuscular and ondulational, statistical-probabilistical and causal-genetical.[9]

The founder of matter wave, L. de Broglie, along with his collaborators, has put out extreme effort towards explaining[10] the connection between the wave and particle aspect of the nature of the microobject, but this connection is still regarded as very difficult to understand. In his well-known work, »Are there quantum jumps«[11] E. Schrödinger, descoverer of the wave equation (1926), developed the theory of the wave as a unique real physical entity, discarding the corpuscular theory of the microobject. Contradicting him, there are two eminent representatives of the corpuscular theory of the microobject, M. Born[12], [13] and A. Landé. We analyze Landé's contribution to the solution of this problem in the light of his most recent book,[2] as his final version of his solution of the »quantum riddle«.

A. Landé, in contrast to the viewpoint of the subjective phenomenalists that the method for exceeding the quantum duality is in the creation of a refined language in which there would be a place for both concepts, »particle« and »wave«, emphasizes that the solution of this problem lies in the possibility that the so-called critical experiments (diffraction, coherence) with electrons could be explained purely corpuscularly, being based on Duane's principle. He regretfully states that physicists the last decades ingnored this principle instead of adding Duane's selection rule (23) for the linear momentum *(p)* to the already accepted selection rules (4) and (5) which are valid for quantities E and p_φ

$$\Delta p = \frac{h}{l} \tag{23}$$

where »l« is the space period. Rule (23) states that a body which has period »l« in space changes its linear momentum in the direction »l«, but only in amounts h/l. Thus, he adds to the three quantities E, p and p_φ, to which applied the law of conservation in classical mechanics, the selection rules which would be valid in the domain of quantum mechanics. Introducing the selection rules (23) instead of the Broglie's (1), he avoids the concept »wave« as a property of the micro-object, and the interpretation of quantum mechanics could be purely corpuscular, i.e. the dualism in quantum mechanics could be replaced by monism with corpuscule as the main entity. It is shown[2] that the diffraction of electrons penetrating through the crystal is a consequence of the mechanical action of the diffractor according to Duane's selection rule. In the case of crystal $l = L, L/2, \ldots L/n$ where »L« is the distance between lattice planes, it could be easily demonstrated that for a particle which is incident with linear momentum »p« through angle Θ on to the lattice plane

$$2p \sin \Theta = n \frac{h}{L}, \quad n = 1, 2 \ldots \tag{24}$$

is valid, which is identical to Bragg's relation at wave treatment of diffraction. The main difference is that the wave theory assumes the period $\lambda = \frac{h}{p}$ to be connected to every electron, while in the corpuscular model periodicity is in the crystal. Landé emphasizes that the possibility of explaining the critical experiments in the corpuscular manner is not the only reason for discarding dualism, but rather also the fact that dualism contradicts the basic laws of physics. Since »p« is dependent on the reference point, then so is λ, which collides with the covariance principle — independence on the reference system in space, in a nonrelativistic case, while for relativistic case the phase velocity of matter wave is larger than light velocity »c« if the real velocity of the particle »v« is smaller, not taking into consideration the group velocity for it is not important in interference which depends only on phases.

Uncertainty principle

Besides critical experiments, the uncertainty principle is also considered as the main support for the dual nature of microparticles, but in works up to the present time alwais derived on the basis of the dual nature of the micro-object. In Heisenberg's original[14] work the uncertainty relation essentially represents an answer[16] to the question: »Can a situation be demonstrated in quantum mechanics in which the electron approximately, i.e. with certain inaccuracy is located in a given place and along with that has approximately, i.e. again with certain inaccuracy, some velocity given in advance, and can that inaccuracy be reduced to such an extent that we do not come to difficalties by an experiment?« It is shown that the spacial-temporal prescription of micro-object could be expressed as

$$\Delta q \Delta p \sim h \tag{25}$$

and

$$\Delta E \Delta t \sim h \tag{26}$$

where »Δ« denotes an average deviation of a given quantity. From their appearance until the present time they represent an object of many interpretations and critics of both physicists and philosophers. We will emphasize the view of Heisenberg, that its basis is in discontinuality of quantum processes and its sence in the limited degree of possibility of precise simultaneous measurement (unsicherheitsrelationen) of conjugate quantities »p« and »q». The absolutely precise determination of »p« leads to entire or infinite indetermination of »q« and vice versa. He also emphasizes sensory-fenomenal and subjective aspect of quantum-physical realization stating: »Der mensch stehtnur noch sich selbst gegenüber«. Becouse of uncertainty relations we can not define initial conditions and thus neither can we predict the future of the microsystem which leads to quantum physical indeterminism.

In reference to the uncertainty relations which, in the opinion of many physisists, is basis from which all other quantum properties could be derived, we quote A. Landé's attitude: »That is not so for the simple reason that it does not contain any hint of phases and probability interference. It only describes averages in which all refinement of the complex imaginary Ψ-metric is lost[2]«. The restriction that is set forth by Heisenberg concerning individual measurement is allowed only for direct measurement. However, since all measurements, including those in quantum domain, are indirect »Δp_x« in Heisenberg's relation should not be regarded as an uncertainty in the determination of individual »p_x« for it can be determined with much greater precision than expressed by the uncertainty relation. That is why statistical character of quantities »Δp_x« and »Δx« should always be kept in mind which, in essence, are nothing other than the statistical dispersion rate of great number of precisely measured quantities »p_x« and »x«. »Do not confuse predictability with measurability. Lack of predictability of an individual (x, p_x) pair: Yes. Lack of simultaneous measurability: No. In answer to the Born-Heisenberg attitude what one can not measure that does not exist i.e. to the attitude of indeterminacy of precise simultaneous existance of pair (x, p_x), Landé states: »Two times No.«

The same case, as with uncertainty, also holds true for principle of complementarity. The interpretation range of this principle goes from total negation to the assertion that it is the most important world view of our ages. A. Landé carefully analises various interpretations. We quote, in a sence of his contra attitude in reference to dualism, that complementarity (as weltanschauung) has not solved physical contrast between particle and wave.

General opinions of A. Landé

The last chapter[2] is devoted to observation and interpretation in quantum mechanics. Accepting the dual microparticle nature brought about the situation that scientists, instead of searching for causes of those effects, state that unique picture is not possible and that we must be satisfied with transformation of particles into waves and vice versa. The various interpretations of the nature of the microobject are quoted: interpretation that matter appears in two different physical states, as particle or wave, in dependence of experimental arrangement, the »as if« interpretation which is called by A. Einstein »the tranquillizer phylosophy«, interpretation of equivalence of the two theories (corpuscular and wave) which is manifested by existance of Bragg's wave and Duane's corpuscular theory of electron diffraction, and so on. A. Landé's answer to the latter one is that equivalence is illusive »becouse continuity of wave action can never be equivalent to statistical point action except in

80

average«. The interpretation of L. de Broglie and D. Bohm is also quoted as an attempt to return to determinism in the quantum domain. According to this interpretation a physical presence of particle and wave in space is stated. The wave continuum is controlled by the deterministic hydrodynamics of the Schrödinger Ψ-wave. This fluidum serves as a guide or pilot for the statistical distribution of the particles, as the continuous wind guides dust particles. Landé's answer, however, is that the primary character of quantum mechanics is the statistical theory of particles. The fact that statistical distribution curves (or the probabilistic expectation curve) can often be calculated by means of wavelike differential equations is a secondary result (see also [16]). The consideration is concluded with the assertion that the principle of duality can prevail only in the case that there exist dual manifestations which could not be reduced to unitary so as to render supernatural magic a necessary part of modern physics. The electron can never be both wave and particle, as a million experiments show that matter consists of descrete particles, real, concrete, countable, with definite rest masses and charges, condensed into small spaces. They can exist even when $h \to 0$ which is not the case with photons. That is why the material particle and electro-magnetic field have the character of physical realities while this is not valid for matter wave and light particles (photons), though they are of great significance to computation in various special cases.

The problem of whether the world is constructed so as to be governed by deterministic laws or by laws of chance, has long affected scientists. According to Landé for the world as a whole this is an idle question becouse there is no possibility of finding out what could have been and what could be later. For finite systems it is the other way around. Here we can make statistical series of tests starting from the same initial state and see if they lead us towards the same future state. Experiments in the atomic domain show that laws of average values dominate here for a great number of individual cases although the prediction of individual events is impossible. In other words, the quantum theory lies on a two way-simmetry $P_{\alpha\beta} = P_{\beta\alpha}$. In agreement with this is the description of a game with a ball[2] which clearly express Landé's position of objective existance of the probabilistic law as the fundamental one. In this context, searching for the subquantum level (in contrast to D. Bohm[17] who explains every transition from state »A« to states B_1, B_2 ... etc. in terms of particular hidden causes) is considered groundless.

PRO ET CONTRA A. LANDÉ

In the process of realization, as the aspect of the relation of subject and object two components are dominant: subjective-phenomenalistic and objective. In the history of gnoseology, and also in physics, thinkers very often emphasized and absolutized one of these components, while another would partially or totally loose its significance. Today, the most broadly-accepted gnoseological viewpoint in quantum physics is subjective phenomenalism, established by Bohr, Heisenberg and others, which especially through Heisenberg's attitudes (der mensch stehtnur noch sich selbst gegenüber) reached subjective idealism, i.e. Heisenberg's anthropologism. On the other hand, in some concepts of classical physics there exists a very present »metaphysical realism«, the statement that what we realize does not depend on us at all.

Landé clearly expresses, in his attacks on the subjective-phenomenalistic viewpoint, his objective-realistic position in solving gnosological problems of quantum mechanics against all mystifications which are largely present in its contemporary interpretations. Also, dissagremeent appears with neodeterminists in explaining phenomena on the quantum level in a causal-deterministic manner. It follows from the fact that in statistical law A. Landé sees the basis of quantum mechanics as independent of other laws, in that way giving it a fundamental character. We cannot agree with the statement that the fact that something can be investigated by statistical method and that it is experimentally verified (the concrete, statistical character of quantum mechanics) carries along with itself the groundlessness in seeking causes of individual behaviour of statistical agregate constituents. Instead, the opposite is shown — that determinism of statistical and dynamical types penetrate, forming in this way two different approaches to the investigation of one phenomenon, depending on the real situation. For example, in statistical physics the statistical approach is not a product of principally impossible use of dynamic treatment, but rather the practical unsuitability of the latter. In the case of aggregates with a small number of constituents (or events) the statistical approach is unsuitable because the determination of such an approach is greatly reduced (statistical dispersion rate is proportional to $n^{-1/2}$ where "n" is number of constituents or events). All real phenomena which are shown by physical apparatuses are not total entities but rather are caused, as phenomena, by other entities.

Concerning the interpretation of the Ψ function A. Landé rightfully emphasises the abstract and subjective-contemplatory character of its meaning. The wave function, as the solution of Schrödinger equation, represents a tool for evaluating probability density »ρ« for finding a particle on a given place by Born's formula

$$\rho = \Psi\Psi^* = /\Psi/^2 \qquad (27)$$

The conclusion of the wave property of the microobject on the basis of the existance of the wave function is incorect becouse it is the same as equaling one property to nature of the whole object as an assambly of properties[16].

As uncertainty relations are obtained on the basis of the dual nature of the microobject, it is not strange that many scientists the recognition of these relations connect with the existence of quantum duality. We agree with Landé that uncertainty relations, according to the corpuscular explanation of electron diffraction, are not inherent concequences of the wave nature of the microobject but ruther the impossibility of predicting the results of individual measurement of pair (x, p_x).

82

In methodological sence the work of A. Landé is characterized by exceptional clearity in constructing the system and a very small number of system elements (symmetry, correspondance and covariance). The manner in which quantum phenomena are explaind from nonquantal principles is impressive and represents the fulfilment of the ultimate task of the theoretical physicist according to A. Einstein's criterion: »The supreme task of the theoretical physicist is to search for those general and elementary laws from which one can derive the world picture by pure reason, although the elementary laws themselves cannot be obtained logicaly but only by intuition based on a broad view of experience«. According to Landé the statistical law is that elementary law.

A. Landé criticized[9] the basic thesis of the logic of C. F. Weitzsäcker on the basis of which quantum mechanics is based on new logic where the law of exclusion of the third is not valid. We must remark that this criticism is obviously limited in its base — accepting of such a gnoseologic-logical attitude represents selflimitation in research work and not preparedness for achieving a qualitatively new conceptual structure, though in some cases emphasising this leads towards a more complicated approach to reality which could be also described in a simpler manner. From the aspect of A. Landé's corpuscular theory the transition to duality represents such a more complicated conception of physical reality. We emphasize, on the other hand, that there exist such new experiments leading to conceptual enrichment of our realisation.

According to the definition of microobject given by Landé, it can be seen that this object has properties of a classical entity. And if he fails to quote newer experiments and successes in the conceptual understanding of the microobject, it would be difficult to say that his endeavors are related to one narrow domain of microphysics. In that sense above understanding of microobject represents incorrect reducing of entire physical reality to mechanical entities. We only quote[18] »that microobjects are excited states of field and therefore one cannot ascribe to them rough corpuscular properties«.

The influence of medium on statistical (wave) behavior of microobject embodied by Duane's selection rule and Landé's explanation of electron difraction is also supported by most recent research in the elementary particle domain where, according to A. Sokolov, the wave property of the electron beam could be considered for statistical arrangement caused by influence of vacuum fluctuations on them.

In Landé's intention of getting a quantum mechanics structure from nonquantal principles a gap could be seen when in a covariance postulate observables are defined as $T(q)$ and $S(p)$, i.e., the state of the system is defined by »q« or »p« and not by both »q« and »p« as in classical mechanics. Lande uses the Delta function $D(q-q')$ and $D(p-p')$ what implicitly states assumption of precise knowledge of coordinate and impulse, respectively. According to Schrödinger's operator rule, equation

$$\frac{h}{2\pi i}\,\frac{\partial}{\partial x}\Psi = p_x \Psi \tag{28}$$

offers an answer to the possible results of precise measurement of linear momentum. The solution of (28) is (20) with $q \equiv x$ and with $p \equiv p_x$ as any real number including zero. Using (20) in Born's formula (27), it is seen that probability density is constant (in general, a complex constant)

$$\rho = /C/^2 \quad (29)$$

which shows complete uncertainty of conjugate coordinate »x«. So we see that the assumption of precise knowledge of linear momentum »p_x« leads to complete ignorance of coordinate »x«, as a consequence of quantum condition (28), which suggests defining the state in quantum mechanics either by »p« or »q«, from which Landé begins.

In seeking function Ψ for which, according to the covariance principle

$$\Psi_{pq_0} \Psi_{p_0q'} = f(p-p') \quad (17.1)$$

and

$$\Psi_{ep^0} \Psi_{p_0q'} = f(q-q') \quad (17.2)$$

will be valid, Landé crosses over the fact that solution (20) is not unique. We see that conditions (17.1) and (17.2) are satisfied by function

$$\Psi = C \exp (i\alpha q - i\beta p) \quad (30)$$

Although the positions against wave properties of the micro-object Landé argues, his attitude against corpuscular nature of light is more of the character of a suggestion.

A. Landé's work for exceeding of problems in quantum mechanics has been followed with exceptional attention in scientific public (for example [9], [19], [20], [21]) as an original and huge endeavor towards the realization of the essence of quantum principles. Through his work we became more familiarized with the domain beyond the quantum.

REFERENCES

1. Einstein-Sommerfeld Briefwechsel, Schwabe, Basel, 1968.
2. A. Landé »Quantum Mechanics in a New Key«, Exposition Press, Jericho, New York, 1973.
3. A. Landé »From Dualism to Unity in Quantum Theory«, Current issues in the Philosophy of Science, edited by H. Fiegel and G. Maxwell, New York, 1961.
4. A. Landé »The Case against Quantum Duality« Phylosophy of Science, vol. 29 January, 1962.
5. A. Lande »Why do Quantum Theory ignore Quantum Theory? British Journal for the Phylosophy of Science, February, 1965.
6. A. Landé »New Foundations of Quantum Mechanics« Cambridge, U. P., London, 1965.
7. A. Landé »Albert Einstein and Quantum Riddle« A. P. J., vol 42/459, June 1974.
8. A. Landé »Foundation of Quantum Theory« Yale U. P., New Haven, 1955.
9. Šešić »Foundation of the Philosophy of Physics« Beograd, 1973 (in Serbocroatian).

10. L. de Broglie »Une tentative d'interpretation causale et non lineaire de la mechanique ondulatoire. La theorie de la double solution, Paris, 1956.
11. E. Schrödinger« Are There Quantum Jumps?« British Journal for the Phylosophy of Science, August—September 1952.
12. M. Born »The Interpretation of Quantum Mechanics« the British Journal for the Philosophy of Science, August, 1955.
13. M. Born »Fizika v žizni moego pokolenija« Im. lit. Moskva, 1963.
14. W. Heisenberg »Ueber den anschaunlichen Inhalt der quantentheorischen Kinematik und Mechanik« Zeitschrift für Physik, band 43, S. 172—198 (1927).
15. W. Heisenberg »Der Teil und das Ganze«, »Fizika i metafizika«, Nolit, Beograd, 1972 p. 131.
16. J. Pop-Jordanov »O prirodi mikročestica«, Dijalektika, 1966, 1. »On the Nature of Microparticles«. Beograd.
17. D. Bohm »Causality and Chance in Modern Physics«, »Uzročnost i slučajnost u savremenoj fizici« Nolit, Beograd, 1972.
18. D. Sineljnikov »O filozofskih voprosah savremenoi fiziki« Fil. voprosi savremenoi fiziki, A. N. USSR, Kiev, 1956, p. 24.
19. Physics today, September 1966, p. 85.
20. Physics today, January 1975, p. 87.
21. W. Yorgrau and A. van der Merwe, eds. Perspectives in Quantum Theory, Essays in Honor of A. Landé, Cambridge, Mass. 1971.

O »KVANTNOJ MEHANICI U NOVOM KLJUČU« PREMA A. LANDÉ'U

KRATAK SADRŽAJ

U radu je prvo prezentirana istorijska shema namenski konstruisana da ukaže na korene rada A. Landé-a, a zatim je njegov celokupan rad na problemu »kvantne zagonetke« i dualne prirode mikroobjekta iznesen na takav način da se lako dođe do njegovih osnovnih gnoseološko-metodoloških tačaka gledišta. Uz to, date su i neke pro et kontra primedbe koje se tiču kako dualističke teorije tako i Landéovog rešenja »kvantne zagonetke«.

U kontekstu istorijske sheme naglasićemo da je još 1926. god. nakon de Broglieve hipoteze o talasima materije, A. Einstein vrlo skeptično pisao A. Sommerfeldu: »Did we now really come closer to the solution of the riddle«, i da je 1923. god. W. Duane dao selekciono pravilo za promenu linearnog momenta.

$$\Delta p = \frac{h}{l}$$

gde je »l« prostorna perioda a »h« Planckova konstanta.

Na gornje Einsteinovo pitanje A. Landé negativno odgovara, a ignorisanje Duaneovog principa smatra uzrokom danas apsurdne situacije u kvantnoj mehanici da na bazi nekakve nove logike moramo biti prinuđeni da shvatimo mikroobjekat kao neko jedinstvo inherentno ekskluzivnih pojmova kao što su »talas« i »čestica«. Njegov stav u odnosu na datu istorijsku shemu je da se čitava struktura kvantne mehanike u svom dosadašnjem obliku može izvesti iz nekvantnih postulata (simetrija, korespondencija i kovarijantnost), a da se eksperiment difrakcije elektrona, kao glavno uporište dualističkog

shvatanja, može objasniti čisto kokpuskularno preko Duaneovog selekcionog pravila.

Pojam verovatnoće prelaza mikrosistema iz jednog stanja u drugo uzet je kao bazični što govori o statističkom karakteru izgradnje čitave Landeove teorije.

Postulat simetrije je izražen kao

$$P_{\alpha\beta} = P(A_\alpha \rightarrow B_\beta) = P(B_\beta \rightarrow A_\alpha) = P_{\beta\alpha}$$

$$P_{\alpha\alpha'} = P(A^\alpha \rightarrow A_{\alpha'}) = \delta_{\alpha\alpha'}$$

gde je P verovatnoća prelaza iz inicijalnog stanja A_α u finalno stanje $B_{\beta'}$ a $\delta_{\alpha\alpha'}$ Croneckerov simbol. Druga relacija govori, na bazi reafirmabilnosti rezultata eksperimenta, o nultoj verovatnoći da u dva sukcesivna eksperimenta mikroobjekat nađemo prvo u stanju A_α a zatim u stanju $A_{\alpha'}$.

Sledeći korak u konstrukciji Landéove teorije je traženje teoreme po kojoj će biti povezane sve verovatnoće prelaza. Najpodesniji za tu svrhu, zahvaljujući svojoj jednostavnosti, je obični zakon sumiranja produkata verovatnoća u formi

$$P_{\alpha\gamma} = \Sigma P_{\alpha\beta} P_{\beta\gamma}$$

međutim, ovaj zakon ne može biti opšti, jer je inherentno kontradiktoran — očigledno je da ne važi za slučaj $P_{\alpha\alpha'}$. Opšta teorema koja povezuje tri skupa veličina $P_{\alpha\beta}$, $P_{\beta\gamma}$ i $P_{\alpha\gamma}$ mora biti takva da daje obični zakon sumiranja produkata verovatnoća u srednjem, a da istovremeno izbegne nekonzistentnost uključujući $P_{\alpha\alpha'} = \delta_{\alpha\alpha'}$ kao poseban slučaj. Ovaj problem Landé je rešio uvođenjem nove veličine $\Psi_{\alpha\beta}$ za koju je dobio

$$\Psi_{\alpha\gamma} = \Sigma \Psi_{\alpha\beta} \Psi_{\beta\gamma'} \qquad \Psi_{\alpha\alpha'} = \delta_{\alpha\alpha'} = P_{\alpha\alpha'}$$

$$\Psi_{\alpha\beta} = (P_{\alpha\beta})^{1/2} \exp\ (\ i\ \Phi_{\alpha\beta})$$

Gornja jednakost je poznata u kvantnoj mehanici kao teorema interferencije i često je bila smatrana za nešto misteriozno što važi u mikrodomenu i što onemogućava bilo kakvo vraćanje na principe klasične fizike. Landéova ideja da ovu teoremu izvede na bazi opštih razmatranja (nekvantnih principa) datira još od 1955. godine i u sadašnjoj formi predstavlja novost u njegovom radu.

Princip kovarijantnosti tj. zahtev da se samo razlike konjugovanih veličina pojavljuju u fizici, Landé koristi u sledećoj formi: »Bilo koja opservabla $T(q)$ definisana kao funkcija od linearne koordinate »q« u odnosu na arbitrarnu nultu tačku mora imati vrednosti prelaza (matrične elemente)

$$T_{pp'} = \int \Psi_{pq}\, T(q)\, \psi_{pq'}\, dq$$

takve da zavise samo od razlike $(p - p')$. Takođe, bilo koja opservabla $S(p)$ definisana kao funkcija od linearnog momenta »p« u odnosu na arbitrarnu nultu tačku mora imati matrični element

$$S_{qq'} = \int \Psi_{qp}\, S(p)\, \psi_{pq'}\, dp$$

86

takav da zavisi samo od razlike linearnih koordinata $(q - q')$. Gornji uslov za $T(q)$ zadovoljava kompleksna funkcija

$$\Psi_{pq} = a(q) \exp(i\alpha(q)\,p) = \psi_{qp}^*$$

a za $S(p)$

$$\Psi_{qp} = b(p) \exp(i\beta(p)\,q) = \psi_{pq}^*$$

čijim upoređenjem dobijamo

$$\Psi_{pq} = C \exp(ipq/c_1) = \langle q/p \rangle$$

Konstanta C_1 je konstanta dejstva $\left(c_1 = \frac{h}{2\pi}\right)$

Vidimo da je najznačajnija kvantna osobina, periodična veza između linearnog momenta i linearne koordinate (angularnog momenta i angularne koordinate i energije i vremena) dobijena kao posledica postulata kovarijantnosti tj. činjenice da u univerzumu ne postoji preferirana referentna tačka. Kako je kompleksno-eksponencijalni oblik za ψ funkciju, a i njene intereferencione osobine, dobijen na osnovu tri opšta nekvantna postulata fizike to sledi da su i sva selekciona pravila u kvantnoj mehanici posledice tih triju principa.

U metodološkom pogledu delo A. Landéa krasi izuzetna jasnost u građenju sistema i veoma mali broj elemenata tog sistema (simetrija, korespondencija i kovarijantnost). A. Landé [3] kritikuje osnovnu tezu logike kvantne mehanike S. F. Weitzsäckera po kojoj kvantna mehanika počiva na novoj logici u kojoj ne važi zakon isključenja trećeg. Moramo dati primedbu na ovu kritiku koja je očigledno ograničena u osnovi, jer predstavlja nepripremljenost na dobijanje kvalitativno novih pojmovnih struktura, mada u nekim slučajevima prenaglašavanje ovoga dovodi do komplikovanijeg pristupa realnosti koja se mogla i prostije opisati.

Iz definicije mikroobjekta koju daje autor vidi se da taj objekt ima svojstva klasičnog entiteta. Takvo shvatanje predstavlja pogrešno svođenje celokupne fizičke realnosti na mehaničke stvari.

U radovima A. Landéa jasno se ispoljava objektivno realistički stav u rešavanju gnoseoloških problema kvantne mehanike, protiv svih mistifikacija kojima je ona u svojim današnjim interpretacijama zaista bogata. U vezi interpretacija ψ funkcije A. Landé sa pravom ističe apstraktni i subjektivno misaoni karakter njenog značenja. Slažemo se sa konstatacijom da je pripisivanje talasnog svojstva mikroobjektu na osnovu postojanja talasne funkcije pogrešno jer je to isto što i izjednačavanje jednog svojstva sa prirodom čitavog objekta kao skupa svojstava [16]. Takođe, podržavamo stav A. Landé-a koji u relacijama neodređenosti ne vidi inherentnu posledicu talasne prirode mikroobjekta, već nemogućnost predskazivanja rezultata individualnog merenja.

Ne možemo se složiti sa konstatacijom da činjenica da se nešto može ispitivati statističkim metodom i da se taj pristup verifikuje eksperimentom (konkretno, statistički karakter kvantne mehanike) povlači za sobom uzaludnost traženja uzroka pojedinačnog ponašanja konstituenata statističkog agregata. Naime, pokazuje se obrnuto da se determinizmi statističkog i dinamičkog tipa prožimaju čineći na taj način dva različita pristupa proučavanju jednog fenomena, u zavisnosti od realne situacije.

U nameri da se iz nekvantnih principa izvede struktura kvantne mehanike primećuje se neprincipijelnost kada se u postulatu kovarijantnosti definišu opservable kao *T (q)* i *S (p)* tj. stanje sistema se definiše preko »*q*« ili »*p*« a ne preko i »*q*« i »*p*« kao u klasičnoj mehanici.

U traženju funkcije ψ za koju će važiti prema principu kovarinjantnosti

$$\Psi_{pq_0}\Psi_{q_0p'} = f\,(p-p')$$
$$\Psi_{qp_0}\Psi_{p_0q'} = f\,(q-q')$$

prećutno se prelazi [2] preko činjenice da rešenje (20) nije jedinstveno. Vidi se da gornje uslove zadovoljava i funkcija

$$\Psi = C\ \exp\ (i\alpha q - i\beta p)$$

Rad A. Landé-a na prevazilaženju problema u kvantnoj mehanici sa velikom pažnjom je praćen u naučnoj javnosti (npr. [9], [19], [20], [21]) kao originalan i ogroman napor u saznavanju suštine kvantnih principa. Ne možemo reći da je kvantna zagonetka potpuno rešena ali možemo reći da smo radovima A. Landé-a postali mnogo familijarniji sa domenom iza kvanta.