Discussion

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Quantum Mechanics and Dialectical Materialism

Of all the philosophic issues posed by modern scientific theory, those involving quantum mechanics have been the most pressing and obstinate. Several problems in the philosophy of science of the past generation—such as the interpretation of special relativity—held the attention of scholars for a decade or more but have now lost much of their allure; other issues—such as the interpretation of cybernetics and information theory—have gained prominence only recently. But forty years after the publication of the essential mathematical apparatus of quantum mechanics the controversy swirls unabated, even intensified.[1] It is a debate in which the scholars of many nations have participated, including those of the USSR.

The structure of quantum mechanics may be divided into a mathematical formalism and a physical interpretation of that formalism. The mathematical formalism which is the core of quantum mechanics is a differential wave equation, the solution of which is usually termed the *psi* (Ψ) function; the wave equation was first developed by Erwin Schrödinger, who pursued Louis de Broglie's extension of the concept of wave-corpuscle duality from light to elementary particles of matter. The advantage of this formalism is that it yields, on a probabilistic basis, numerical values permitting a more complete mathematical description of microphysical states, including prediction of future states, than has any other formalism so far. The disadvantage of the mathematical apparatus of quantum mechanics is that the only widely accepted (some would say the only possible) physical interpretation for it contradicts several of man's most basic intuitions concerning matter. Spe-

[1] Two recent and valuable collections of articles indicating the diversity of the views expressed are S. Körner, ed., *Observation and Interpretation in the Philosophy of Physics with Special Reference to Quantum Mechanics* (New York, 1962); and R. G. Colodny, ed., *Beyond the Edge of Certainty* (Englewood Cliffs, 1965).

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cifically, quantum mechanical computations, in contrast to the classical laws of the macrophysical realm, do not yield arbitrarily exact values for position and momentum coordinates of microparticles. According to the well-known uncertainty relationship, the more exactly the position of a microparticle is known, the less exactly the momentum, and vice versa.[2]

In view of the success of the mathematics of quantum mechanics for the derivation of useful physical values, the obvious question arises, "What is the physical significance of the wave function?" Can it be that matter is, indeed, undulatory? It is over this question of the physical interpretation of the mathematics of quantum mechanics that scores of philosophers and scientists have splintered their pens.

The evolution of quantum mechanical theories is a trail littered with unsatisfactory explanations. De Broglie originally proposed that matter *is* wave-like and that the waves described by quantum mechanics do not "represent" the system; they *are* the system.[3] This explanation encounters enormous difficulties, far too complex to enter into here, but the nature of some of them may be indicated by noting that a literal acceptance of the physical reality of the wave function would involve such concepts as that of physical space with an almost unlimited number of dimensions. And, most graphically, such an interpretation cannot explain satisfactorily the fact that a single micro-object upon impact on a sensitive emulsion leaves a spot, not the imprint of a wave front.[4] Max Born originally suggested the alternative: matter is corpuscular, and the wave function describes not the particles but our knowledge about them. This ingenious theory unfortunately runs into equally disastrous physical facts, which are best illustrated by reference to the now classic two-slit interference experiment. When particles are allowed to pass through two narrow slits in a barrier before striking a sensitive emulsion, the impacts form an interference pattern which can be explained only on the basis of the wave-like characteristics of microbodies.

The Copenhagen Interpretation, developed by Niels Bohr and Werner Heisenberg, resolves the contradictions of previous interpretations by postulating that no observable has a value before a measurement of that observable has been made. Thus, it becomes meaningless to speak of the characteristics of matter at any particular moment without empirical data in hand relating to that moment. It is senseless to speak of the position of a particle ("position" is a property of the corpuscular theory) without a measurement of position; it is equally unjustified to speak of the momentum (a wave property) without a measurement of momentum. This reconciling of classically incompatible properties by granting them existence only at the moment of measurement

[2] Expressed mathematically as $\Delta x \Delta p_x \geqq \hbar/2$, where Δx and Δp_x are the limits of precision within which the value of a coordinate and of momentum, respectively, can be simultaneously determined and $\hbar$ = Planck's constant divided by 2π. When physical values are involved in this sort of relationship, the term "canonically conjugate parameters" is employed.

[3] See Hilary Putnam, "A Philosopher Looks at Quantum Mechanics," in Colodny, p. 78.

[4] The explanation for the spot imprint given by de Broglie was that of the "reduction of the wave packet."

is usually called *complementarity* and is the heart of the most critical discussions of quantum mechanics.[5]

Before World War II the views of Soviet physicists on quantum mechanics were indistinguishable from those of advanced scientists elsewhere. Russian physics was in many ways an extension of Central and West European physics. The work of such men as Bohr and Heisenberg influenced scientists in the Soviet Union as it did everywhere. Indeed, Soviet physicists spoke of the "Russian branch" (*filial*) of the Copenhagen School, composed of a group of highly talented theoretical physicists, including M. P. Bronshtein, L. D. Landau, I. E. Tamm, and V. A. Fock. And yet behind this exterior of agreement with the West on quantum mechanics (or, more accurately, disagreements similar to those in the West), as early as the 1920s certain Soviet physicists were aware that dialectical materialism might some day be interpreted in a way that could influence their research.[6] Lenin had, after all, devoted an entire book, *Materialism and Empirio-Criticism,* to the "crisis" in Western interpretations of physics and particularly attacked the neopositivism of Ernst Mach, out of which much of modern physics grew. Lenin's contention that a dialectical materialist must recognize the existence of matter separate and independent from the mind, while not inherently contradictory to quantum mechanics, could be regarded as at least uncongenial to the Copenhagen School's disinclination to comment upon matter in the absence of sensible measurement. And the extension of the concept of complementarity beyond physics to other phenomena, including ethical and cultural problems, by certain members of the Copenhagen School almost guaranteed some conflict with representatives of Marxism.[7] As early as 1929 the leading Soviet philosopher at that time, A. M. Deborin, gave a lecture on "Lenin and the Crisis of Contemporary Physics" to the Academy of Sciences.[8] But the first serious attack on the customary interpretation of quantum mechanics in a physics journal, rather than a philosophical journal, occurred in 1936, written by K. V. Nikol'skii.[9] In the dispute which developed be-

[5] There is a great deal of disagreement among physicists and philosophers of science on the definition of complementarity, and some would not accept the explanation above. Another common statement of the meaning of complementarity is that the quantum description of phenomena divides into two mutually exclusive classes which complement each other in the sense that one must combine them in order to have a complete description in classical terms.

[6] A summary of the early warnings is in David Joravsky, *Soviet Marxism and Natural Science, 1917–1932* (New York, 1961), *passim*, esp. pp. 285–86.

[7] Bohr indicated that the concept of complementarity might be applied to such areas as physiology, psychology, biology, and sociology in his *Atomtheorie und Naturbeschreibung* (Berlin, 1931) and "Causality and Complementarity," *Dialectica,* II, No. 3–4 (1948), 312–19. This issue of *Dialectica* was devoted entirely to the concept of complementarity and included one article in which the author advanced the thesis that complementarity is potentially valid in all areas of systematic study: F. Gonseth, "Remarque sur l'idée de complémentarité," pp. 413–20.

[8] *Otchet o deiatel'nosti Akademii nauk SSSR za 1929 g.* (Leningrad, 1930), Vol. I (Appendix).

[9] Nikol'skii, "Printsipy kvantovoi mekhaniki," *Uspekhi fizicheskikh nauk* (hereafter UFN), XVI, No. 5 (1936), 537–65. Nikol'skii later published a book setting forth the same

tween Nikol'skii and V. A. Fock, a leading interpreter of quantum mechanics in the Soviet Union to the present day and originally an adherent of the Copenhagen School, Nikol'skii called the Copenhagen Interpretation "idealistic" and "Machist," [10] two appellations which were to be frequently utilized after World War II by Marxist critics. Nikol'skii's own view of quantum mechanics deserves examination for still another reason: it was a purely statistical approach, with only a few differences from D. I. Blokhintsev's postwar "ensemble" interpretation, which will be discussed in greater detail below.

With mention of Nikol'skii's "purely statistical" approach, it is appropriate at this point to insert a few remarks on the concept of probability, which is crucial to any interpretation of quantum mechanics. Probability in quantum mechanics has been interpreted by different scholars in both epistemological and statistical senses. The statistical, or frequency, approach, used by Nikol'skii, was an attempted objective interpretation in which probability was seen as inherent in nature. On the other hand, a number of scholars have seen quantum mechanics, particularly through Born's original interpretation, as containing probability as a result of its epistemological assumptions, and have even discussed such peculiar things as "waves of knowledge." The distinction between these two approaches, often blurred in discussions of quantum mechanics, is necessary in attempting to answer the question whether a theory which is irreducibly probabilistic is also necessarily idealistic.

Fock's interpretation in 1936 of the physical significance of the wave function was essentially the same as that of the Copenhagen School, which combined Born's emphasis on the mathematical description of man's knowledge of the microworld with its own emphasis on the role of measurement; Fock stated in an introduction to a Russian translation of the 1935 debate of Einstein, Podolsky, and Rosen versus Bohr:

> In quantum mechanics the conception of state is merged with the conception of "information about the state obtained as a result of a specific maximally accurate operation." In quantum mechanics the wave function describes not the state in the usual sense, but rather this "information about the state." [11]

The importance of this prewar position of Fock lies in its subtle difference from his stated views after the beginning of the *Zhdanovshchina,* when he

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view: *Kvantovye protsessy,* 1940. Nikol'skii's 1936 article indicated his agreement with the position of Einstein, Podolsky, and Rosen in their debate with Bohr. See A. Einstein, B. Podolsky, and N. Rosen, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Review,* XLVII, No. 10 (May 15, 1935), 777–80; and Niels Bohr, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *ibid.,* XLVIII, No. 8 (Oct. 15, 1935), 696–702.

[10] Nikol'skii, "Otvet V. A. Foku," UFN, XVII, No. 4 (1937), 555. In his criticism of Nikol'skii, Fock maintained that quantum mechanics described the action of an individual micro-object as well as statistical groups ("K stat'e Nikol'skogo 'Printsipy kvantovoi mekhaniki,'" *ibid.,* pp. 553–54).

[11] Fok, "Mozhno li schitat', chto kvantomekhanicheskoe opisanie fizicheskoi real'nosti iavliaetsia polnym?" *ibid.,* XVI, No. 4 (1936), 437. In his introduction Fock clearly indicated that he considered Bohr the victor in the debate.

was placed under heavy pressure to desert the Copenhagen School.[12] Nevertheless, Fock's change in position was small compared to the swerves which occurred in the views of several other prominent Soviet philosophers and scientists.

The debate of the 1930s did not, however, leave a permanent imprint on Soviet attitudes toward quantum mechanics. Even many philosophers accepted much of the Copenhagen view. Early in 1947 M. E. Omel'ianovskii, a Ukrainian philosopher who with Fock and Blokhintsev completes the triumvirate whose views will be examined in detail in this article, argued a position on quantum mechanics close enough to the Copenhagen orientation to cause him intense embarrassment only a few months later. This 1947 book has become more interesting in the middle of the 1960s, since it represents a view to which Omel'ianovskii seems to be returning after many years.

In this work, *V. I. Lenin and Twentieth-Century Physics,* Omel'ianovskii was rather charitable toward much of the common Western interpretation of quantum mechanics. He accepted and used such terms as "the uncertainty principle" and "Bohr's principle of complementarity." (A year later Omel'ianovskii's terminology became "the so-called 'principle of complementarity.' ") He guarded against using these concepts in a way that might deny physical reality, as he said certain people (including Bohr on occasion) had done, but his major thesis in this book was a defense of the surprising but necessary concepts of modern physics against adherents of the determinism of Laplace, now clearly outdated.[13] Buried within Omel'ianovskii's arguments, however, one may observe, at least in retrospect, the core of his own interpretation of quantum mechanics and of his later criticisms of the Copenhagen School. Although he acquiesced in the vocabulary of Copenhagen, he emphasized that the correct interpretation of quantum mechanics began with a recognition of the peculiar qualities of microparticles, not with problems of cognition: "And so we have come to the conclusion that Heisenberg's uncertainty principle, just as Bohr's principle of complementarity, is a generalized expression of the facts of the dual (corpuscular and undulatory) nature of microscopic objects." [14] Thus, the uncertainty principle was not actually an epistemological limitation or a limitation of knowledge but a direct result of the combined wave-like and corpuscle-like nature of micro-objects, which was the *material* reason why classical concepts could not be applied to the microworld. In view of this material source of the phenomenon of canonically conjugate parameters, one could not expect ever to possess simultaneous exact values of position and momentum of elementary particles. For his

[12] Fock also engaged in a debate before the war with A. A. Maksimov, another important participant in the later controversy. See Fok, "K diskussii po voprosam fiziki," *Pod znamenem marksizma* (hereafter PZM), No. 1, 1938, pp. 149–59. In 1937 and 1938 PZM contained a number of articles on the philosophic interpretation of quantum mechanics, including contributions by Maksimov, E. Kol'man, P. Langevin, and Nikol'skii.

[13] Omel'ianovskii, *V. I. Lenin i fizika XX veka* (Moscow, 1947), *passim*, esp. p. 77. Omel'ianovskii accepted the relativity of simultaneity and of spatial and temporal intervals, concepts which were to be severely criticized in Soviet philosophical journals in the coming months.

[14] *Ibid.*, p. 95.

recognition of the basic position of Western views on quantum mechanics, Omel'ianovskii was soon criticized severely, and eventually produced a second edition of his book, in which, most notably, the principle of complementarity was repudiated.[15]

The most important event of the postwar years for Soviet scholarship was A. A. Zhdanov's speech on June 24, 1947, at the discussion of G. F. Aleksandrov's *History of Western European Philosophy*, an event well known to historians of the Soviet Union. Only near the end of that speech did Zhdanov mention specific issues in science, and less than a sentence referred directly to quantum mechanics: "The Kantian vagaries of modern bourgeois atomic physicists lead them to inferences about the electron's possessing 'free will,' to attempts to describe matter as only a certain conjunction of waves, and to other devilish tricks." [16]

Although Zhdanov's speech is now known as the beginning of the most intense ideological campaign in the history of Soviet scholarship, the *Zhdanovshchina*, it is often forgotten that the first few issues of the new journal, *Voprosy filosofii*, which appeared after the speech were surprisingly unorthodox.[17] Evidently taking seriously the slogan of the journal—"to develop and carry further" Marxist-Leninist theory—the editors promoted vital discussions of several philosophic issues. In no field was this vitality more apparent than in the philosophy of physics; the second issue of *Voprosy filosofii* contained an article by the outstanding theoretical physicist M. A. Markov, a specialist in the relativity theory of elementary particles, which may well still be the most outspoken presentation of the Copenhagen point of view to appear in a Soviet philosophical journal since World War II.[18] Just why Markov chose this moment, after Zhdanov's condemnation of Aleksandrov and during the tightening of ideological controls, to expose himself so extensively may never be known, but there are several hints. Markov was a research scientist in the Physics Institute of the USSR Academy of Sciences, the organization which in the past had most stoutly defended international viewpoints in science, and which would do so in the future, incurring sharp criticism from political activists.[19] It is probable that the theoretical physi-

[15] For critical reviews of Omel'ianovskii, see M. Karasev and V. Nozdrev, "O knige M. E. Omel'ianovskogo 'V. I. Lenin i fizika XX veka,'" *Voprosy filosofii* (hereafter VF), No. 1, 1949, pp. 338–42; V. V. Perfil'ev, "O knige M. E. Omel'ianovskogo 'V. I. Lenin i fizika XX veka,'" VF, No. 1, 1948, pp. 311–12. The second edition was published in Ukrainian, *Borot'ba materiializmu proty idealizmu v suchasnii fizytsi* (Kiev, 1947).

[16] Zhdanov, *Vystuplenie na diskussii po knige G. F. Aleksandrova "Istoriia zapadnoevropeiskoi filosofii," 24 iiunia 1947 g.* (Moscow, 1951), p. 43.

[17] The first four issues were under the editorship of B. M. Kedrov, who was replaced by D. I. Chesnokov after Kedrov had sponsored a series of controversial articles. Kedrov obviously supported the Markov article and was held responsible for the criticism it incurred. Five articles in the first issues of *Voprosy filosofii*, including Markov's, were criticized in an article in *Pravda*, "Za boevoi filosofskii zhurnal" (September 7, 1949).

[18] Markov, "O prirode fizicheskogo znaniia," VF, No. 2, 1947, pp. 140–76.

[19] Maksimov charged that around Fock in the P. N. Lebedev Physics Institute of the Academy of Sciences there was a group of scientists who refused to admit dialectical materialism into science (A. A. Maksimov, "Bor'ba za materializm v sovremennoi fizike," VF, No. 1, 1953, p. 178). When Markov's viewpoint was discussed in this institute, very little substantive criticism was expressed; see L. L. Potkov, "Obsuzhdenie raboty M. A. Markova

cists in the Academy, aware since the 1930s that, given the will, dialectical materialism could be used against prevalent interpretations of quantum mechanics, decided that the nascent *Zhdanovshchina* meant that an official position on quantum mechanics was very likely to be imposed and felt that an early attempt to make that official position compatible with contemporary quantum theory was necessary. Markov probably knew well just how controversial his article would be but hoped, first, that it would be vindicated and, second, that even if his point of view was rejected, the final compromise would be more palatable to the physicists as a result of his strong stand. Furthermore, Markov was able to capitalize on a feud among the professional philosophers. As the course of the debate illustrated, the chief editor of the new philosophical journal *Voprosy filosofii* was disliked by the old guard, which had published *Pod znamenem marksizma,* the major Soviet journal of philosophy from 1922 to 1944. The debate over Markov, consequently, contained many dimensions: it was an effort by the physicists to protect quantum mechanics, it was a volley in a feud among philosophers, and it was a decisive struggle over the question whether physicists or philosophers would have the ultimate influence on the philosophy of science in the postwar period.

Markov accepted modern quantum theory completely and agreed with Bohr's position in Bohr's debate with Einstein, Podolsky, and Rosen. Thus, Markov considered quantum mechanics to be complete, in the technical sense that no experiment which did not contradict it could yield results not predicted by it, and he consequently rejected all attempts to explain the behavior of microparticles on the basis of "hidden parameter" theories which would later permit restitution of the concepts of classical physics: "It is impossible to regard quantum mechanics as a classical mechanics which has been corrupted by our 'lack of knowledge.'" [20] Such complementary functions as *"impulse" and "position" simply did not have simultaneous values;* to suggest that they did would mean contradicting quantum theory.[21]

Not only was Markov's view on conjugate parameters typical of the Copenhagen School, but his total approach to science bore no distinguishable traits of dialectical materialism despite his initial quotations from Marxist classics. He asked that no statements be made which could not be empirically verified; he accepted relativity theory, including relativity of spatial and temporal intervals; he used the term "complementarity" without hesitation. To be sure, he affirmed that his view of science was "materialist" and criticized James Jeans and other Western commentators on science, but nowhere in his article did he make any effort to illustrate the relevance of dialectical materialism to science.

Markov maintained that "truth" is obtained from many sources; when we

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'O mikromire,'" VF, No. 2, 1947, pp. 381–82. The criticism came later, primarily from philosophers.

[20] Markov, p. 150. The "hidden parameter" theories have been promoted in recent years by David Bohm in particular.

[21] *Ibid.*, p. 146.

speak of knowledge of the microworld, which we gain with instruments, we are speaking about knowledge which has come from three sources: nature, the instrument, and man. The language which we use to describe our knowledge is perforce always "macroscopic" language, since this is the only language we possess. The measuring instrument performs the role of "translating" the microphenomenon into a macrolanguage accessible to man. "We consider physical reality to be that form of reality in which reality appears in the macro-instrument." [22] Thus, according to Markov, our concept of physical reality is subjective to the extent that it is formed in macroscopic language and is "prepared" by the act of measurement, but it is objective in the sense that physical reality in quantum mechanics is a macroscopic form of the reality of the microworld.

The role of the measuring instrument is one of the thorniest issues in quantum mechanics. Markov's view was essentially in agreement with that of the Copenhagen Interpretation, according to which the wave describing a physical state spreads out over larger and larger values until a measurement is made, when a reduction of this spread (wave packet) to a sharp value occurs. Such an interpretation does indeed imply that complementary microphysical quantities have no inherent sharp values but that such values instead result from, or are "prepared by," the measurement. The most imaginative attempt, no doubt, to illustrate the striking results of some interpretations of this view of microphysical measurements was made by Schrödinger: A live cat is imprisoned in a cage in such a fashion that it will be poisoned if a light-sensitive trigger is activated by a photon. In order to strike the trigger, however, the photon, whose position is mathematically described by a wave function spread through space, has to pass through a half-silvered mirror. If the emitter sends one photon toward the half-mirror at a certain time, say, twelve o'clock, and then no one looks at the cat until one o'clock, are we still to assume, as Schrödinger suggests, that the cat is neither dead nor alive until someone actually looks in the cage and thus "prepares" the cat in a state of life or death?[23]

The cat paradox raises a basic question about the difference in quantum mechanics between relational aspects and subjective aspects. It is quite possible to interpret the cat paradox from a relational standpoint in which subjective considerations play no role. The moment of interaction between the micro-entity and the macro-entity is not the moment when the observer looks in the cage but the moment when the photon either was reflected by the half-silvered mirror or passed through it, poisoning the cat. As Hilary Putnam has pointed out, contemporary physicists explain the cat paradox by saying that all macro-observables always have sharp values, and therefore the poisoning of the cat (if it occurred) was in itself a "measurement." [24]

[22] *Ibid.*, p. 163.

[23] E. Schrödinger, "Die gegenwärtige Situation in der Quantenmechanik," *Die Naturwissenschaften*, XXIII, No. 48 (Nov. 29, 1935), 812.

[24] Putnam, pp. 94 ff. Hans Reichenbach also analyzed the cat paradox in "The Principle of Anomaly," *Dialectica*, II, No. 3–4 (1948), 344.

Similarly, the moment of measurement when a photographic plate is used to record a quantum phenomenon is the moment of exposure, not the moment a human being looks at the plate. Thus, although measurement theory is still an uncertain area in the philosophy of science, measurement can be made an essential part of quantum mechanics without necessarily including subjective or epistemological considerations.

Whatever Markov's views on the cat paradox, his opinion that the instrument "prepares" the state of microphysical reality, together with his acceptance of the Copenhagen Interpretation in general, exposed him to criticisms from a number of quarters, ranging from dogmatic ideologues to ordinary physicists with hopes for the eventual replacement of the views of Bohr and his colleagues by an interpretation more agreeable to common-sense intuition. The Markov article very quickly became the occasion for a full-blown controversy, involving several dozen participants, on the nature of physical reality and the dialectical materialist interpretation of quantum mechanics.

The polemic began with the appearance of an article by A. A. Maksimov in *Literaturnaia gazeta*, an unusual place for a commentary on the philosophy of science.[25] The article, entitled "Concerning a Philosophic Centaur," contained very serious allegations against Markov. As the title indicates, Maksimov considered Markov to be a strange species, a creature combining Western idealistic views on the philosophy of science with professions of loyalty to dialectical materialism. The background of the article reveals that it was more than a mere alternative viewpoint on quantum mechanics. Maksimov, once described by a Western scholar as a "physicist to philosophers, a philosopher to physicists," [26] was a veteran of the struggles in philosophy of the 1920s and 1930s and had been a member of the editorial board of the journal *Pod znamenem marksizma* when it ceased publication in 1944. After the war he became a defender of the most dogmatic positions in the philosophy of science; he accused such scientists as Einstein and Bohr not only of committing grievous mistakes in the interpretation of science but even of factual errors. Maksimov originally submitted his article to *Voprosy filosofii,* whose editor, B. M. Kedrov, disagreed strongly with it but decided to print it "for discussion purposes," along with a rebuttal. After Maksimov had already returned galley proofs to the journal, another article of his of identical title and very similar content appeared in *Literaturnaia gazeta,* prefaced with a condescending note from the editors about the questionable quality of the new Soviet theoretical journal, *Voprosy filosofii.* Kedrov immediately canceled Maksimov's article in *Voprosy filosofii* and in the following issue accused both Maksimov and the editors of *Literaturnaia gazeta* of bad faith.[27] Why were the editors of *Literaturnaia gazeta* carrying on a vendetta against another publication? Here again the actual facts may never be known, but any attempt to explain this very rare disagreement between editorial

[25] Maksimov, "Ob odnoi filosofskom kentavre," *Literaturnaia gazeta,* April 10, 1948, p. 3.
[26] Joravsky, p. 185.
[27] "K diskussii po stat'e M. A. Markova," VF, No. 1, 1948, p. 225.

boards in Stalinist Russia must begin with the fact that the member of the board of *Literaturnaia gazeta* responsible for philosophy was none other than M. B. Mitin, who had been one of the editors of the defunct *Pod znamenem marksizma* and was obviously discontented with the new philosophy journal which had appeared in the wake of Zhdanov's speech.[28]

The central point of Maksimov's article was that Markov was a supporter of the Copenhagen Interpretation of quantum mechanics and was trying to whitewash this view with a few statements about its agreement with dialectical materialism. According to Maksimov,

> M. A. Markov, following directly behind Bohr, asserts that in physical experiments there is a mutual influence of the microworld and the instrument which in essence can never be overcome. However, this argument in no way touches upon the basic epistemological question, "Does microreality with such properties exist before the application of an instrument by man?" M. A. Markov answers that it does not exist, but is "prepared" by the instrument.[29]

After the appearance of Maksimov's article in *Literaturnaia gazeta*, the editors of *Voprosy filosofii* published a discussion of quantum mechanics. A number of authors (D. S. Danin, M. V. Vol'kenshtein, and M. G. Veselov) gave Markov strong support, revealing the numerous errors of Maksimov, and the noted D. I. Blokhintsev also took a fairly positive view of Markov's interpretation of quantum mechanics. Other critics, however, pointed out Markov's "anthropomorphism" in science, a result of his emphasis on the "observer" (L. I. Storchak) and his disregard of Party loyalty, or *partiinost'* (I. K. Krushev, V. A. Mikhailov).[30] But the factor which determined the eventual disapproval of Markov's article was a decision, beyond any doubt promoted by the Party, to replace Kedrov as editor of *Voprosy filosofii* by D. I. Chesnokov. It is clear that Maksimov's attack on Markov played an important role in Kedrov's downfall. Maksimov's *Literaturnaia gazeta* article was a clear criticism of Kedrov, and in a statement which appeared after Kedrov's dismissal Maksimov commented:

> Only a decisive rejection of the idealistic inventions of N. Bohr and M. A. Markov, only a decisive repudiation of the position taken on this question by the editorial board of the journal *Voprosy filosofii* [in No. 1, 1948] can lead our philosophical organ out of this blind alley into which it attempted to lure several sections of our intelligentsia, those inclined to waver on the basic questions of Marxist-Leninist ideology.[31]

[28] Mitin is currently chief editor of *Voprosy filosofii*.

[29] Maksimov, "Ob odnoi filosofskom kentavre," p. 3. One of the characteristics of Maksimov's article was its inaccuracies, as many critics in letters to the editor of *Literaturnaia gazeta* pointed out. In the quotation cited, for example, Maksimov stated that Markov had said that microreality "does not exist" before measurement, a statement which Markov never made, although he did say that the state of a system is "prepared" by measurement. In addition, Maksimov described Markov as saying that there existed a sharp division between the microlevel and the macrolevel of physical reality, a statement which Markov not only did not make but specifically denied.

[30] See "Diskussiia o prirode fizicheskogo znaniia: Obsuzhdenie stat'i M. A. Markova," VF, No. 1, 1948, pp. 203–32. Among the other contributors were B. G. Kuznetsov and S. A. Petrushevskii.

[31] Maksimov, "Diskussiia o prirode fizicheskogo znaniia," VF, No. 3, 1948, p. 228.

In a note in the third issue of 1948 the reformed editorial board of *Voprosy filosofii* admitted that the journal had not taken the correct position on quantum mechanics and, particularly, on Markov's article, which had "weakened the position of materialism." The article had contained "serious mistakes of a philosophic character" and was in essence a departure from dialectical materialism "in the direction of idealism and agnosticism." [32]

In terms of personnel, the immediate casualty of the Markov affair was Kedrov, but in terms of the philosophy of science the casualty was the principle of complementarity. The period from 1948 to roughly 1960 may be called, with respect to discussions of quantum mechanics in the Soviet Union, the age of the banishment of complementarity.[33] Only a few scientists in this period, most notably V. A. Fock, attempted to include complementarity as an integral part of quantum theory.

The new attitude toward complementarity was made clear in an article by Ia. P. Terletskii which immediately preceded the final statement on the Markov controversy by the editors of *Voprosy filosofii*. Terletskii observed that Markov's article was actually an attempt to justify the acceptance of complementarity by maintaining that, as a result of the role of measuring instruments as "translators" of reality, statements about microphysics often contradict each other. Such a view, thought Terletskii, was merely a restatement of Mach's opinion that scientists must describe nature in terms of sensations. A true dialectical materialist approach, however, showed, Terletskii continued, that the principle of complementarity was in no way a basic physical principle and that quantum mechanics could very well "get along without it." [34]

The result of the Markov affair, then, was a victory for dogmatic ideologists. Maksimov, primarily a philosopher, had triumphed over Markov, an outstanding active theoretical physicist in the Academy of Sciences. But it also became fairly clear that Maksimov was not capable of advancing an official interpretation of quantum mechanics which held any chance of acceptance.[35] His articles on quantum mechanics revealed all too clearly his ignorance of the subject. And it was the same Maksimov who was simultaneously opposing not only Einsteinian relativity but even Galilean relativity, maintaining that every object has an absolute trajectory and that a meteorite inscribes this trajectory on the earth upon collision with it.[36] Maksimov clearly represented pseudoscience, and his role in both quantum

[32] "Ot redaktsii," *ibid.*, pp. 231–32.

[33] Soviet philosophers were quite straightforward in recognizing the discrediting of complementarity. Thus, Storchak observed, "In the course of the discussion of M. A. Markov's article it was established that the principle of complementarity was contrived as an idealistic distortion of the foundations of quantum mechanics" ("Za materialisticheskoe osveshchenie osnov kvantovoi mekhaniki," VF, No. 3, 1951, p. 202).

[34] Terletskii, "Obsuzhdenie stat'i M. A. Markova," VF, No. 3, 1948, p. 229.

[35] He seems to have played a role in this controversy similar to Chelintsev's in the theory of resonance dispute. See my "A Soviet Marxist View of Structural Chemistry: The Theory of Resonance Controversy," *Isis*, LV, No. 179 (March 1964), 20–31.

[36] Maksimov, "Marksistskii filosofskii materializm i sovremennaia fizika," VF, No. 3, 1948, p. 114.

mechanics and relativity theory was a purely destructive one, isolating the "Machists" and "idealists" among Soviet scientists, and winning a certain support for that service, but presenting no tenable alternatives to Western interpretations of physical theory. As in the case of relativity theory, Maksimov soon lost his influence among Soviet interpreters of quantum theory. The period after 1948 was dominated instead by physicists and a small number of philosophers with some knowledge of physics, all of whom, however, were influenced by the atmosphere created by the Markov affair. Until approximately 1958 the major interpreter of quantum mechanics was the philosopher of science Omel'ianovskii, who drew upon the theories of the physicist Blokhintsev, advocate of the "ensemble" interpretation. Also important was Fock, who termed his interpretation a recognition of the "reality of quantum states." And a good many others, including A. D. Aleksandrov, Ia. P. Terletskii, B. G. Kuznetsov, as well as the foreign scholars Louis de Broglie, J.-P. Vigier, and David Bohm influenced the discussions of dialectical materialism and quantum mechanics.

D. I. Blokhintsev

D. I. Blokhintsev, one of the best known Soviet specialists in quantum mechanics and after 1956 director of the Joint Institute of Nuclear Research at Dubna, as well as winner of Lenin and Stalin prizes, published in 1944 the first complete and systematic university textbook on quantum mechanics in the Russian language.[37] He produced a revised second edition in 1949, that is, after the Markov affair and after quantum mechanics had become a subject of heightened ideological interest.[38] The two editions, straddling the beginning of the debate, differ on several interesting points. As Blokhintsev himself commented:

> The chapter which concerns the concept of state in quantum mechanics has been changed, and the clarity of the discussion of the uncertainty relationship has been improved. In the new edition of the book ideological questions connected with quantum mechanics are also considered, and the idealistic conceptions of quantum mechanics which are now widespread abroad are subjected to criticism.[39]

In the 1944 publication Blokhintsev's interpretation of the physical significance of the wave function was a version of the original Born interpretation, according to which the wave does not represent the state of the system but the scientist's *knowledge* of the state. As Blokhintsev observed, "The de Broglie waves give . . . only statistical information (*svedenie*) concerning the movement of particles." [40] According to Blokhintsev, quantum mechanics describes the actions of microparticles in a purely statistical fashion. The wave function is an instrument for ascertaining probabilities. The intensity of the de Broglie waves in a certain location of space is proportional to the probability "of finding" the particle at that particular spot. The important

[37] Blokhintsev, *Vvedenie v kvantovuiu mekhaniku* (Moscow and Leningrad, 1944).
[38] *Osnovy kvantovoi mekhaniki* (Moscow and Leningrad, 1949).
[39] *Ibid.*, p. 8.
[40] *Vvedenie v kvantovuiu mekhaniku*, p. 34.

phrase here is "of finding" as it obviously places emphasis on the process of measurement, since only by measuring does one "find." Blokhintsev's attitude toward measurement was crucial if he was to stake out an independent view on quantum mechanics. Yet in his 1944 publication he made no effort to characterize the Ψ function as something inherently objective, as he did later, but instead discussed it in terms of the results of individual measurements. "Knowing the Ψ function," he remarked, "permits one to predict the *results of different measurements* carried out on particles." [41]

An exhaustive statement of Blokhintsev's position in 1944, which can be characterized as a probability interpretation of the Ψ function, would have led him to a normal particle interpretation of the electron, similar to Born's original position.[42] Blokhintsev attempted to avoid the causal anomalies which arise from this view (see page 382 above) by maintaining that microparticles were inherently different from macroparticles. His statistical description did not imply, he pointed out, that each microparticle had a normal trajectory (possessed simultaneous values of momentum and position):

A priori one might think that such trajectories also exist in the realm of the microworld but that quantum mechanics pays attention only to a certain statistical average of those movements along trajectories, similar to what occurs in statistical mechanics. Simple considerations illustrate that such is not the case. In the area of the microworld mechanical values are in different relationships than in the realm of the macroworld.[43]

Blokhintsev was, in effect, refusing to accept microparticles as being either corpuscular or undulatory, although his approach leaned toward the corpuscular camp. By refusing to go beyond the mathematical formalism any further than absolutely necessary he avoided answering such questions explicitly, and he did not refer to "complementarity."

In his statistical interpretation of quantum mechanics Blokhintsev put great emphasis on "ensembles." He noted that the probability yielded by the wave function was derived from a series of repeated measuring operations. Therefore, when one talked about the wave function of one particle, or one system, what was actually being talked about was a large number of such particles or systems. A collection of such particles which were independent of one another and which could serve as material for repeated independent experiments was called an ensemble. The Heisenberg uncertainty relationship, which was often discussed in terms of one particle, was actually a result, according to Blokhintsev, of measuring operations carried out on particles belonging to an ensemble. If all the particles in an ensemble could be described by one wave function, it was a "pure ensemble." If, however, an ensemble consisted of sub-ensembles, each of which was described by a wave function, then the total was a "mixed ensemble." The relevance of this breakdown of the ensembles for the question of the nature of the wave function was the following: if a measurement was carried out on a pure ensemble,

[41] *Ibid.*, p. 42.
[42] See Reichenbach, "The Principle of Anomaly," p. 345.
[43] *Vvedenie v kvantovuiu mekhaniku*, p. 42.

according to Blokhintsev, that very operation caused the ensemble to become mixed, since the act of measurement placed those few (perhaps one) microparticles affected by the measurement in a different state, described by a different wave function.[44]

In the 1949 edition of his textbook Blokhintsev altered the wording of his interpretation of the wave function, eliminated the section which described the wave function as a prediction of measuring operations, and added a section on "methodological questions" in which for the first time he explicitly criticized Bohr's complementarity and the Copenhagen School.[45] In the section entitled "The Statistical Interpretation of the de Broglie Waves" Blokhintsev changed only a few words, but in exactly the most crucial area: in 1944 he had said that the de Broglie waves gave only "statistical *information* concerning the movement of particles"; in 1949 the sentence was changed to say that the waves gave a "statistical *description* of the movement of microparticles."[46] The latter statement emphasized the objective nature of the microparticles. The words "description of" were more easily accommodated to Lenin's copy theory of epistemology than "information about."

The main difficulty with the Copenhagen School, Blokhintsev thought, was its attachment to complementarity, or the belief that the quantum description of phenomena divided into two classes complementary to each other in the sense that one must combine them to have a complete description in classical terms. From complementarity the adherents of the Copenhagen School drew conclusions favoring the denial of causality, the liquidation of materialism, and the subjective nature of the wave function.[47] According to Blokhintsev, the Copenhagen followers considered the wave function not an objective characteristic of the quantum ensemble but an expression of the information possessed by the observer. The irony of Blokhintsev's position is revealed in his criticism of the Copenhagen "idealists'" and "Machists'" use of a description of the wave function which he himself had used in the earlier edition of the same book.[48] But now he no longer considered the wave function a representation of "information" but instead a "completely objective characteristic of the quantum ensemble, independent of the observer."[49]

The most complete statement of Blokhintsev's criticism of the Copenhagen School and the philosophic significance of his alternative ensemble interpretation was a long article which appeared in a leading Soviet physics

[44] *Ibid.*, pp. 52, 58.

[45] In a laudatory review of Blokhintsev's second edition, Storchak observed that the book would serve well as a dialectical materialist statement of quantum mechanics ("Za materialisticheskoe osveshchenie osnov kvantovoi mekhaniki," VF, No. 3, 1951), p. 202.

[46] *Vvedenie v kvantovuiu mekhaniku*, p. 34, and *Osnovy kvantovoi mekhaniki*, p. 45; italics added.

[47] Blokhintsev drew his references from Bohr's *Atomtheorie und Naturbeschreibung* (Berlin, 1931) and P. Jordan's *Physics of the Twentieth Century* (New York, 1944).

[48] Compare *Osnovy kvantovoi mekhaniki*, p. 547, lines 17–21, with *Vvedenie v kvantovuiu mekhaniku*, p. 34, lines 6–7.

[49] *Osnovy kvantovoi mekhaniki*, p. 57.

journal in 1951.[50] Blokhintsev set himself the task of proving that quantum statistics had objective reality and in no way depended on the observer, in contrast to Bohr's early belief that the statistics could be considered a result of the uncontrollable influence of the instrument upon the object. He noted that radioactive atoms decayed according to statistical laws which were independent of observers and instruments. Blokhintsev considered radioactivity to be a phenomenon of a "certain statistical ensemble of radioactive atoms, existing independently in nature." [51] Cosmic rays were similarly dependent on objective statistical laws. And, he observed, the microlevel of matter was an area where such statistical laws were inherently "objective" (did not derive from underlying causal factors) and therefore commonplace. In contrast,

> the Copenhagen School relegates to secondary importance the fact that quantum mechanics is applicable only to statistical ensembles and concentrates on analysis of the mutual relations of a single phenomenon and the instrument. This is an essential methodological error: in such an interpretation all quantum mechanics takes on an "instrumental" character, and the objective aspect of things is extinguished.[52]

Blokhintsev's definition of the quantum ensemble underwent a slight but interesting change between 1949 and 1951. Whereas in 1949 the ensemble was defined as a large number of microparticles in a certain state, or combination of states—and therefore was definable in terms of phenomena on the microlevel—by 1951 the ensemble included part of the macrolevel also, namely, the connection of the microsystem to the macroscopic environment, of which the measuring instrument was a special case.[53] This change was prompted by two motivations, one of which, interestingly enough, derived from an interpretation of dialectical materialism, while the other derived from physics. One of the tenets of dialectical materialism, as defined by the Stalinist *Short History of the Communist Party*, was that "not a single phenomenon in nature can be understood if it is considered in isolation, disconnected from the surrounding phenomena." [54] In this light Blokhintsev's earlier statements about the "sharp border" between the microlevel and the macrolevel seemed suspect. By defining the ensembles in terms of both the microsystems themselves *and* their connections with the macroworld Blokhintsev mended this rift. At the same time, he was able to present the Ψ function as a statement of values for potential measuring operations, as did quantum theorists all over the world, including those of the Copenhagen School.

The important question, after this shift in the definition of the ensembles, was, "How would Blokhintsev preserve a uniquely dialectical materialist

[50] Blokhintsev, "Kritika idealisticheskogo ponimaniia kvantovoi teorii," UFN, XLV (1951), No. 2 (Oct.), 195–228 (reprinted with two pages of preface as "Kritika filosofskikh vozzrenii tak nazyvaemoi 'kopengagenskoi shkoly' v fizike," in A. A. Maksimov *et al.*, eds., *Filosofskie voprosy sovremennoi fiziki* [Moscow, 1952], pp. 358–95).

[51] "Kritika idealisticheskogo ponimaniia kvantovoi teorii," p. 209.

[52] *Ibid.*, p. 210.

[53] Blokhintsev now defined the ensemble as the microsystem plus the macro-instrument (*ibid.*, p. 212).

[54] *Istoriia Vsesoiuznoi kommunisticheskoi partii (bol'shevikov): Kratkii kurs* (Moscow, 1945), p. 101.

position toward quantum mechanics?" Blokhintsev attempted to answer this question by maintaining that quantum mechanics was inapplicable to individual micro-objects, since no individual micro-object could be studied in isolation from its environment. In this way, by studying large numbers of microparticles, knowledge of objective reality could "in principle" be attained: "Quantum mechanics studies the properties of a single microphenomenon by means of the study of the statistical laws of the collective of such phenomena." [55] Blokhintsev readily granted that a measuring operation would change the state of a particular particle, placing the particle in a different ensemble, but asserted that all the other particles in the old ensemble would still be in their previous state. Therefore the scientist could conceive of objective reality through the concept of the totality, or ensemble.

Blokhintsev also indicated that a "hidden parameter" theory of quantum mechanics might at some future date permit a numerical description of the individual microparticle, although at the present time he considered such a description to be impossible. He dismissed John von Neumann's and Hans Reichenbach's well known attempts to disprove hidden parameter theories by pointing out that both rested their cases on the existing mathematical apparatus of quantum mechanics, which would surely be changed if a new theory were devised.[56] He also dismissed the position of Einstein, Podolsky, and Rosen, noting that these authors based their views on the application of the wave function to individual particles, whereas he believed it should be applied only to groups or ensembles.[57]

The central weakness of Blokhintsev's interpretation was his definition of ensembles. He had assigned himself the goal of separating the quantum description of matter from the process of measurement; yet he had ended up by defining his ensembles as combinations of the microsystems and their macro-environments, and he considered measuring instruments to be special cases of the macro-environment. He then defined the wave function as the "association" of a particle with this or that ensemble.[58] But his chain of reasoning had led him full circle, since he had started with the desire to separate quantum mechanics from measurement and ended by including measurement in his definition of the ensemble. Thus, the Ψ function became, as before, a probabilistic statement of the results of measurement. Blokhintsev did not, therefore, achieve the separation which he sought.

In the controversy between Blokhintsev and Fock which soon followed, the concept of ensembles became a basic issue. Fock very quickly located the weakness at the bottom of Blokhintsev's discussions of the ensemble. He extracted the fundamentals of quantum mechanics which Blokhintsev had

[55] "Kritika idealisticheskogo ponimaniia kvantovoi teorii," p. 213.

[56] Many contemporary analysts of quantum mechanics agree with Blokhintsev on this point. See, for example, P. K. Feyerabend, "Problems of Microphysics," in R. G. Colodny, ed., *Frontiers of Science and Philosophy* (Pittsburgh, 1962), p. 207.

[57] This position of Blokhintsev's illustrates that he was not in complete agreement with the interpretation of Nikol'skii before World War II, as has often been said. Nikol'skii agreed with Einstein, Podolsky, and Rosen. See Nikol'skii, "Printsipy kvantovoi mekhaniki."

[58] "Kritika idealisticheskogo ponimaniia kvantovoi teorii," p. 211.

defined in 1949: (a) an ensemble is a collection of particles which independently of one another are in a state such that the ensemble can be characterized by the wave function Ψ; (b) it follows that the state of a particle should be understood as the association of that particle with a definite ensemble, so that (c) the wave function does not concern an individual particle. Fock then demonstrated that these propositions are in contradiction to each other:

In assertion (a) the state of an individual particle is defined by means of its wave function, but in assertion (c) it is denied that the wave function concerns the individual particle. This is a contradiction. Furthermore, in assertion (a) the ensemble is defined by means of the wave function, but in assertion (b) the wave function is defined through the ensemble. This is a vicious circle.[59]

Furthermore, continued Fock, Blokhintsev could not treat the ensembles as statistical collectives, as he intended to do, unless they met the standard criteria of such collectives in accordance with established theory of statistics. Within this theory, a statistical collective is a collection of elements which may be sorted out in accordance with a certain indicator (*priznak*). Such an indicator would be the value of a certain physical magnitude, or a group of physical magnitudes simultaneously measured. But according to quantum mechanics, microparticles do not possess definite values which would permit the sorting out of a definite collective. Therefore, Blokhintsev, said Fock, had no way of even denoting the members of his much touted ensembles, which were really only "speculative constructions." Instead, he should frankly state that his quantum ensembles concealed a reference to a statistical statement of the results of measurements on a micro-object, conducted with the aid of a classical instrument designed for measuring a given magnitude. Fock concluded that Blokhintsev's incorrect position was connected with that of Bohr:

We see the basic cause of all difficulties in the fact that a purely statistical point of view is incorrect in a philosophic sense. In contrast to what dialectical materialism teaches us, the statistical point of view issues not from the objects of nature but from observations, not from the micro-object and its state but from the statistical collective of the results of observations. This draws it toward the positivist point of view of Bohr, which also denies that the wave function relates to the micro-object, and attributes to the wave function only a purely symbolic significance.[60]

A reply to this criticism was no easy task for Blokhintsev, who must have felt somewhat uneasy about the definition of his ensembles, to judge from the waverings in his writings on the subject. Much of his answer to Fock was a criticism of the latter's own belief that the wave function is an objective description of individual microbodies. This aspect of their debate will be considered in the following section, which concerns Fock's own interpretation of quantum mechanics. On the question of the definition of the ensembles, Blokhintsev merely affirmed his previous views: "The wave function . . . defines the relationship of a particle to definite conditions of the macrosetting,

[59] V. A. Fok, "O tak nazyvaemykh ansambliakh v kvantovoi mekhanike," VF, No. 4, 1952, p. 170.
[60] *Ibid.*, p. 173.

but the combination of particles associated with one macrosetting forms a pure or mixed ensemble. Therefore, there is no sort of vicious circle in my definitions." [61]

Since 1951 Blokhintsev's position on the philosophic interpretation of quantum mechanics has remained basically unchanged. In recent articles he has been less concerned with the physical significance of the wave function than with relativistic quantum mechanics, quantum field theory, and attempts to find a system for the rational arrangement of elementary particles.[62]

V. A. Fock

Academician V. A. Fock, a theoretical physicist and a winner of both a Stalin and a Lenin prize, has been a frequent contributor to discussions of the philosophic implications of relativity theory and quantum mechanics. Throughout a number of controversies he has been noted for his intense sense of independence, defending himself on numerous occasions against both Soviet and Western critics. Fock may be correctly defined as a follower of Bohr's Copenhagen Interpretation if one defines the Copenhagen Interpretation in terms of its minimum rather than its maximum claims. (This "core-meaning" of the Copenhagen Interpretation was once described by N. R. Hanson as "a much smaller and more elusive target to shoot at than the *ex cathedra* utterances of the melancholy Dane.")[63] The most accurate evaluation of Fock's position might be to say that, with a few temporary waverings, his thinking has undergone transitions quite similar to the shifts in Bohr's thinking. In several cases these shifts, all toward de-emphasis of the role of measurement and stress on a realist point of view, occurred first in Fock's interpretation, then in Bohr's, and it is possible that Fock may have been one of the influences on Bohr. Fock believes that he helped alter Bohr's opinions. The two scientists were aware of each other's work and on at least one occasion had a long and very thorough face-to-face exchange of views on the interpretation of quantum mechanics. It was after this exchange that Fock commented, "After Bohr's correction of his formulations, I believe that I am in agreement with him on all basic items." [64] This observation followed a period in which Fock had been rather critical of what he considered Bohr's carelessness on philosophic issues.

In the 1930s, however, when Bohr had been even less cautious in his statements, Fock was one of the leaders of the "Copenhagen branch" in the USSR and repeatedly defended its viewpoint in the journals. His agreement with Bohr in the latter's debate with Einstein over the completeness of quantum

[61] "Otvet akademiku V. A. Foku," VF, No. 6, 1952, pp. 172–73.

[62] See, for example, his "Problema struktury elementarnykh chastits," in I. V. Kuznetsov and M. E. Omel'ianovskii, eds., *Filosofskie problemy fiziki elementarnykh chastits* (Moscow, 1964), pp. 47–59.

[63] N. R. Hanson, "Five Cautions for the Copenhagen Interpretation's Critics," *Philosophy of Science*, October 1959, p. 327.

[64] Fok, "Ob interpretatsii kvantovoi mekhaniki," in N. N. Fedoseev *et al.*, eds., *Filosofskie problemy sovremennogo estestvoznaniia* (Moscow, 1959), p. 235.

theory is quite clear. During and shortly after the *Zhdanovshchina* Fock retreated a bit in the terminology of his defense of Copenhagen but never abandoned its position. Indeed, one of the remarkable aspects of Fock's career, and of the history of Soviet philosophy of science, is that he was able to defend the concept of complementarity during a long period when it was officially condemned in the philosophy journals. During this time Fock occupied an anomalous position: his view on quantum mechanics was disapproved, but his interpretation of relativity theory, which did not include the concept of general relativity, became more and more influential and after 1955 was *de facto* the official interpretation. Nothing illustrates better the subtlety of Soviet controversies in the philosophy of science—a subtlety greater than most Westerners are willing to grant—than Fock's views being simultaneously under ban and approval. After 1958 Fock's interpretation of quantum mechanics gained greater acceptance and was finally adopted by the philosopher Omel'ianovskii, who had previously supported Blokhintsev. Ironically, in this period Fock's interpretation of relativity, although still very influential, was coming under more and more criticism from such people as M. F. Shirokov.[65] If the shifts seem confusing, some consistency may be perceived in the fact that these latter changes (away from Fock in relativity, toward him in quantum mechanics) both put Soviet science in a closer position to dominant Western interpretations, which had themselves undergone certain changes.

Most of Fock's effort in interpreting quantum mechanics has been directed toward establishing the fact that the Copenhagen Interpretation, including the principle of complementarity, did not violate dialectical materialism. As early as 1938 he maintained that "the thesis that a contradiction exists between quantum mechanics and materialism is an idealistic theory." Bohr's principle of complementarity was, to Fock, "an integral part of quantum mechanics" and a "firmly established objectively existing law of nature." [66] Throughout the years he has defended the essential Copenhagen position, although he carefully disassociated himself from certain of Bohr's views, such as the latter's early attribution of primary importance to the process of measurement. Nevertheless, his interpretation of the physical significance of the Ψ function was the same as that of Bohr. Before the war Fock did not consider the wave function to be a description of the state of matter. This was, he noted, the position of Einstein, who then became involved with paradoxes. Fock, along with Bohr, considered the Ψ function to be a description of "information about the state" (*svedeniia o sostoianii*).[67] It is not surprising, then, that Fock engaged in two particularly bitter exchanges with Maksimov, which were separated by a period of fifteen years. Maksimov advertised Fock as a conscious partisan of the idealistic, bourgeois Copenhagen School, while

[65] See, for example, Shirokov, "Filosofskie voprosy teorii otnositel'nosti," in V. N. Kolbanovskii *et al.*, eds., *Dialekticheskii materializm i sovremennoe estestvoznanie* (Moscow, 1964), pp. 58–80.

[66] Fok, "K diskussii po voprosam fiziki," PZM, No. 1, 1938, p. 159.

[67] See p. 384 above and note 11.

Fock observed that Maksimov was a wonderful example of how *not* to defend materialism.[68]

The most difficult period for Fock was immediately after the Markov affair. The new position, advanced by Terletskii and quickly supported by Omel'ianovskii, was that Heisenberg's uncertainty relationship was, indeed, an integral part of quantum mechanics and must be retained but that complementarity in no way followed from uncertainty.

According to Fock, on the contrary, there was no essential difference between the Heisenberg uncertainty relationship and complementarity.[69] Both were the result of crossing the dividing line between the macrolevel and the microlevel. It was quite conceivable, Fock indicated in a preface to the works of N. S. Krylov, that if it were possible to give a description of the microlevel of matter in terms appropriate to that level (microlanguage), then there might exist a new kind of "complementarity" which would arise when one attempted to describe the macrolevel in microlanguage. This new complementarity would be analogous to, but different from, the complementarity of existing quantum mechanics, which was based on description in macrolanguage.[70] In this view the kernel of objective reality which dialectical materialism demands as a minimum in every physical description becomes very elusive indeed.[71]

Fock's identification of uncertainty and complementarity despite the decisions by the editors of *Voprosy filosofii* brought him under very heavy criticism. In the famous 1952 "Green Book" on philosophic problems of science, edited by a group headed by the ultraconservative Maksimov, Omel'ianovskii observed: "Unfortunately several of our scientists . . . have not yet drawn the necessary conclusions from the criticism to which Soviet science subjected the Copenhagen School. For example, V. A. Fock in his earlier works did not essentially distinguish the uncertainty relationship from Bohr's principle of complementarity." [72]

It was this kind of criticism which caused Fock to alter his terminology and temporarily to hesitate in his advocacy of complementarity. While previously he had considered the Ψ function to be a description of "information

[68] Fok, "K diskussii po voprosam fiziki"; and "Protiv nevezhestvennoi kritiki sovremennykh fizicheskikh teorii," VF, No. 1, 1953, pp. 168–74; Maksimov, "O filosofskikh vozzreniiakh akad. V. F. Mitkevich i o putiakh razvitiia sovetskoi fiziki," PZM, No. 7, 1937, pp. 25–55; and "Bor'ba za materializm v sovremennoi fizike," VF, No. 1, 1953, pp. 175–94.

[69] Fok, "Osnovnye zakony fiziki v svete dialekticheskogo materializma," *Vestnik Leningradskogo universiteta*, No. 4, 1949, p. 39; and M. E. Omel'ianovskii, *Filosofskie voprosy kvantovoi mekhaniki* (Moscow, 1956), p. 35.

[70] V. A. Fok and A. B. Migdal, in N. S. Krylov, *Raboty po obosnovaniiu statisticheskoi fiziki* (Moscow and Leningrad, 1950), p. 8.

[71] Even if Fock's hypothesis were to be granted, the existence of objective reality would not necessarily be denied, since there is no reason why such reality has to be defined in terms of certain parameters, such as position and momentum. Nevertheless, such an interpretation would require a more sophisticated view of reality than is often granted it.

[72] Omel'ianovskii, "Dialekticheskii materializm i tak nazyvaemyi printsip dopolnitel'nosti Bora," in A. A. Maksimov *et al.*, eds., *Filosofskie voprosy sovremennoi fiziki* (Moscow, 1952), pp. 404–5.

about the state," he now called the Ψ function a characterization of the "real state" of the micro-object.[73] In 1951 Fock indicated that as a result of the blurring of the original meaning of complementarity he might abandon it altogether:

> At first the term complementarity signified that situation which arose directly from the uncertainty relationship: complementarity concerned the uncertainty in coordinate measurement and in the amount of motion . . . and the term "principle of complementarity" was understood as a synonym for the Heisenberg relationship. Very soon, however, Bohr began to see in his principle of complementarity a certain universal principle . . . applicable not only in physics but even in biology, psychology, sociology, and in all sciences. . . . To the extent that the term "principle of complementarity" has lost its original meaning . . . it would be better to abandon it.[74]

One of the most complete statements of Fock's interpretation of quantum mechanics appeared in a collection of articles on philosophic problems of science published in Moscow in 1959.[75] Written at a time of relative freedom from ideological restriction, it is both a statement of scientific rigor and of philosophic conviction. Fock began his discussion by considering and then dismissing attempts to interpret the wave function according to classical concepts. De Broglie's and Schrödinger's attempts originally to explain the wave function as a field spread in space, similar to electromagnetic and other previously unknown fields, were examples of classical interpretations, as was also de Broglie's later view that a field acts as a carrier of the particle and controls its movement (pilot-wave theory).[76] Bohm's "quantum potential" was essentially the same type of explanation, since it attempted to preserve the concept of trajectory.[77] Similarly, Vigier's concept of a particle as a point or focus in a field was an attempt to preserve classical ideas in physics.[78] All these interpretations, according to Fock, were extremely artificial and had no heuristic value; not only did they not permit the solution of problems which were previously unsolvable, but their authors did not even attempt such solutions.

Fock believed that the true significance of the wave function first began to emerge in the statistical interpretation of Max Born, especially after Bohr combined this approach with his own view of the importance of the means of

[73] Fok, "O tak nazyvaemykh ansambliakh v kvantovoi mekhanike," VF, No. 4, 1952, p. 172.

[74] Fok, "Kritika vzgliadov Bora na kvantovuiu mekhaniku," UFN, XLV (1951), No. 1 (Sept.), p. 13.

[75] Fok, "Ob interpretatsii kvantovoi mekhaniki," in N. N. Fedoseev *et al.*, eds., *Filosofskie problemy sovremennogo estestvoznaniia* (Moscow, 1959), pp. 212–36.

[76] In 1952 de Broglie, after defending the Copenhagen Interpretation for over twenty years, returned to his earlier belief in its replacement by a theory based on the "instinctive" position of a physicist, that of realism. Louis de Broglie, "La Physique quantique restera-t-elle indéterministe?" *Revue d'Histoire des Sciences et de leurs applications*, V (1952), No. 4 (Oct.–Dec.), 309.

[77] See David Bohm, *Causality and Chance in Modern Physics* (New York, 1961).

[78] Vigier remarked, "A particle is thus considered as an average organized excitation of a chaotic subquantum-mechanical level of matter, similar in a sense to a sound wave propagation in the chaos of molecular agitation." In this same article Vigier credited Blokhintsev with providing the essential ideas for his model. J.-P. Vigier, "Probability in the Probabilistic and Causal Interpretation of Quantum Mechanics," in Körner, pp. 75, 76.

observation. This emphasis on measuring instruments was essential for quantum mechanics, Fock agreed, but it was exactly on this point that Bohr also slipped:

> In principle it seems that it is possible to reduce a description to the indications of instruments. However, an excessive emphasis on the role of instruments is reason for reproaching Bohr for underrating the necessity for abstraction and for forgetting that the object of study is the properties of the micro-object, and not the indications of the instruments.[79]

Bohr then compounded the confusion, said Fock, by utilizing inexact terminology—terminology he was forced to invent in order to cover up the discrepancy which arose when he attempted to use classical concepts outside their area of application. One of the most important of these uses of inexact terminology was his opposition of the "principle of complementarity" to the "principle of causality." According to Fock, if one defines terms with the necessary precision, no such opposition exists. The complementarity which *does* exist in quantum mechanics is a complementarity between *classical descriptions* and causality. But this does not deny causality in general because classical descriptions of macroparticles are necessarily inappropriate for microparticles. Using classical descriptions (macrolanguage) is merely a necessary method since we do not have a microlanguage. Realizing that a microdescription of microparticles would be different from a classical description of the same particles, we can say that on both levels (micro- and macro-) the principle of causality holds. Since we always use a macrodescription, however, we should redefine causality in such a way that it fits both levels. Our new approach, said Fock, should be to understand causality as an affirmation of the existence of laws of nature, particularly those which are connected with the general properties of space and time (finite velocity of action, the impossibility of influencing the past). Causal laws can, therefore, be either statistical or deterministic. Fock concluded his remarks on causality by commenting that in his recent conversations he had found Bohr in agreement with these observations. Thus, a few redefinitions of complementarity and causality would go far toward strengthening the Copenhagen Interpretation.

Fock's opinion of the role of measurement in quantum mechanics was based on a recognition of what he termed objective reality. He accepted Heisenberg's uncertainty relationship as a factual statement of the exactness of measurements on the microlevel. But this relativity with respect to the means of measurement in no way interfered with objectivity: "In quantum physics the relativity which arises from the means of observation only increases the preciseness of physical concepts.... The objects of the microworld are just as real and their properties just as objective as the properties of objects studied by classical physics." [80] The instrument in quantum mechanics plays an important role, Fock observed, but there is no reason to exaggerate that role

[79] Fok, "Ob interpretatsii kvantovoi mekhaniki," p. 215.
[80] *Ibid.*, p. 218.

since the instrument is merely another part of objective reality, obeying physical laws. The importance of the instrument is that it necessarily gives its descriptions in classical terms.

The root of quantum mechanics, according to Fock, is, however, something radically new in science: the potential possibility for a micro-object to appear, in dependence on its external conditions, either as a wave, a particle, or in an intermediate form.[81] This new concept, coupled with the statistical characteristics of the state of an object, leads us to a different understanding of causality and of matter. Bohr tried to find his way to this new understanding by way of emphasizing the role of the instrument and by stressing the concept of complementarity. Fock preferred a slightly different way: "I try to bring in new concepts, for example, the concept of potential possibilities inherent in the atomic object, and it seems to me that the mathematical apparatus of quantum mechanics may be correctly understood only on the basis of these new concepts." [82] Fock, then, considered his essential contribution to the interpretation of quantum mechanics to be the idea of "potential possibilities" and the consequent distinction between the potentially possible and the actually realized results in physics.

In experiments designed to study the properties of atomic objects, Fock distinguished three different stages: the preparation of the object, the behavior (*povedenie*) of the object in fixed external conditions, and the measurement itself. These stages might be called the "preparatory part" of the experiment, the "working part," and the "registering part." In diffraction experiments through a crystal, the preparatory part would be the source of a monochromatic stream of electrons, as well as the diaphragm in front of the crystal; the working part would be the crystal itself; and the registering part would be a photographic plate. Fock emphasized that in such an experiment it is possible to change the last stage (the measurement) without changing the first two, and he would build his interpretation of quantum mechanics on this recognition. Therefore, by varying the final stage of the experiment, it is possible to make measurements of different values (energy, velocity, position) all of which are derived from the same initial state of the object:

> To each value there corresponds its own series of measurements, the results of which are expressed as a distribution of probabilities for that value. All the indicated probabilities may be expressed parametrically through one and the same wave function, which does not depend on the final stage of the experiment and consequently is an objective characteristic of the state of the object immediately before the final stage.[83]

In this last sentence, then, is the meaning of Fock's often quoted statement

[81] The intermediate form, said Fock, would be a case when wave-like and corpuscle-like properties appear simultaneously (although not sharply), such as when an electron is partially localized (corpuscle-like property) and at the same time displays wave properties (wave function has the character of a standing wave with an amplitude rapidly decreasing with increasing distance from the center of the atom).

[82] *Ibid.*, p. 219.

[83] *Ibid.*, p. 222.

that the wave function is an objective description of quantum states, a position which he adopted after World War II. The wave function is objective, said Fock, in the sense that it represents an objective (independent of the observer) description of the *potential possibilities* of mutual influences of the object and the instrument. Therefore, the scientist is correct, Fock believed (contrary to Blokhintsev), in saying that the wave function relates to a given single object. But this objective state is not yet actual, he continued, since none of the potential possibilities has yet been realized. The transition from the potentially possible to the existing occurs in the final stage of the experiment. Thus, Fock completed his interpretation of quantum mechanics with an affirmation of a realist (he would say dialectical materialist) position in the philosophy of science. Nevertheless, the extension of a concept of realism to statements concerning potential situations rather than actual situations was open to a number of logical objections.

M. E. Omel'ianovskii

Omel'ianovskii, a member of the Ukrainian Academy of Sciences and one of the leading Soviet philosophers of science, published in 1956 his most significant contribution to a Soviet Marxist interpretation of quantum mechanics, his *Philosophic Problems of Quantum Mechanics*.[84] Although this attempt was again ill starred, as was his 1947 volume, it established Omel'ianovskii for the remainder of the 1950s as the major Soviet interpreter of quantum mechanics. The work was an extremely ambitious one, indeed, hopelessly so; Omel'ianovskii, a philosopher, not a physicist, was attempting to outline a clearly independent position on quantum mechanics. He agreed completely with no major physicist, Soviet or Western, although his interpretation was closest to that of Blokhintsev. Among physicists, he set himself apart most markedly, of course, from the Copenhagen School (to which he implied Fock primarily belonged), much less strongly but still significantly from "materialist" Western physicists such as Bohm and Vigier, and least of all but still perceptibly from Blokhintsev.

Omel'ianovskii viewed the controversy in quantum mechanics as one of the latest developments in the ancient struggle between materialism and idealism, a contest directly connected to class interests. He maintained that the "conception of complementarity grew out of the reactionary philosophy of Machism-positivism. This conception is foreign to the scientific content of quantum mechanics. It is not accidental that P. Frank, H. Reichenbach, and other modern reactionary bourgeois philosophers joined with Jordan, who, invoking Bohr and Heisenberg, 'liquidated materialism.' "[85] Once having delivered this primitive Marxist analysis of the relationship of philosophy and the economic order, however, Omel'ianovskii proceeded to the theoretical problems of a physical interpretation of quantum mechanics according to dialectical materialism.

Omel'ianovskii believed that such an interpretation must proceed from

[84] Omel'ianovskii, *Filosofskie voprosy kvantovoi mekhaniki* (Moscow, 1956).
[85] *Ibid.*, pp. 21–22.

the following basic points, considered by him to be intrinsic in any dialectical materialist view of the microworld: (1) microphenomena and their regularities (*zakonomernosti*) exist objectively; (2) macroscopic and microscopic objects are qualitatively different; (3) although they are qualitatively different, there is no impassable gulf between the microworld and the macroworld, and all properties of micro-objects appear in one form or another on the macrolevel; (4) there are no limits to man's knowledge of microphenomena. Omel'ianovskii attempted to utilize points (1) and (4) as his main criticisms of the "physical idealists" of the Copenhagen School, and point (2) against misguided but goodhearted Western critics of Copenhagen who hoped for a return to the laws of classical physics.

According to Omel'ianovskii, the physical significance of the wave function is its "representation" (*otobrazhenie*) of the peculiar statistical laws of microphenomena, laws which are not the same as the statistical laws of macrophenomena (statistical mechanics). The peculiarity of these new statistical laws on the microlevel consists in the fact that micro-objects simultaneously possess both corpuscular and wave properties. To look upon micro-objects first as particles and then as waves would be to fall prey to complementarity, a concept which Omel'ianovskii totally rejected. Instead, one must always consider micro-objects as *simultaneously* possessing wave-like and particle-like properties. Micro-objects thus represent a dialectical unity of contradictory properties. Consequently, the wave function cannot be applied to individual micro-objects (here the Copenhagen School and Fock were wrong, thought Omel'ianovskii) but only to the quantum ensemble, developed by Blokhintsev and also favored on several occasions by Einstein, who, however, "failed" to understand the qualitative differences between the statistical laws of classical mechanics and those of quantum mechanics. The difference between these two classes of statistical laws, said Omel'ianovskii, can be illustrated by the fact that in classical ensembles the distribution of momenta and coordinates are not connected with each other, whereas in quantum ensembles they are. In his definition of the quantum ensembles Omel'ianovskii differed with his colleague Blokhintsev, who in the second edition of his textbook said that quantum ensembles must be defined in relation to macro-instruments, which "fix" or "settle" the ensemble. Omel'ianovskii, on the contrary, believed that the question of the measuring instrument was not relevant to the definition of the quantum ensemble. But by so stating his position he ran into the very serious problem of isolating the ensemble, which had been one of the reasons which led Blokhintsev to bring the measuring instrument into the definition in the first place. Omel'ianovskii's only way out was through the weak substitute of defining the ensemble in terms of what it is not, and in terms of what it "represents," not in terms by which it could be rigorously identified. To quote from Omel'ianovskii: "The quantum ensemble is not a 'collective of experiments,' not a 'collective of results of measurements.' It is not a speculative formulation; it is a concept which reflects the association of a sufficiently large number of equal, in this or that measure, micro-objects which under definite conditions belong to one and the same species (*vid*)." He capped this very loose definition of ensembles with the even weaker observation that "the problem of the corpuscular-wavelike nature of micro-objects is still insufficiently worked out. This circumstance is of importance also in the exposition of the conception of quantum ensembles." [86]

Omel'ianovskii believed that the concept of complementarity arose from Bohr's and Heisenberg's exaggeration of the meaning of the uncertainty relationship. The first step in this exaggeration was the raising of the uncertainty relationship to a higher rank, the "uncertainty principle." Omel'ianovskii accepted the uncertainty relationship as a fact of science, but this physical fact in itself said nothing, he maintained, about the "uncontrollable influence" of the instrument, upon which Heisenberg in particular based the "uncertainty principle." [87] Omel'ianovskii believed this view of the role of the instrument to be directly responsible for complementarity. While he used the term "uncertainty relationship," he refused to use the phrase "uncertainty principle," substituting the term "Heisenberg relationship." Omel'ianovskii's opinion of the "Heisenberg relationship" is revealed clearly by his remark that "the relationship established by Bohr and Heisenberg by means of the analysis of several thought experiments—we call it the Heisenberg relationship—has no physical significance and is a 'principle' changing the content of quantum mechanics in the spirit of the subjective concept of complementarity." [88] The error of complementarity, in turn, was that it does not emphasize the characteristics of atomic objects, which are the proper subject of study of quantum mechanics, as much as it does the role of the measuring instrument. Omel'ianovskii's position, which ignored the tendency of many members of the Copenhagen School, including Bohr, to attribute the uncertainty relationship not to the measuring instrument but to the simple nonexistence of conjugate parameters, was thus primarily a criticism of alleged subjectivism in measurement.

Omel'ianovskii devoted the last section of his book to a discussion of determinism and statistical laws. In his opinion, determinism, a basic principle of nature, was in no way threatened by quantum mechanics. On this issue he agreed with P. Langevin that "that which is understood at the present time as the crisis of determinism is really the crisis of mechanism." [89] Determinism is perfectly compatible, according to Omel'ianovskii, with statistical laws. Furthermore, Omel'ianovskii considered the statistical laws of quantum mechanics to be not a result of the uncontrollable influence of measurement (Heisenberg), not the result of indeterminism governing the individual micro-object (Reichenbach), not the result of hidden parameters (Bohm), not the result of the relationship of the micro-ensemble and its macro-environment (Blokhintsev), but instead the result of what he called the "peculiar wave-corpuscular properties of micro-objects." Such a position, according to Omel'ianovskii, does not preclude the existence of hidden parameters (contrary to

[86] *Ibid.*, pp. 253, 254.
[87] *Ibid.*, p. 74. See note 2 above.
[88] *Ibid.*, p. 71.
[89] *Ibid.*, p. 32.

Neumann), although it does not promise them, and does not suppose that their discovery would result in a classical description of micro-objects, as Omel'ianovskii believed Bohm, Vigier, and the latter-day de Broglie hoped. Thus, Omel'ianovskii completed the edifice of his interpretation of quantum mechanics, a structure consisting almost entirely of statements telling what quantum mechanics *is not* but very rarely hinting what it *is*. In answer to the question, "What *is* quantum mechanics?" Omel'ianovskii could cite only the first of his original four points, that it is the study of objectively existing micro-objects and their regularities, a point on which all Soviet interpreters of quantum mechanics agreed.

Recent Developments

Since 1956 a number of changes have occurred in Soviet views of quantum mechanics, although no basically new positions have been developed. The most striking change has been the shift of Omel'ianovskii from relying primarily on Blokhintsev to relying on Fock. This shift can be traced in two steps: first, an acceptance of the view that quantum mechanics can be applied to the individual micro-object and, second, a rehabilitation of the term "complementarity," although with continuing reservations. Omel'ianovskii's position may even yet be in the process of evolution.

In October 1958 an all-Union conference on the philosophic problems of modern science was held at Moscow. This conference was called, in the words of E. N. Chesnokov, as a result of "some instances of insufficiently profound appreciation by certain philosophers of the achievements of modern science." [90] The reports concerned relativity theory, cybernetics, cosmogony, biology, and physiology as well as quantum mechanics. In the discussion which followed the reports, the scientists, including A. D. Aleksandrov, V. A. Fock, S. L. Sobolev, V. A. Ambartsumian, and A. I. Oparin, clearly dominated the philosophers. In his report entitled "V. I. Lenin and the Philosophic Problems of Modern Physics" Omel'ianovskii radically changed his position on the significance of the wave function. Whereas earlier he had believed that it could be applied only to Blokhintsev's ensembles, he now believed that "the wave function characterizes the probability of action of an individual atomic object." This description is very similar to Fock's statements on the significance of the wave function, and in expanding on his interpretation Omel'ianovskii revealed that he had accepted Fock's distinction between the "potentially possible" and the "actually existing."

In the question period which followed the formal papers, Omel'ianovskii was accused of vacillation in his views in the last few years between Fock's and Blokhintsev's positions. To this, Omel'ianovskii replied, "I believe that a scholar, as Voltaire once said, changes, and if he does not change he is stupid." [91] Omel'ianovskii then quoted various definitions of the significance of

[90] The record of the conference was published in N. N. Fedoseev *et al.*, eds., *Filosofskie problemy sovremennogo estestvoznaniia* (Moscow, 1959). For the Chesnokov reference, see p. 650.

[91] *Ibid.*, p. 561. De Broglie referred to the same statement of Voltaire in his well-known 1952 article, "La Physique quantique restera-t-elle indéterministe?" p. 310.

the wave function given over the years by Fock, clearly implying that if such an eminent scientist could change his views, so could he.

In 1958 Omel'ianovskii had not accepted the term "complementarity," still considering it to be synonymous with the Copenhagen Interpretation. At the Thirteenth World Congress of Philosophy held in 1963 in Mexico City, however, he came even more fully in line with Fock by accepting complementarity and even maintaining that it is based on a dialectical way of thinking through its assertion that "we have the right to make two opposite mutually exclusive statements concerning a single atomic object." [92] Thus, according to the new Omel'ianovskii, the link between dialectics and the notion of complementarity "lies at the center of the Copenhagen Interpretation of quantum mechanics." [93] A glimmer of the old Omel'ianovskii can be seen in his comments about the remaining "deficiencies" in the concept of complementarity, such as its insistence on applying classical notions in the new realm of atomic objects, but everyone who is familiar with his past positions is struck by his departures. Until Omel'ianovskii publishes further detailed studies of quantum mechanics, his viewpoint will be somewhat unclear.

At the same time that Omel'ianovskii has redefined his interpretation of quantum mechanics, a number of other Soviet scholars have become interested in the philosophic problems of quantum mechanics, and most of them are seeking a unified theory which would combine the realms of quantum mechanics and relativity theory. Soviet authors discussing these attempts have become relatively accustomed to handling ideas which only a few years ago would automatically have been considered ideologically suspect, such as the theory of a finite universe or the hypothesis that in the "interior" of microparticles future events might influence past events. In a recent article in *Voprosy filosofii* the veteran philosopher E. Kol'man pleaded that Soviet scientists be granted permanent freedom to consider such theories; naturally, he observed, these viewpoints

> give idealists cause for seeking arguments in favor of their point of view. But this does not mean we should reject these "illogical" conceptions out of hand, as several conservative minded philosophers and scientists did with the theory of relativity, cybernetics, and so forth. These conceptions are not in themselves guilty of idealistic interpretations. The task of philosophers and scientists defending dialectical materialism is to give these conceptions a dialectical-materialist interpretation.[94]

[92] Omel'ianovskii, "The Concept of Dialectical Contradiction in Quantum Physics," in *Philosophy, Science and Man: The Soviet Delegation Reports for the XIII World Congress of Philosophy* (Moscow, 1963), p. 77.

[93] *Ibid.*, p. 75.

[94] Kol'man, "Sovremennaia fizika v poiskakh dal'neishei fundamental'noi teorii," VF, No. 2, 1965, p. 122. Kol'man, a Czech who has spent long periods of time in Moscow, has played a very interesting role in disputes over the philosophy of science. Among Czech scientists he is generally known as a rigid ideologue, but in the Soviet Union he has often been a "liberal" in the various controversies, although he favored Lysenko in the early genetics controversy. As early as 1938 he was praised by Fock for his views on relativity physics. In cybernetics he was the first person to plead with Party officials for a recognition of the value of the new field (Kol'man, "Chto takoe kibernetika," VF, No. 4, 1955, pp. 148–59). The article on physics cited above is definitely within this liberal tradition.

The interpretation of quantum mechanics is still a very open question, not only in the Soviet Union but in all countries where there is an active concern with current problems of the philosophy of science. One of the most notable characteristics of the Soviet controversy is its similarity in its most intellectually legitimate aspects to the worldwide controversy. If Omel'ianovskii objects to the idea that the macrophysical system surrounding the microparticle somehow causes the particle to display the particular properties with which we describe it, so have many non-Soviet authors, such as the American philosopher Paul K. Feyerabend. If Blokhintsev rejects von Neumann's claim to have refuted the possibility of hidden parameters, so do many Western scientists, including David Bohm. If Fock refuses to accept the idea that quantum mechanics has denied causality, so have the scientist de Broglie and the philosopher Ernest Nagel (for different reasons).[95] Yet one should be extremely careful in making generalizations from these similarities. The conclusion either that the Copenhagen Interpretation is in serious danger or that the various people who agree with each other in certain criticisms of the Copenhagen Interpretation are in fact in general agreement on quantum mechanics would be false indeed. In the Soviet Union the main participants in the debate—Fock, Blokhintsev, and Omel'ianovskii—all have disagreements with each other, and in the West the interpreters of quantum mechanics have even wider and more intense disputes.

If certain essential features of the discussion of quantum mechanics in the Soviet Union are similar to those in the West, can the controversy there be considered an integral part of such discussions elsewhere? In the USSR the controversy has been similar to that in the West only in its most intellectually legitimate aspects, which must be painstakingly sifted from a body of militantly ideological writings—for every article discussing quantum mechanics soberly and on a scholarly level one can point to a host of articles in which concepts were used as weapons rather than as objects of study. At the worst moments of the *Zhdanovshchina* discussions of ideology and physics were offensive parodies of intellectual investigations, and even now articles with such characteristics are not rare.

In recent years a rather large degree of freedom has returned to the discussions. If dialectical materialism currently influences the thinking of such scientists as Fock in any way, it is surely only in the sense of defining their positions as cognitive realists, scholars who accept the objectivity of the external world. "Objectivity" here in no way denotes that spatial and temporal intervals must have absolute values but only that on the ancient question of the nature of cognition one sides with the belief that knowledge ultimately derives from matter existing separate from the mind. The laws of the dialectic

[95] De Broglie would find causality by replacing current quantum theory by a theory (pilot-wave) which would restore classical concepts. Nagel would consider existing quantum theory "causal." See the latter's "The Causal Character of Modern Physical Theory," in S. W. Baron, E. Nagel, and K. S. Pinson, eds., *Freedom and Reason: Studies in Philosophy and Jewish Culture* (Glencoe, Ill., 1951), pp. 244–68; and *The Structure of Science: Problems in the Logic of Scientific Explanation* (New York, 1961), pp. 316–24.

play no role in the minds of Soviet physicists except very rarely, perhaps, as a reminder that "matter and its laws are more complicated than a simple materialist might think."

All scientists in the course of their investigations must occasionally proceed beyond physical facts and mathematical methods. Choices between alternative courses which are equally justifiable on the basis of the mathematical formalism and the physical facts must be made. The choice will often be based on philosophic considerations and will often have philosophic implications. Thus, Fock in his interpretation of quantum mechanics defined "complementarity" as a "complementarity between classical descriptions of microparticles and causality." [96] In his subsequent choice between retaining either a classical description or causality, he chose causality, and thereby lost the possibility of a classical description. He could have gone the other way. This decision inevitably involved philosophy, but if a person believes that a philosophy other than dialectical materialism would have led to a necessarily different decision, he is attributing to dialectical materialism a uniqueness which it does not approach.

[96] See p. 402 above.