LÉON ROSENFELD WAS Niels Bohr’s close collaborator from 1930 until Bohr’s death in 1962, serving in this capacity even when he held positions abroad and Bohr had other assistants in Copenhagen. After World War II, Rosenfeld acted as a particularly fierce and uncompromising defender of the Copenhagen Interpretation of quantum mechanics. However, unlike earlier “missionaries” of the Copenhagen Interpretation, 1.

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1. Probably the first reference in the literature to the Copenhagen Interpretation or rather to the “Kopenhagener Geist der Quantentheorie . . . which has directed the entire development of modern atomic physics,” is in Werner Heisenberg’s Chicago lectures of 1929. Heisenberg, The physical principles of the quantum theory (Chicago, 1930). Calling it an interpretation, and thereby indicating that there might be other interpretations, seems to occur for the first time in Heisenberg, “The development of the interpretation of the quantum theory,” in W. Pauli, L. Rosenfeld, and V. Weisskopf, eds., Niels Bohr and the development of physics (London, 1955), 12–29. However, Heisenberg might have taken it from Soviet critics of Bohr’s views in the late 1940s and early 1950s, such as D.I. Blokhintsev and A.D. Alexandrov. Catherine Chevalley, “Why
such as Wolfgang Pauli, Werner Heisenberg, Pascual Jordan, and Hendrik A. Kramers, Rosenfeld’s case has not previously been analyzed in depth. By seeking philosophical, political, and socio-cultural factors that induced him to take on the role as defender of Bohr’s ideas, this paper reveals the complexity of his thought, contrary to the general perception that he was simply a vicious or “vitriolic” attacker of unorthodox interpretations. First, Rosenfeld’s Marxist position is acknowledged and analyzed. That Rosenfeld professed Marxism is evident from his papers and correspondence and was often mentioned by his colleagues, for example, by Pauli, who once ironically addressed him “Dear (√Trotsky × Bohr = Rosenfeld)!” Indeed, Marxist philosophy was crucial to Rosenfeld’s worldview in general and his defense of complementarity in particular. Nevertheless, in most biographical papers and obituaries emanating from colleagues and friends, notably at the Niels Bohr Institute, this dimension is conspicuously absent. This paper suggests some reasons why, as well as what role Marxist philosophy played in Rosenfeld’s fierce defense of complementarity from the late 1940s through the 1950s and how his campaign was received at the Niels Bohr Institute in Copenhagen and elsewhere. Furthermore, it shows why some Marxists opposed complementarity and why a few, most notably Rosenfeld and the Soviet physicist Vladimir A. Fock, supported it.

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3. Lars Becker-Larsen, interview with Bryce De Witt, 10 Apr 2003, tape 10. See also Freire’s publications (ref. 2).


5. About complementarity, see section 2 below.

1. ROSENFELD’S CAREER AND MARXIST BACKGROUND

Rosenfeld was only a couple of years younger than Pauli, Heisenberg, and Jordan, the other main actors, apart from Bohr, in what J.L. Heilbron has denoted the “intellectual imperialism” of the Copenhagen Interpretation.7 Rosenfeld grew up as an only child in Belgium. His father was an electrical engineer and inventor working for an electrical company. He died in a tragic accident at a factory during World War I when Rosenfeld was only fourteen. According to Rosenfeld’s recollections, this traumatic incident had a marked impact on his immediate choices and dispositions. Until this time, his primary interests were history, Greek, Latin, and natural history, but his father’s premature death made him turn to science, “to be like his father,” despite the poor prospects in that field in Belgium at the time.8

Rosenfeld began his mathematics and physics studies in 1922 at the University of Liège where he graduated in 1926 with great distinction. However, Belgium at the time was peripheral in the development of mathematics and quantum physics. Students were introduced to neither relativity theory nor quantum physics, and Rosenfeld studied these topics on his own during his last year at the university.9 Soon after graduation Rosenfeld obtained Belgian scholarships to continue his studies in physics at the prestigious École Normale Supérieure in Paris, where he took courses and was supervised by Paul Langevin, Léon Brillouin, and Louis de Broglie. As for the latest developments in quantum physics, Paris was also not at the forefront apart from the contributions by de Broglie. De Broglie and Brillouin were the first with whom Rosenfeld discussed quantum physics, and he seems to have initially adopted de Broglie’s realistic interpretation of quantum waves.10

It was also in Paris during this period (1926/7) that Rosenfeld’s political and social awakening took place.11 At the time, graduates and professors at École Normale Supérieure took a keen interest in the combination of science and socialism. Rosenfeld soon made friends with a politically engaged graduate student in physics, Jacques Solomon, who later became Paul Langevin’s son-in-law.

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7. Heilbron (ref. 2).
9. Kuhn and Heilbron (ref. 8), 5–8.
11. Kuhn and Heilbron (ref. 8), 16.
Solomon introduced Rosenfeld to the group of leading scientists, on its way to becoming an influential and predominantly leftwing intellectual circle, which consisted of Langevin, the Curies, Jean Perrin, and others. Rosenfeld, in return, was later instrumental in arranging Solomon’s visit to Bohr’s institute in the early 1930s. On the whole, this time of social, political, and intellectual ferment in Paris gave Rosenfeld the impetus that soon made him engage more actively, albeit mainly intellectually, with Marxism.

In 1927–29, Rosenfeld worked as Max Born’s assistant in Göttingen, the blossoming center of theoretical physics. According to his recollections, this was also the period in which he began to study Karl Marx’s Das Kapital. Subsequently he joined Wolfgang Pauli’s group in Zurich for one year (1929/30). Before he went to Zurich, Rosenfeld had asked both Bohr and Einstein if he could come and work with them. It is unclear why nothing came of the contact with Einstein, who had responded positively: “I am glad that you will work with me on the topic you mention,” namely “the relation between quantum mechanics and theory of relativity.” It is likely that Rosenfeld did not get the fellowship for which he had applied.

Bohr and Rosenfeld met for the first time at Easter 1929 in connection with the first of the famous Copenhagen conferences. But according to Rosenfeld, Bohr was too busy at the time to take him in. However, starting in 1930—the same year he obtained a lectureship at the University of Liège—Rosenfeld began assisting Bohr, “oscillating” back and forth between Copenhagen and Liège “according to Bohr’s convenience until the outbreak of the war in 1940 [sic].” Bohr and Rosenfeld developed a close and intense collaboration in which their quite different

13. See correspondence between Bohr and Jacques Solomon, BSC.
14. Kuhn and Heilbron (ref. 8), 17.
15. Rosenfeld to Einstein, 25 Apr 1928; Einstein to Rosenfeld, 3 May 1928; Albert Einstein Archives, Jewish National and University Library, Jerusalem.
16. The first Copenhagen conference was an informal gathering of about 30 physicists from Denmark and abroad, at which the participants briefly presented their field of interest and discussed recent developments in physics. The meeting proved such a success that a tradition was established. Peter Robertson, The early years: The Niels Bohr Institute 1921–1930 (Copenhagen, 1979), 136–138. Rosenfeld, “My initiation,” SP, xxxi–xxiv; originally published in Journal of jocular physics, 2:7 (1945). Journal of jocular physics was a humorous and satirical endeavor that spiced the daily work at the Niels Bohr Institute. Some of the papers in the journal, among them a few by Rosenfeld, were later published elsewhere. Rosenfeld, “Quantum theory in 1929: Recollections from the first Copenhagen Conference,” SP, 302–312, on 304; originally published in (Copenhagen, 1971). Kuhn and Heilborn (ref. 8), session 2, 19 Jul 1963, 5–6.
17. Ibid., session 1, 10–11, session 2, 13–14.
approaches and strengths harmoniously and efficiently complemented each other. It was a collaboration that was to have great significance for both of them. Bohr admired Rosenfeld’s clear thinking, capacity to formulate ideas, wide knowledge, and quick ability to master new problems. He was probably also encouraged by Rosenfeld’s enthusiasm for his ideas.

During the 1930s, at the same time that Rosenfeld joined the group of physicists around Bohr in Copenhagen who represented the orthodox interpretation of the quantum mechanical formalism, Rosenfeld’s Marxist worldview matured. His Marxist views were mainly expressed and developed in historical publications during this period, and historical studies were also a way he came to grips with the paradoxes of quantum physics. Studying the historical genesis of the theory enabled him to understand it better. In other words, he used history in this way as a genetic epistemology.

Rosenfeld never adhered to any form of Lebensphilosophie, Spenglerism, or vitalism, which prevailed in Weimar Germany prior to his arrival there, and was therefore not seduced to embrace an acausal and probabilistic quantum theory by a propensity to mysticism or idealism.

During the difficult times of World War II, Rosenfeld held the chair of theoretical physics at the University of Utrecht in the Netherlands. Not surprisingly, this was a time when Rosenfeld’s political engagement seems to have been set aflame, and immediately after the war he expressed his political views widely in articles and letters to the editor in Dutch, Belgian, and British leftist newspapers and periodicals. He also played an active part in various leftwing organizations such as the World Federation of Scientific Workers and the Dutch Verbond van

18. Aage Bohr (ref. 6); Møller (ref. 6), 3; Jørgen Kalckar “Niels Bohr and his youngest disciples,” Niels Bohr: His life and work as seen by his friends and colleagues (Amsterdam, 1967), 227–239, on 230; originally published in Danish: Niels Bohr: Hans liv og virke fortalt af en kreds af venner og medarbejdere (Copenhagen, 1964).
Wetenschappelyke Onderzoekers (Federation of Scientific Researchers). In 1947, Rosenfeld obtained a position in Manchester as Director of the Department of Theoretical Physics, where he stayed until he was offered a position at the newly founded Nordic Institute for Theoretical Atomic Physics (NORDITA) in Copenhagen in 1958. He remained in Copenhagen until his death in 1974.

There are many testimonies to Rosenfeld’s kind and timid personality, but he could be rather blunt and highly satirical in his book reviews and polemical papers, not to mention private correspondence aimed at opponents of complementarity.22 His friend, the chemist Ilya Prigogine, who collaborated with Rosenfeld in later years, found it an “extraordinary spectacle” to see such convinced engagement in this otherwise modest and timid man. He referred to Rosenfeld as the “paper tiger.”23

The nature of Rosenfeld’s Marxism

To understand why Rosenfeld disagreed with many other Marxist scientists and philosophers about the interpretation of quantum mechanics, it is important to take a closer look at how he used the Marxist canon. The Marxist texts relied on by individual Marxist scientists were often the same. However, deep discrepancies existed between different, more or less literal, interpretations and their relation to other philosophical positions, not to mention the uses of Marxist doctrine to analyze the lessons of modern physics.24

A draft of a reply of February 20, 1957 from Rosenfeld to a Dr. Koefoed, concerning where to read about dialectical materialism, gives information on Rosenfeld’s reliance on Marxist texts.25 Rosenfeld suggested that Koefoed read Engels’ publications “in which the main points are set up as clearly as possible.”26 These included the pamphlet “Ludwig Feuerbach und der Ausgang der klassischen Philosophie,” which Rosenfeld said was “a pregnant characterization of the attitudes of mind called materialism and idealism and of what is meant by the dialectical and metaphysical way of looking at things.”27 Next came Herrn Eugen Dührings

23. Prigogine (ref. 6), 845.
25. It may have been Otto Kofoed-Hansen who was professor of physics at the Danish Risø National Laboratory erected in 1956–58; Henry Nielsen, Keld Nielsen, Flemming Petersen, and Hans Siggaard Jensen, Til samfundets tarv—Forskningscenter Risøs historie (Roskilde, 1998).
27. Ibid.
an example of the application of the dialectical method to history, one of the most instructive is “Der deutsche Bauernkrieg” because the historical situation analyzed in that little book is a very complex one. You may wonder perhaps why I do not mention any book by Marx: this is only because Marx concentrated more on economics and politics, and left to Engels the task of dealing with the philosophical and other aspects.

What is striking is that Rosenfeld did not mention Vladimir I. Lenin’s notorious book, Materialism and empirio-criticism, originally published in Russian in 1908 and translated into English and German in 1927. Alongside Engels’ Anti-Dühring and Dialektik der Natur, published posthumously in 1925, Lenin’s book was the most influential publication in the early years of the Soviet Union as well as among most Marxist scientists and intellectuals in the West. In 1953, Rosenfeld characterized Lenin’s book in the following way: “Lenin, while no doubt intending to follow Engels, in effect advocated mechanistic materialism, with its metaphysical conception of determinism.” Rosenfeld blamed this book and Joseph Stalin’s pamphlet Über dialektischen und historischen Materialismus (1938), which Rosenfeld simply dismissed as “Stalinist rubbish,” for the “prevailing muddle between mechanistic and scientific materialism” in the 1950s, which resulted in severe criticism of the Copenhagen Interpretation in this period (see below).

Rosenfeld subscribed to the criticism of Lenin’s thought conveyed by his Dutch friend, the “very distinguished astronomer” and “socialist militant of the old guard”

28. Ibid.
29. Ibid.
30. Josephson (ref. 24), 204, 226, 249–250. Loren Graham, Science, philosophy, and human behavior in the Soviet Union (New York, 1987), 25–26, 34–35. Lenin’s book has its own complex Russian context connected with the political tumult prior to the Bolsheviks coming to power. However, the doctrines and positions upheld in the book, most notably against Ernst Mach, were taken at face value by Lenin’s later followers, not seen in this historical context. See Joravsky (ref. 24). Rosenfeld’s use of the word “metaphysical” refers to Engels’s meaning of it, i.e., the opposite of dynamical or dialectical.
31. Rosenfeld, “Strife about complementarity,” SP (1979), 465–483, on 482; originally published in Science progress, 163 (1953), 393–410. It is unclear if Rosenfeld was aware of the debates about dialectical materialism taking place in the Soviet Union at the time the book appeared, but his remark echoes some of the views about Lenin’s position presented at that time. See Joravsky (ref. 24). Rosenfeld’s use of the word “metaphysical” refers to Engels’s meaning of it, i.e., the opposite of dynamical or dialectical.
32. Draft of letter from Rosenfeld to Born, 10 Apr 1957, RP, “Correspondance particulière.”
33. Ibid.
Anton Pannekoek.\textsuperscript{34} Pannekoek’s and Rosenfeld’s philosophical disagreements with Lenin concerned the form of materialism that Lenin advocated and his position against Ernst Mach in \textit{Materialism and empirio-criticism}. To Rosenfeld and Pannekoek, Lenin’s materialism was not properly dialectical, but mechanistic or bourgeois, akin to the naive and reductionist mechanical materialism of the middle class of the 19th century. Lenin’s book was a reaction in part to the attempt by some Russian Marxists, such as Alexander A. Bogdanov, to combine Marxism with Mach’s empirio-criticism.\textsuperscript{35} Mach held that we can only achieve knowledge about matter by means of sense impressions, i.e., we cannot have any knowledge about the \textit{objective} existence of matter. Lenin, on the other hand, claimed that it was possible through sense experience and the intellectual activities derived from it to obtain \textit{absolute} knowledge of physical reality, which he identified with physical matter. Rosenfeld agreed with Mach to the extent that we only know reality through our senses; scientific epistemology is grounded in and determined by the material, empirical world. Nature, or the surrounding world, is for the scientist the objectively given reality, which he observes and affects him through his senses.\textsuperscript{36}

For Pannekoek and Rosenfeld, the concept of physical matter did not suffice to explain the experienced world, and concepts like mind and consciousness were needed, too. In accordance with his interpretation of Engels’ materialism, Rosenfeld conceived of mind as the receiver of sense perceptions of the active surrounding world. Mind, therefore, somehow both perceives and reflects reality. He understood materialism to mean that “thought [is] a product of the development of the organic being gradually adapting itself to experience.”\textsuperscript{37} The creation of ideas and concepts was in this sense in itself a dialectical process.

On the basis of Rosenfeld’s rejection of Lenin’s and Stalin’s interpretations, we may infer that he would also reject the Soviet political system, but he never seems to have criticized it explicitly in print. Indeed, although nothing suggests that Rosenfeld was ever a communist,\textsuperscript{38} apparently he did not automatically dismiss communism; in 1952 he still expressed hope that “the new movement in Russia, Poland, and Hungary is an intellectual revolution, which will overcome

\textsuperscript{34} Anton Pannekoek, \textit{Lenin as philosopher} (1st edn. [1938], London, 1974); Rosenfeld to Pauli, 6 Apr 1952, \textit{PSC}, 1 (1950–52), 598–600, on 599; Rosenfeld to Stephen G. Brush, 7 Oct 1966, RP, “History of science: XIXe siècle.”

\textsuperscript{35} Vladimir I. Lenin, \textit{Materialism and empirio-criticism: Critical comments on a reactionary philosophy} (Moscow, 1970).

\textsuperscript{36} Rosenfeld, “The epistemological conflict between Einstein and Bohr,” \textit{SP}, 517–521, on 518. This paper is more or less the same as “Professor Einstein’s dilemma,” \textit{The listener}, 44 (1950), 823; published in French in \textit{Revue de métaphysique et de morale}, 67 (1962), 147–151, and subsequently in Russian, German, and English. Rosenfeld, “Berkeley redivivus,” a review of Werner Heisenberg’s \textit{Natural law and the structure of matter}, in \textit{SP}, 686–687; originally published in \textit{Nature}, 228:5270 (1970), 479; Pannekoek (ref. 34), 35–36.

\textsuperscript{37} Rosenfeld to Pauli (ref. 34), 599.

\textsuperscript{38} According to his children, he was not. Anja Skaar Jacobsen, e-mail with Jean Rosenfeld (Rosenfeld’s son), 12 Jan 2005.
the dogmatism.” Even though Rosenfeld never, to my knowledge, professed Trotskyite allegiances, it makes sense to denote him so, as Pauli suggested in his equation “Rosenfeld = √Trotsky × Bohr,” inasmuch as Rosenfeld’s Marxist position amounted to a strong rejection of Lenin as a Marxist philosopher and a return to classical Marxism—that is, the body of thought developed by Marx, Engels, and their contemporaries.

Rosenfeld was in contact with Marxist and leftist peers in Western as well as in Eastern Europe, Russia, the United States, and South America, notably the influential British science journalist James Gerald Crowther, the British physicist Patrick M.S. Blackett, and the East German physicist Martin Strauss. He was well acquainted with the physicists John D. Bernal and Frédéric Joliot-Curie through their joint work in the World Federation of Scientific Workers after World War II, among other things. With Bernal, however, Rosenfeld entered into a dispute in 1956 about Bernal’s book *Science in history* (1954). The dispute concerned Marxism, historical materialism, and, to a certain extent, Bohr’s interpretation of quantum mechanics. Rosenfeld’s friendship with some of the Russian physicists, primarily Igor E. Tamm, seems to stem from his stay in Göttingen in 1928. A few letters were exchanged between Rosenfeld and Vladimir A. Fock in 1956 and 1959/60.

2. COMPLEMENTARITY AND DIALECTICAL MATERIALISM

Bohr introduced his complementarity argument in his Como lecture in 1927 in order to overcome the “inevitable dilemma” faced when attempting to express experimental evidence in quantum physics by means of classical concepts. Complementarity accounts for the relation between two mutually exclusive aspects of the same quantum reality, both of which express important sides of the phenomenon

in question. The example highlighted by Bohr in this paper is the functional representation or “definition” of a quantum state which then means “the elimination of all external disturbances” on the one hand, and “observation,” on the other hand, which will then require that “we permit certain interactions with suitable agencies of measurement, not belonging to the system.” Another example of complementary sets is the wave and particle descriptions of a quantum system. In the following years, Bohr attempted to clarify his thoughts on complementarity, extend it to the complicated case of relativistic quantum mechanics (with Rosenfeld), and provide more popular accounts of it while drawing broad analogies to complementary aspects in general philosophy, psychology, and biology.\(^{45}\)

As for dialectical materialism as a natural philosophy, it comprises both metaphysical and epistemological principles. Rosenfeld considered dialectical materialism to be a theory of social as well as scientific change. In his historical publications he provided examples of what he saw as the dialectical development of physics, and in papers and correspondence he discussed the dialectical development of society.\(^{46}\) He denied the possibility of ever capturing dialectical materialism or complementarity, which he saw as synonyms, in strict definitions:\(^{47}\)

> [I]t must be realised that it is impossible in principle to write a text-book about dialectics, since this would be to fix a mode of thought which is essentially flowing. It is exactly the same with complementarity (which is the modern form of dialectics): you cannot give a “definition” of it, but only understand what it is by re-thinking for yourself the typical cases in which it occurs.


Thus, to Rosenfeld, complementarity was simply another expression of a dialectical relation. Accordingly, Bohr’s idea of mutually exclusive aspects was turned into “contradictive,” or “antagonistic,” aspects in Rosenfeld’s terms. In quantum mechanics, complementarity was the dialectical synthesis of the contradictory wave and particle aspects of light and matter, for instance, the totality is neither the former picture nor the latter, but the synthesis of both. In this way, nature on the atomic level displayed dialectical behavior and therefore required a dialectical description, and that, according to Rosenfeld, defines complementarity.

Another lesson to be drawn from quantum mechanics, in Rosenfeld’s view, which harmonized well with his interpretation of dialectical materialism, and was in sharp contrast to mechanistic materialism was that:

> analysis of the conditions of rational description of the phenomena has consequences which go far beyond the realm of physics, they affect our whole attitude toward the function of science. We now recognize that the task of science is not to picture the world as a spectacle watched “from outside,” . . . but rather to give us the means of communicating, in a rational and objective way, the experience derived from our interaction with the world around us, of which we ourselves are a part. It is clear that this relationship between the material universe and the human mind transcends the antiquated opposition of materialism and idealism, but could rather be described as a synthesis of these mutually exclusive points of view, in the sense of complementarity.

Thus the material world and human consciousness were intimately connected. In this connection, Rosenfeld often insisted that complementarity is “forced upon us by the laws of nature and the peculiar relationship in which we . . . stand to the world of atoms.” Therefore, complementarity was not only an inherent part of quantum theory, it was also materialistic, because “[i]t arises from an effort to adapt our ideas to a novel experimental situation in the realm of atomic physics.” This was, according to him, in complete correspondence with Engels’s idea of materialism.

49. Rosenfeld, “The conception of the meson field. Some reminiscences and epistemological comments,” SP, 327–334, on 330; originally published in Progress of theoretical physics supplement, 41 (1968), C1–C7, 330. See also Rosenfeld to Pauli (ref. 34), in which Rosenfeld maintains that the dialectical relation between idealism and materialism is not symmetric, but that a materialistic standpoint is more favorable from his point of view.
It should be noted that other adherents of complementarity, such as Max Born, disagreed with Rosenfeld as to whether complementarity was simply derived from experience. In general, according to Born, it was naive to think that metaphysical speculations did not play a role in theory formation on the basis of experience. Heisenberg, too, expressed the epistemological consequences of quantum theory somewhat differently from Rosenfeld. According to Heisenberg:

The atomic physicist has had to resign himself to the fact that his science is but a link in the infinite chain of man’s argument with nature, and that it cannot simply speak of nature “in itself”. . . . As Bohr has said, we must become conscious of the fact that we are not merely observers but also actors on the stage of life.

With this much Rosenfeld could agree. However, to Heisenberg the above implied that

the natural laws formulated mathematically in quantum theory no longer deal with the elementary particles themselves but with our knowledge about them. Nor is it any longer possible to ask whether or not these particles exist in space and time objectively, since the only processes we can refer to as taking place are those which represent the interplay of particles with some other physical system, e.g., a measuring instrument. Thus, the objective reality of the elementary particles has been strangely dispersed, not into the fog of some new ill-defined or still unexplained conception of reality, but into the transparent clarity of a mathematics that no longer describes the behavior of the elementary particles but only our knowledge of this behavior.

Heisenberg’s position thus appeared to be idealistic not only with regard to epistemology but even with respect to ontology, and he held that ideas originated in mathematics, not in “objective reality,” and not in the material world. Rosenfeld strongly disagreed with Heisenberg’s idealism as presented here and would stress that “mathematical concepts are also human inventions and accordingly bear the mark of their material origin.” As for objective reality, Rosenfeld would vexatiously burst out at Marxist colleagues who accused him of positivism that “of course there are atoms . . . it is impossible to understand it [quantum mechanics] without assuming that there is an external world which is independent of what we think and which is the ultimate origin of all our ideas.”

Bohr may have cast doubt on our theories’ ability to capture the whole reality, but not that the entities we are trying to describe exist.

52. Born to Rosenfeld, 21 and 28 Jan 1953, RP, “Correspondance particulière.”
54. Ibid., 15.
55. Rosenfeld, “Berkeley redivivus” (ref. 36), 687.
The dialectical development of physics

Complementarity was not only a dialectical description of atomic phenomena; according to Rosenfeld, it was also the result of a progressive dialectical development of quantum theory. In other words, the historical development of quantum physics was dialectical. The old quantum theory was dominated by contradictory experiences and explanations, but this was a driving force in the continuous development of the theory up to a certain point when the development entered a phase of “negation.” This negation consisted of recognizing a limit to the validity of classical determinism. The crisis brought about by this negation was solved (the negation of the negation) with the construction of quantum mechanics and its interpretation in terms of complementarity. Thus the solution of the crisis, the emergence of quantum mechanics, was a synthesis in which all previous antagonisms disappeared and a new harmony was created. As for subsequent developments after this synthesis, Rosenfeld boldly prophesied in 1942:

But on this score, what must we think of the fate in store for today’s triumphant synthesis? Will not the moment arrive when complementarity, still taught to young students as one of the clear foundations of human reason, will be called “prejudiced” by the theorists of that day...? Assuredly it would deny all the lessons which we have attempted to draw from the past development of science suddenly to claim that complementarity has been established as a dogma never to be surpassed. Quite to the contrary, if there is a sure prognosis which can be drawn from the lessons of history, it is that other renewals of our conception of the relationships among the various aspects of phenomena must be expected, not, certainly, in the sense of a return to classical causality, but rather in establishing new complementary relationships.

The prophecy that complementarity would be questioned and termed dogmatic and that a return to classical causality would be attempted anew were to come true in the following years, probably more vigorously than Rosenfeld had imagined. When this happened, Rosenfeld, more than anyone else, was prepared to defend complementarity.

Bohr as a dialectical materialist

In close connection with his historiographical view of the dialectical development of quantum theory, Rosenfeld considered Niels Bohr a prime example of a dialectical thinker. According to Rosenfeld, Bohr was eminently skilled in solving

57. Rosenfeld, “Strife” (ref. 31), 466–471.
58. Rosenfeld, “The evolution of the idea of causality” (ref. 46), 459.
59. Rosenfeld, “Niels Bohr in the thirties: Consolidation and extension of the conception of complementarity,” in Niels Bohr: His life and work as seen by his friends and colleagues (Amsterdam, 1967), 114–136, on 116–118; originally published in Danish (Copenhagen, 1964); Rosenfeld, “Niels Bohr. Naar aanleiding van zijn 60e verjaardag,” De Vrije Katheder, 5:28 (Oct 1945); Rosenfeld, “Strife” (ref. 31), 481.
contemporary crises and conflicts in physics by integrating new contradictory aspects into a rational synthesis, thereby achieving order and coherence. Bohr displayed this skill, for instance, in developing his quantum theory of atomic structure, published in 1913, as a solution to the acute dilemma brought about by Ernest Rutherford’s atomic model. Classical physics could not account for the stability of such atoms since it predicted that electrons emit electromagnetic radiation, with the result that they should fall into the nucleus. This contradiction between experience of stable atoms and the available theory made Bohr introduce his quantum description of atomic structure and hence overcome or supersede the contradiction between experience and theory. Another example of Bohr’s dialectical approach, according to Rosenfeld, was his introduction of complementarity as a new form of causal description of the contradictory wave and particle properties of matter and light.

As a dialectical thinker, according to Rosenfeld, Bohr was capable of approaching such crises in physics, not seeking to avoid the contradictory elements, but to synthesize them into a broader understanding. Erwin Schrödinger is said to have remarked of Bohr that he “wanted to complement away all the difficulties” faced by the physicists in the midst of the quantum crisis. To Schrödinger’s regret, Bohr would not accept the premises of the old way of thinking in classical mechanics. Instead, Bohr broke with preconceived ways of thinking and ended up solving the problem by introducing a new way of thinking. Schrödinger viewed this step as avoiding the problem and failing to solve it within the given theoretical framework. By contrast, Rosenfeld saw Schrödinger’s approach as an attempt to solve the problem by “conjuring it away,” since Schrödinger wanted to reduce quantum reality to the wave aspect only. From a dialectical point of view, Schrödinger was simply stuck in an old-fashioned, rigid way of thinking, not being open-minded towards new experience and new ways of thinking as would a true dialectical thinker. As Rosenfeld would phrase it, Schrödinger was “fossilized in metaphysical dogmas.”

Sometimes Rosenfeld denied that Bohr could be termed a materialist. However, more often he argued that Bohr was a materialist simply because Bohr’s

60. Rosenfeld, “Introduction” to Niels Bohr, On the constitution of atoms and molecules (Copenhagen, 1963), xi–liv, on xlii; Rosenfeld, “The velocity of light and the evolution of electrodynamics,” SP, 134–177, on 136; originally published in Nuovo cimento, 4, suppl. (1956), 1630–1669; Rosenfeld, “The evolution of the idea of causality” (ref. 46), 456.


63. Draft of letter from Rosenfeld to Adolf Grunbaum, 21 May 1957, RP, “Correspondance générale 1955–58” in “Epistemology.” Kuhn and Heilbron (ref. 8), session 3, 6. See also draft of letter from Rosenfeld to Bohm, 6 Dec 1966: “I certainly have never played the
ideas and concepts were “the result of a process of gradual adaptation of mind to experience; ideas are not at the origin, but at the end of this process,” contrary to what is the case in idealism.\textsuperscript{64} Bohr’s thought took its starting point in experimental experience. On this basis Rosenfeld said that Bohr was a Marxist, albeit unconsciously.\textsuperscript{65} Rosenfeld thus believed that dialectical materialism and therefore also what he considered the modern version of it, complementarity, was a \textit{scientific method}.\textsuperscript{66} In his view, the finest exponent of it was Bohr himself.

Other than Rosenfeld, only a small number of Marxist physicists held that complementarity was compatible with Marxist philosophy, most notably the Soviet physicist Vladimir A. Fock.\textsuperscript{67} Fock came to believe, and apparently independently of Rosenfeld, that Bohr was a dialectician, and found correspondence between dialectics and complementarity.\textsuperscript{68} However, this still left Rosenfeld’s views on dialectical materialism and complementarity rather marginal among Marxist physicists.

3. QUANTUM MECHANICS BETWEEN IDEALISM AND MATERIALISM

Like other Marxists, Rosenfeld saw in the history of science and in contemporary science an ongoing struggle between the materialist and idealist camps.\textsuperscript{69} He was strongly committed to refuting idealistic viewpoints in science. In his inaugural lecture of 1942 in Utrecht, he expressed particular concern about the “error of those who believe that they have found in complementarity the penetration of irrational or extra-rational tendencies into the very citadel of determinism.”\textsuperscript{70} Here Rosenfeld may very well have hinted at Pascual Jordan’s writings about complementarity and parapsychology from the 1930s.\textsuperscript{71}

\begin{thebibliography}{99}
\bibitem{65} Rosenfeld, “Strife” (ref. 31), 473; Rosenfeld, “The epistemological conflict” (ref. 36), 521; Rosenfeld to Pauli (ref. 34), 598–599.
\bibitem{66} Kuhn and Heilbron (ref. 8), session 3, 11.
\bibitem{67} V.A. Fock, “Quantum mechanics and dialectical materialism: Comments,” \textit{Slavic review}, 25:3 (Sep 1966), 411–413, on 412.
\bibitem{68} Fock also held views similar to Rosenfeld’s on the distinction between dialectical and mechanistic materialism. Fock (ref. 67).
\bibitem{69} See, for example, Rosenfeld, “Berkeley redivivus” (ref. 36).
\bibitem{70} Rosenfeld, “The evolution of the idea of causality” (ref. 46), 461.
\bibitem{71} Heilbron (ref. 2), 226–227.
\end{thebibliography}
After the war, Rosenfeld continued to be concerned about idealistic inferences from quantum mechanics. For example, in 1947, in a letter to Bohr he expressed the view that “the situation in the quantum theory is still being abused by all kinds of ‘idealists,’ who after all hated science and only sought to misguide people in a mist of ‘mysticism.’”\(^2\) Rosenfeld complained about a tendency to idealism among the students, which he thought originated from a “holy” and “reactionary” atmosphere in Dutch society following the war. The most famous example of the mixing of the lessons of quantum theory with theology appeared in the popular writings on contemporary physics by the astrophysicists James Jeans, and Arthur Eddington, the latter a devout Quaker, in the late 1920s and 1930s. From a Marxist perspective, idealists left science weak by reducing it to just one means among many for seeking truth from the world. In this way they opened the door for mysticism and religious speculation to creep in where science did not yet have answers. According to the historian Matthew Stanley, Eddington’s and Jeans’s popular books had a tremendous impact on theologians and public opinion across the Western world in the 1920s and 1930s. Many influential theologians even called them essential reading.\(^3\) From Rosenfeld’s reaction, we may infer that this religious movement was still alive after the war. In May 1949, after having moved to Manchester, Rosenfeld again expressed his concern to Bohr about\(^4\) the different misunderstandings which appear when trying to blend complementarity and all kinds of mysticism (whether it concerns idealism a la Eddington and others or the Russian pseudo-Marxism). All these “isms” are probably too trivial for you, but I feel, after all, that one cannot any longer content oneself with ignoring all that nonsense. More than ever the spirit of science needs to be defended against attacks from all sides.

Rosenfeld seems not to have received a reply from Bohr, but as we shall see the parallel situation in Denmark was being followed at the Niels Bohr Institute. Rosenfeld also worried about renewed attacks on Bohr’s complementarity which had started to appear in Soviet intellectual journals. Indeed, after World War II an intense ideological campaign in Soviet scholarship was initiated by Stalin’s assistant in the Central Committee of the Party, Andrei A. Zhdanov. The campaign had wide implications for scientific work in the Soviet Union through a series of demands.

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72. Rosenfeld to Bohr, 1 Feb 1947, BSC.
74. Rosenfeld to Bohr, 31 May 1949, BSC. Rosenfeld discussed Jeans’ and Eddington’s views on many occasions in these years. See, for example, Rosenfeld to Johannes Martinus Burgers, Utrecht, 1 Feb 1947, Burgers’s papers in Internationaal Instituut voor Sociale Geschiedenis, Amsterdam.
on socialist scholarly work. In the following period, the Party steered the course of events and controlled journal editors and the like. Loren Graham refers to the period between 1948 and 1960 as “the age of the banishment of complementarity.” With respect to discussions of quantum mechanics in the Soviet Union, critics included, among others, the physicists and philosophers A.A. Maksimov, A.D. Aleksandrov, Ia.P. Terletskii, B.G. Kuznetsov, and D.I. Blokhintsev. It seems to have been in this postwar Russian scientific and philosophical milieu, in connection with the growing criticism of complementarity and proposals for new interpretations of quantum mechanics, that the term “Copenhagen Interpretation” began to gain ground.

What bothered these opponents of the Copenhagen Interpretation was its lack of causality, determinism, and realism. Many Marxist thinkers rejected the idea that we can get no immediate knowledge of the quantum system as such through the wave function, nor classical objective knowledge about the system during measurements, nor talk about the behavior of the system between measurements. These were regarded by Marxist physicists as idealistic features of the interpretation, because taken to their extreme they would imply that the quantum world, and thus matter, was dependent on our apprehension of it. Complementarity was rejected because it suggested an epistemology depending on experimental context. It was therefore viewed as a subjective principle, not material and realist. These Marxists further suggested that Bohr could not have been led to complementarity empirically, and that it was therefore an a priori doctrine. Finally, they strongly criticized Bohr’s proposals to introduce complementarity as an explanatory principle in psychology, biology, and sociology, in that way turning it into a universal principle. This they viewed as positivism and a violation of the antireductionism of dialectical materialism. Therefore the Copenhagen Interpretation was termed idealistic, bourgeois science, and Bohr an idealist.

Beginning in the late 1940s, criticism of Bohr and Heisenberg’s ideas from a communist perspective also reached the Danish press. Zhdanov’s Party-ideological program from June 1948, in which the role of Soviet philosophy in the sciences was consolidated, was immediately reproduced in the Danish Marxist journal Tiden: Tidsskrift for aktivt Demokrati (Time: Journal for active democracy).

75. For the equally heated philosophical discussions about modern physics that took place in the 1920s and 1930s in the Soviet Union, see Josephson (ref. 24); Joravsky (ref. 24); Andrew Cross, “The crisis in physics: Dialectical materialism and quantum theory,” Social studies of science, 21 (1991), 735–759.
76. The political “games” in which scholars were enrolled in the postwar milieu is described in Alexei B. Kojevnikov, Stalin’s great science: The times and adventures of Soviet physicists (London, 2004), 188–207.
77. Graham (ref. 30), 328.
78. Ibid., 329–343; Cross (ref. 75).
79. Chevalley (ref. 1), 62–63.
So were excerpts from an extremely radical speech by the Russian philosopher, A.A. Maksimov in January 1949, promoting anew Lenin’s book *Materialism and empirio-criticism* and its significance for the sciences.\(^{82}\) In this paper, Bohr’s and Heisenberg’s ideas were called “idealistic figments of the imagination,” among other things, and it was asserted that all Soviet scientists were obligated to fight such idealistic viewpoints.\(^{83}\) Maksimov’s paper seems to have initiated a dispute in the Danish press about dialectical materialism and the new physics. Shortly afterward, the young communist physicist, Ib Nørlund (the nephew of Margrethe Bohr, Niels Bohr’s wife) reiterated Maksimov’s viewpoints.\(^{84}\) The situation was discussed and followed closely at the Niels Bohr Institute, particularly by the young physicist and historian of science Mogens Pihl, later professor of physics at Copenhagen University, who soon got involved in the dispute with Nørlund.

Pihl had been in Cambridge in 1947/8 on a fellowship to study history of science, and in this connection he had close contact with Rosenfeld in Manchester. Rosenfeld intimately knew the British history of science milieu.\(^{85}\) A few months after Nørlund’s first paper had appeared in the journal *Tiden*, Pihl reported to Rosenfeld\(^{86}\)

> By the way, Danish public opinion is crazy about the concept of complementarity and while twenty years ago people said that “everything is relative,” the slogan is now: “everything is complementary.” There is a great need for a decent account in a popular form, which can contribute to put things in perspective. The nonsense comes partly from the side of orthodox communists and partly from the side of clergymen and fellow travellers.

The reference to “clergymen and fellow travellers” suggests that the development alluded to above in theological circles also took place in Denmark. Indeed, in Denmark, theologians studied Bohr’s own writings and discussed the possibility of extending theology with complementarity, among other things.\(^{87}\)

In the following years, the dispute between Nørlund, his supporters, and his opponents, gained momentum in the Danish press. Pihl attempted to reason with


\(^{83}\) Ibid., 265–266.


\(^{85}\) Pihl to Rosenfeld, 6 Oct 1948, RP, “History of science 1: (1948–51) (Manchester).” However, their viewpoints differed considerably; Pihl was a strong opponent of dialectical materialism as employed in both science and history of science. Jacobsen (ref. 19).

\(^{86}\) Pihl to Rosenfeld, 18 Dec 1949, RP, “History of science 1: (1948–51) (Manchester).”

Nørlund at a meeting in the students’ association, on the airwaves, and later in print in the Marxist intellectual journal *Dialog*. Nørlund apparently refused to budge.88 Rosenfeld was not involved in this local dispute in Denmark in the early 1950s, however, he learned about it indirectly from Pihl, and it may well have aroused his concern about the public conception of complementarity.

Apart from what Max Jammer has pointed to as “social-cultural movements and political factors such as the growing interest in Marxist ideology in the West,” which made room for renewed criticism of Bohr’s ideas and even attempts at other interpretations, an important factor was also the appearance of a younger generation of physicists who felt encouraged to reopen the interpretive discussions about quantum mechanics.89 Jammer has suggested that the famous volume by Paul A. Schilpp, published in 1949 to celebrate Einstein’s seventieth birthday, which included a review by Bohr of the Bohr-Einstein debate as well as Einstein’s reply, may have played an important role here.90 Another publication which might have contributed was the special issue of the periodical *Dialectica* in 1948, edited by Pauli and devoted to the discussion of the idea of complementarity, to which Bohr, Einstein, Heisenberg, and de Broglie, among others, contributed.91

Several new ideas about the interpretation of quantum mechanics were published in the next decades by the younger generation of physicists, not necessarily Marxists, who had begun to wonder whether the description of quantum phenomena could be different from that established by Bohr and Co., i.e., whether a theoretical account could be found that corresponded more closely with classical scientific virtues. The best known alternative interpretation was put forward by a young American physicist, David Bohm, in 1952.92 Bohm was a Marxist, which, along

88. Nørlund, “Videnskab i krise. Om “komplementaritetsteorierne” i den moderne fysik—og andre steder,” Dialog, 4:1 (Feb 1954), 13–27. This particular number of *Dialog* with Nørlund’s contribution soon sold out completely. Pihl, “Om den dialektiske materialisme,” Dialog, 5:1 (1955), 19–27, on 19. In 1992 Bohr’s assistant since World War II, Stefan Rozental, jotted down some comments about the dispute. Rozental, manuscript, 3 pp. (1992), Rozental Papers, NBA. To Rozental’s regret, no consensus was reached between Pihl and Nørlund. In this connection Rozental mentioned the Soviet physicist Fock as a Marxist scientist who combined dialectical materialism with Bohr’s views. It is quite strange that Rozental did not mention the views of his close friend Rosenfeld. After all, Rozental had written the introduction to Rosenfeld’s *Selected papers*, which was published in 1979 and in which Rozental briefly dealt with Rosenfeld’s Marxist views. Thus he must have known Rosenfeld’s viewpoints quite well.
90. Ibid., 250; Paul A. Schilpp, ed., *Albert Einstein: Philosopher-scientist* (Evanston, IL, 1949).
with his teaching and authorship of a textbook on quantum mechanics and his reading of papers critical of Bohr’s views by the Russian physicists D.I. Blokhintsev or Terletskii, seem to have motivated him in constructing a new hidden variables interpretation.\textsuperscript{93} The aim of Bohm’s interpretation was to reintroduce classical causality and determinism into the description of quantum phenomena and suggest a “more complete” description dealing with a deeper level of reality than did the Copenhagen Interpretation. In order to achieve this goal he introduced so-called hidden parameters. Bohm’s ideas did not find many adherents, but his theory or interpretation was celebrated by a small group of physicists in France, including Louis de Broglie, Jean-Pierre Vigier, and Evry Léon Schatzman. De Broglie, who had been interested in similar hidden variables ideas earlier in the century, took up this approach again after Bohm’s work. The fact that Bohm was a Marxist was to some extent significant both in determining who supported his approach and where he expected support.\textsuperscript{94} With the notable exception of de Broglie, the group around him and Vigier in France were strongly motivated in their work on the causal program by Marxist thought.\textsuperscript{95}

Rosenfeld expressed great annoyance with the new attempts to find other descriptions of quantum phenomena; for one thing, these new approaches were not grounded in new empirical findings.\textsuperscript{96} But Rosenfeld was also deeply distressed because the younger generation did not turn to the original sources when studying these issues. In particular, he found that they did not understand Bohr’s ideas properly. As for Marxist criticisms, as mentioned above, Rosenfeld blamed the renewed interest in Lenin’s old book \textit{Materialism and empirio-criticism} and Stalinism for the “prevailing muddle between mechanistic and scientific materialism,” which to Rosenfeld constituted the heart of the matter in Marxist opponents’ criticism of the Copenhagen Interpretation. Thus he found troubling that what he saw as idealist approaches in quantum physics, such as Schrödinger’s, would also find support among Soviet physicists such as Iakov Frenkel and Blokhintsev, “who profess to derive their inspiration from a ‘materialistic’ philosophy.” According to Rosenfeld, Frenkel was not a dialectical materialist in Engels’s sense, but advocated Lenin’s mechanistic, deterministic, and reductionistic materialism.\textsuperscript{97}

\textsuperscript{95} Ibid.
\textsuperscript{96} Rosenfeld, “Complementarity” (ref. 40), 486.
\textsuperscript{97} Rosenfeld, “Strife” (ref. 31), 465–483, on 473, 482 note 1; Rosenfeld, “Complementarity” (ref. 40), 493.
4. “STRIFE ABOUT COMPLEMENTARITY”

Rosenfeld’s concern and annoyance soon resulted in his taking up the fight against all disbelievers of complementarity, whether Soviet or Western Marxist physicists or just supporters of the causal program with no Marxist agenda. It was a fight in which he used all possible means, including polemical papers, book reviews, and personal connections. In addition, he served as consultant or referee in matters of epistemology of physics and the like at several well-reputed publishing houses and at the influential journal Nature. In this capacity he used his influence effectively, and several books and papers, among them some by Frenkel, Bohm, and de Broglie, were rejected on this account.

Rosenfeld’s most important polemical paper was his contribution to a festschrift for de Broglie’s sixtieth birthday in 1952, which he deemed an appropriate occasion to set some things straight. In this paper, referring to de Broglie and Bohm, Rosenfeld sarcastically remarked, “[I]t is understandable that the pioneer who advances in an unknown territory does not find the best way at the outset; it is less understandable that a tourist loses his way again after this territory has been drawn and mapped in the twentieth century.”

Bohm responded to Rosenfeld that the term “tourist” could just as well be applied to Rosenfeld; Bohr would then be the pioneer who did “not find the best way at the outset.” Thus, according to Bohm, it “worked both ways.” In fact, the double meaning of the word “tourist” in relation to Bohm, who was by then in more or less enforced exile in Brazil because of McCarthyism in the United States, was resented by the Brazilian physicist Guido Beck, among others. Rosenfeld apparently acknowledged the point and as a result, this paragraph of the paper was left out in its English translation, “Strife about complementarity.”

Being a Marxist himself and believing that complementarity was synonymous with dialectics, Rosenfeld could not accept the ideological rationale for the criticism of this interpretation. Committed as he was to fighting idealistic viewpoints in


science, he strongly objected when Bohr and complementarity were placed under this heading.\textsuperscript{103} True, the Copenhagen Interpretation meant rejection of determinism and causality, but Rosenfeld accepted the loss of determinism and still found it complied with Engels’s materialism. As for causality, Rosenfeld referred to the historical development of this concept from ancient Greek science to the present. He argued that the principle of causality had to be adapted to new experimental experience, and this was done by introducing complementarity as the new form of causality reigning in the quantum mechanical realm. He argued that causality had been adapted before the changing conditions of experience, for example when Galileo Galilei formulated the principle of mechanical inertia in opposition to the Aristotelian conception of the cause of motion or when Isaac Newton formulated his law of gravitation in contradiction to the prevalent mechanical conception of causality, according to which actions between bodies were transmitted by contact.\textsuperscript{104} Rosenfeld argued that every time causality had undergone such an adaptation, long-lasting dispute had followed. Therefore it was only natural that a crisis arose following the renunciation of classical causality and determinism in quantum physics.\textsuperscript{105}

With the usual scathing irony and sarcasm that pervades the correspondence between Rosenfeld and Pauli, Rosenfeld wrote to the latter in 1952 about the group of young French physicists around Jean-Pierre Vigier, on the one hand, and de Broglie and one of his former philosophically minded students who advocated complementarity, Jean Louis Destouches, on the other:\textsuperscript{106}

Is it not delightful that poor Bohr’s only supporters in Paris should be this logical couple [de Broglie and Destouches], while all the youth is in arms against him “under the banner of Marxism”? Poor Marx too, I would add, since I belong, as you know, to the almost extinct species of genuine Marxists; the kind of theology dished up under this name today is just as repulsive to me as to you, perhaps even more so because I see it against the background of what Marx really meant.

Rosenfeld referred here to the influential Soviet journal of philosophy of science \textit{Pod znamenem marksizma (Under the banner of Marxism)}, in which discussions of the philosophy of quantum mechanics had taken place between 1922 and 1944, as the medium spreading false doctrines.\textsuperscript{107} Beneath the sarcasm, however, Rosenfeld expressed sincere concern about the development he witnessed: “We may well have a laugh at it between us . . . but I feel we have also a duty to help these people out

\textsuperscript{103} Rosenfeld to Bohr, 31 May 1949, BSC.
\textsuperscript{104} Rosenfeld, “The evolution of the idea of causality” (ref. 46), 446, 449–450.
\textsuperscript{105} Ibid., 459.
\textsuperscript{106} Rosenfeld counted de Broglie as pro-Bohr and complementarity on this occasion. De Broglie had abandoned his own theory of pilot waves from 1927 until the work by Bohm and Vigier prompted him to take up the idea again in 1952. Rosenfeld to Pauli, 20 Mar 1952, \textit{PSC}, Part 1, 587–588, on 588.
\textsuperscript{107} Graham (ref. 30), 326. Joravsky (ref. 24), 78–80.
of the bog if we can.” Rosenfeld knew Joliot-Curie quite well from his time in Paris and through their shared involvement in the World Federation of Scientific Workers. Joliot was a communist and Rosenfeld sought to make the most of this in addressing him:

I think it my duty to inform you of a situation which I consider quite serious and which is close to you. It concerns your “foals” Vigier, Schatzman, Vassails and the whole lot, all young intelligent people and all full of desire to do well. Unfortunately, at the moment, they are quite sick. They have gotten it into their heads that it is necessary persistently to shoot down complementarity and save determinism. The ill fortune is that they have not understood the problem and—what is even worse—that they have made no serious effort to understand it. I have done what I could to redeem them... I have taken pains to do an explicit Marxist analysis of the question and clearly show the simultaneously dialectical and materialistic character of complementarity. As the only response, Schatzman sent me a polemical writing full of incorrect physics and quotations from Stalin which he maintains, through a casuistry that frightens me, oppose physical evidence. This reveals a profound crisis among these young people and it is high time (if it is not already too late) to straighten them out. They are under the spell of a scholasticism which borrows the external forms of Marxism, but is as opposed to its genuine spirit as is the blackest Catholicism. The best Soviet physicists are subjected to attacks from this scholasticism, which creates even more havoc in Moscow than in Paris. Surely it would be desirable that the French physicists show themselves capable of distinguishing the wheat from the chaff. At the moment, these young fanatics are the laughing stock of the theoreticians and they discredit Marxism and the Party to the great joy of reactionaries such as Destouches and de Broglie. I am ready to give you all possible support to redress the situation, on the basis of the ideas explained in my paper. But it is up to you, my dear Joliot, to take the initiative.

Joliot-Curie appears not to have been much interested in the philosophical subtleties of quantum physics, but from his reply he seems to have agreed completely with Rosenfeld in his critique of those youngsters and on the need to take action.

Rosenfeld’s aggressive tone did not pass unnoticed, and he was probably asked more than once what he intended and expected to gain from his campaign. To this question, in connection with his review in Nature of Bohm’s book Causality and...
chance in modern nature (1957), Rosenfeld gave the following answer to the British industrial physicist and philosopher of science Lancelot Law Whyte:112

Why then . . . do I bother to write all these articles and reviews? I am not concerned with Bohm’s own salvation; he is past healing . . . all I actually wish to do is to sound a warning to the bewildered students, who don’t know what to make of it, and to interested outsiders, who—however clear-minded and critical—cannot reasonably be expected to be sufficiently familiar with the technicalities of the case to discover by themselves the utter emptiness of the claims of Bohmism. I realize that I may give the impression of being “intolerant” and “dogmatic,” in spite of the fact that I have been all these years advocating tolerance and free thinking . . . and waging a fight against the modern brand of dogmatism which represents the greatest threat to our scientific tradition, viz. pseudo-marxist theology.

Thus, his aim was threefold: first, he was concerned that physicists “of the younger generation . . . adopt the right attitude regarding the epistemological problems of quantum theory;”113 second, he aimed to communicate to lay people the difficult tenets of quantum philosophy, hoping to prevent them from being led astray by idealists or Stalinists; third, he wanted to put an end to what he saw as the false doctrine causing the stir, Stalinism in science.

In the end, Rosenfeld seems not to have succeeded in straightening up the communist physicists. In a letter to Martin Strauss in 1953, he complained, “Indeed, I have had animated discussions about this matter, first with the Paris group of communist physicists, then with the London group around Bernal, without succeeding at convincing them that the true dialectics is expressed through complementarity, and that determinism represents an outdated metaphysical idea.”114 If Rosenfeld had hoped to win support from Strauss, he must have been disappointed. Strauss instead expressed unambiguous support for Lenin and for Soviet physicists’ critique of Bohr and denoted Rosenfeld positivistic.115 In the correspondence between Bernal and Rosenfeld, the former considered the dialectics of complementarity formal and subjective, not materialistic, while Bohm denied to Rosenfeld that Bohr could be considered a materialist, although he might be a dialectician in a certain sense.116

As mentioned above, a couple of letters between Fock and Rosenfeld were exchanged in 1956, among which only Fock’s reply to Rosenfeld has been found. In this reply, Fock expressed his general agreement with Rosenfeld’s criticism of Blokhintsev as well as the blending of Bohr’s views with dialectical materialism,

112. Rosenfeld to Law Whyte (ref. 51).
114. Copy of letter from Rosenfeld to Strauss, 24 Apr 1953, NBA.
115. See draft of letter from Strauss to Rosenfeld, 5 May 1953, copy at NBA.
a viewpoint that Fock had reached independently of Rosenfeld. Still, Fock regretted Bohr’s positivistic vocabulary.\textsuperscript{117} This exchange, which may have been Rosenfeld’s attempt to reach the Soviet opponents of complementarity just as he had attempted to reach the French opponents through Joliot-Curie, took place about a year before Fock visited Bohr in Copenhagen. In February and March 1957, Fock and Bohr discussed the philosophical significance of quantum mechanics and the alleged positivistic language in Bohr’s papers. Fock and the historian Loren Graham later suggested that Fock may have influenced Bohr to subsequently use a less positivistic vocabulary.\textsuperscript{118} Rosenfeld seems not to have played any role in arranging the meeting between Bohr and Fock.\textsuperscript{119}

Although Rosenfeld fought the communist opposition to the Copenhagen Interpretation, he also recognized and regretted that there was indeed a tendency to idealistic viewpoints among the founders of the Copenhagen Interpretation, but in Heisenberg rather than in Bohr.\textsuperscript{120}

\begin{quote}
It is a pity that the creators of the conception of complementarity have . . . sometimes expressed themselves in ambiguous or even frankly idealistic terms. But this ought not to disconcert us. Are we going to lay complementarity under an interdict because Heisenberg is an idealist? We might just as well condemn the \textit{Principia} because Newton dishes up his dialectics in the guise of Puritan theology.
\end{quote}

Rosenfeld’s criticism applied in this context to Heisenberg’s view of the relation of experience to physical theories. According to Heisenberg, physical theories were built on the basis of experience, just like a crystal nucleating around a germ seed. However, eventually theories would end up as closed systems which would then work loose again from the experience from which they were originally derived and stand out as pure mental \textsuperscript{[geistig]} constructs.\textsuperscript{121} Rosenfeld attempted to acquit

\begin{itemize}
\item \textsuperscript{117} Fock to Rosenfeld (ref. 43); Jammer (ref. 89), 250. Rosenfeld seems to have had no direct exchange of views with the Nagoya group of Marxist physicists in Japan. About this group’s philosophical inclinations, see Kent W. Staley, “Lost origins of the third generation of quarks: Theory, philosophy, and experiment,” \textit{Physics in perspective}, 3 (2001), 210–229.
\item \textsuperscript{118} Graham (ref. 30), 337; Fock, “Critique épistémologique de théories récentes,” \textit{La Pensée: Revue du rationalisme moderne}, 91 (1960), 8–15.
\item \textsuperscript{119} Fock, “Report ‘The journey to Copenhagen,’” originally published in Russian in \textit{Vestnik Akademii Nauk}, 27:7 (1957), 54–57; English translation in BSC. According to Fock, Bohr’s collaborator Christian Møller, originally asked Fock to visit Copenhagen when the two met at a conference in Bern, Switzerland, in 1955. The invitation was confirmed by Niels Bohr in 1956 and later arranged with Aage Bohr, during a visit by the latter to the Soviet Union the same year.
\item \textsuperscript{120} Rosenfeld, “Strife” (ref. 31), 480.
\end{itemize}
Bohr of similar idealistic viewpoints and stressed that Bohr was a much more subtle thinker. However, Rosenfeld was keenly aware of the “unhandy formulations” in some of Bohr’s early writings: “when you look at those sentences, you can understand, at least, that outsiders and casuists, like those pseudo-Marxists . . . can accuse him of the worst kind of idealism and even solipsism.”122 The American philosopher of science Adolf Grünbaum drew Rosenfeld’s attention to some of these critical sentences such as Bohr’s statement that “the theory of relativity reminds us of the subjective character of all physical phenomena.”123 In response Rosenfeld recounted that he did everything he could to prevent such idealistic formulations when he became Bohr’s assistant in 1930, “but I was not always successful.”124

Rosenfeld’s campaign met with opposition not only from Marxists critical of complementarity but also from the founders of quantum mechanics. Indeed, Rosenfeld ended his “Strife” paper, “I seem to quarrel with everybody.”125 Surely Pauli, Born, and Heisenberg did not like that the Copenhagen Interpretation was criticized from the perspective of Marxism, but neither did they agree with Rosenfeld’s mixture of Marxism with complementarity. Pauli and Born also expressed their distaste for Rosenfeld’s criticism of Heisenberg’s idealism.126 Heisenberg for his part did not conceal his idealistic views but expressed them quite openly, just as he was quite open to discussing philosophical matters with Rosenfeld. However, it is not clear if a dialogue ever took place.127

Born characterized Rosenfeld’s “Strife about complementarity” as “your tight-rope walk over the abyss of being either heretical to your St. Niels or to your St. Marx” and saw that Rosenfeld “will be, of course, always between two stools and will be attacked from both sides.”128 Both Pauli and Born wrote more detailed

122. Kuhn and Heilbron (ref. 8), session 3, 6.
123. Niels Bohr, Atomic theory and the description of nature (ref. 45), 116; Grünbaum to Rosenfeld, 20 Apr 1957; RP, “Correspondance générale 1955–58” in “Epistemology”; Rosenfeld to Grünbaum (ref. 63).
124. “Personally I am very glad to have the exact reference to the weak spots you have detected in his writings. I hope this will strengthen my hand when I again try to persuade him to be more careful in his terminology,” draft of a letter from Rosenfeld to Grünbaum, 11 Dec 1957, RP, “Correspondance générale 1955–58” in “Epistemology”; Kuhn and Heilbron (ref. 8), session 3, 6–7.
125. Rosenfeld, “Strife” (ref. 31), 482.
126. “I am first concerned . . . with Heisenberg and with you. I have already corresponded with Heisenberg (whom you are free to consider idealistic, if you only consider this letter to be sufficiently materialistic). . . . To say it frankly, I am very much against your writing again on complementarity (it is urgent that Bohr do this himself again), simply because it is slowly getting dull. We should not keep repeating the same Schmus.” Pauli to Rosenfeld, 21 May 1954, PSC, Part 2, 639–640, on 640.
127. See, for example, Heisenberg, “The development” (ref. 1), 28; Heisenberg, Natural law and the structure of matter (London, 1970), 32–33. Rosenfeld, “Berkeley redivivus” (ref. 36); Rosenfeld, “Strife” (ref. 31), 480–481; Heisenberg to Rosenfeld, 16 Apr 1958, RP, “Correspondance particulière.”
128. Born to Rosenfeld (ref. 52).
responses to Rosenfeld’s contribution to the de Broglie festschrift. In addition, Born wrote a long piece in which he discussed dialectical materialism scientifically, philosophically, and politically. He never published the manuscript, but only sent it to Rosenfeld. Born expressed an unwillingness to enter into a public debate because he found the topic too sensitive during the Cold War. Despite the polemic and disagreements about philosophy and politics, Pauli, Born, and Heisenberg remained close friends with Rosenfeld.

The question that both Born and Pauli asked Rosenfeld again and again during the early 1950s was how Bohr reacted to his blending of complementarity and dialectical materialism. Born wrote to Rosenfeld in 1955, “You indicate that he [Bohr] shares your views. If I should see him again I shall ask him point-blank.” And in another letter: “I think you are quite wrong in your judgment about Heisenberg’s and other people’s attitude, and I also cannot believe that Bohr agrees with you.” So what did Bohr think of the matter? Apparently, he was eager to get a copy of Rosenfeld’s “Strife” paper. However, Bohr seems to have refused to engage in discussions about the issue. Rosenfeld later suggested, “Bohr would never hear of those words [dialectical materialism]. [He] regarded the question of the foundations of physics in the external world as something so trivial that it was not worth discussing.” In the same interview with Thomas S. Kuhn and J.L. Heilbron in 1963, Rosenfeld described a conversation with Bohr about these issues. Bohr asked Rosenfeld, he reported:

“Why are those Russians dissatisfied?” And I tried to explain, “They accuse you of being a positivist,” and so on. Then he said, “Is that it? But those things are so trivial; they are not of interest to physicists. Physicists are beyond that point and that is not the thing that we are interested in. We are struggling with real problems, not with those trivial statements about our living in an external world.”

If such a conversation ever took place, it may have been in connection with Fock’s visit to Copenhagen in 1957, when Bohr’s positivistic language was Fock’s concern. Bohr’s silence about Rosenfeld’s Marxist ideology and his campaign for complementarity

131. “Professor Bohr has asked me to say how interested he has been in reading your paper for the Festschrift for de Broglie [see ref. 100]. The professor would now like very much to have a copy of the whole Festschrift, but so far I have not succeeded in getting hold of it. Could you be so kind to inform us of the exact title as well as the publisher so that we can procure it immediately.” Sophie Hellmann to Rosenfeld, 27 Oct 1952, RP.
132. Kuhn and Heilbron (ref. 8), session 3, 6.
133. Ibid., 12.
should be seen in connection with the fact that Rosenfeld was called to Copenhagen as the first professor at NORDITA in 1958, which may be viewed as a sign that Bohr notoriously did not care about philosophical “isms.”

No one at the Niels Bohr Institute seems to have reacted to Rosenfeld’s campaign. According to Bohr’s assistant Jørgen Kalckar, if Niels or his son Aage Bohr had considered it important to enter into a discussion with them and other Copenhagen physicists, he would have considered the matter differently. Kalckar suggested another plausible reason why no one in Copenhagen reacted—simply, non-Marxist physicists lacked sufficient knowledge of dialectical materialism to enter into the discussion. Later, as editor of Bohr’s Collected works, Kalckar did find the need to specify, if only in a footnote, that he did not consider Heisenberg’s, nor Rosenfeld’s, views in complete correspondence with Bohr’s. According to Kalckar, “in later years Rosenfeld’s doctrines were identified in wide circles with Bohr’s complementarity point of view—not with complete justice, I should like to add.”

Rosenfeld continued to fight the disbelievers in complementarity for the rest of his life, but his Marxist vocabulary was considerably toned down in public beginning around 1960. This seems to be in line with the fact that Marxist motivation has played a much less prominent role in quantum controversies after the late 1950s, probably following Khrushchev’s denunciation of Stalin at the Twentieth Party Congress and the invasion of Hungary by the Soviet Union in 1956.

5. LESSONS FROM HISTORY

What makes an otherwise timid man turn so hypersensitive and take such extreme measures to secure the survival of a scientific idea like complementarity? Simple belief in its truth, paired with anxiety in seeing it criticized and challenged seems insufficient. Regarding Bohr as a father figure was by no means uncommon among his disciples, and it is very likely that Rosenfeld, who lost his own beloved father as a young boy, was especially susceptible to the intense interest and attention Bohr showed everyone working with him and his ability to advise, guide, comfort and support his co-workers in all circumstances of life. Thus many factors may have played a role in Rosenfeld’s engagement. If we turn to his ideas in history and

137. Freire, “Quantum controversy” and “Science and exile” (ref. 2); Cross (ref. 75), 751–752, Graham (ref. 30), 343–353.
138. Heilbron (ref. 2), 222–223, 225–228; Kalckar (ref. 18).
philosophy of science we find yet another possible motivation for his campaign, once again with Marxist origins.

As I have described elsewhere, in the history of science, Rosenfeld was pre-occupied with patterns of pioneers versus forerunners of scientific discovery in history. He believed that a society that has arrived at a certain level of cultural development is never prepared to accept a new scientific idea without resistance. In addition, the introduction of a new idea in science will happen only as a result of a veritable fight between the pioneer and the conservative tradition of the scientific community and the broader society. For example, in the case of causality, Rosenfeld asserted, “Each step forward . . . implies a critical stage where a conflict explodes between accepted conceptions and the new element which does not fit into them.” According to Rosenfeld, it was the responsibility of the pioneer to bear his ideas to triumph and make sure that they would be accepted by the scientific community, and also more broadly. If he did not succeed, for whatever reasons, he would be reduced to a forerunner in history and the idea would fall into oblivion until it was rediscovered.

To be sure, Bohr had been quite active in trying to convince the physical community of his ideas in quantum mechanics, culminating with the Bohr-Einstein debate in the 1930s. Moreover, Bohr’s other disciples had also taken great pains to promote Bohr’s ideas in this period. From the late 1930s onward, however, Bohr seems to have devoted his time to other matters, such as nuclear physics and later politics, and withdrew more or less from the ongoing quantum controversy. After World War II, when Bohr’s ideas were met with renewed challenge, it seems that Rosenfeld was prepared to continue or take his turn in the fight for Bohr’s ideas in order that complementarity remained viable.

6. CONCLUSION

A closer look at individual Marxist positions like Rosenfeld’s reveals several varieties of Marxist thought in combination with scientific thought. This becomes particularly evident in scientists’ different attitudes towards the interpretation of quantum mechanics. Different versions of Marxism are already carefully taken into account for the early Soviet period in David Joravsky’s Soviet

139. Jacobsen (ref. 19).
140. Rosenfeld, “The evolution of the idea of causality” (ref. 46), 461.
142. Heilbron (ref. 2).
144. See also Forstner’s analysis of David Bohm’s reflections on dialectical materialism and quantum mechanics (ref. 93).
Marxism and natural science 1917–1932 (1961), for example.\textsuperscript{145} However, the historical literature about Marxist debates over quantum mechanics after World War II can benefit a good deal from more careful analyses of the variety of Marxist positions involved. From a socio-political and cultural perspective, this paper also clearly supports the claim put forward by historians Olival Freire and Andrew Cross that the postwar Marxist debate over quantum philosophy cannot be bypassed in the historical development of attitudes toward the interpretation of quantum mechanics.\textsuperscript{146} One specific outcome seems to have been the growing tendency to denote orthodox views in quantum mechanics as the “Copenhagen Interpretation,” thereby suggesting the possibility of alternative interpretations.

Likewise, Rosenfeld’s apparently anomalous standpoint and role in the postwar quantum controversy, both from the point of view of other Marxists and from that of his fellow physicists following Bohr’s lead, becomes clearer when we view his defense of complementarity in combination with his Marxist thought. Apart from his great admiration and almost filial love for Bohr, paired with his deep belief in the truth of complementarity, the crucial factor behind Rosenfeld’s campaign indeed seems to have been his Marxist worldview, according to which complementarity was in harmony with a dialectical materialist view. In order to uphold this conviction, Rosenfeld emphasized the dialectical side of Engels’s doctrine over its materialistic side. He saw both the physics of the past and the physics of his own time through the filter of historical and dialectical materialism, identifying physicists as idealists or materialists. In particular, Niels Bohr appeared to him to be the best example of a dialectical materialist.

In the 1940s, when Rosenfeld experienced how complementarity was abused, on the one hand, to justify idealistic and mystical ideas, and, on the other, strongly criticized by physicists motivated by Marxist thought, he was greatly worried. He saw this development as reflecting the idealistic intellectual currents characteristic of societies in decline, the general conservatism of scientific communities when faced with new ideas, the younger generation of physicists’ ignorance with respect to Bohr’s original publications, and, in particular, the harmful influence by Stalin’s party ideology in science. Rosenfeld felt an urge to take action in order that complementarity would continue to be a central tenet of quantum mechanics. Thus, a few years after World War II, he launched a campaign against all the new disbelievers who seemed to be popping up everywhere, and who more or less set forth the same points of criticism as Schrödinger, Einstein, and others had earlier, but now in a Marxist guise. In this campaign Rosenfeld fought for complementarity, for what he termed “genuine” Marxism, and against idealism. He attempted to convince Marxist opponents that although the Copenhagen Interpretation entailed a view on matter that was probabilistic, non-deterministic, and non-causal, this could still be considered in harmony with a dynamic interpretation of dialectical materialism when adopting complementarity as a new form of causality.

\textsuperscript{145} Joravsky (ref. 24).
\textsuperscript{146} Freire, “Quantum controversy” (ref. 2); Cross (ref. 75).
Given Rosenfeld’s Marxist views and his Marxist campaign for complementarity, it may seem rather surprising that several of his colleagues ignored or were even unaware of his Marxist position. However, Rosenfeld was not a militant Marxist or activist like Pannekoek, Bernal, or Joliot-Curie, but mainly a philosophically-oriented Marxist. Closely connected with this, he distanced himself clearly from Leninist Marxism and the communists, typically identified as the Marxists. Moreover, Rosenfeld never bothered or managed to publish a longer, more thorough exposition of his Marxist position on a par with Pannekoek’s *Lenin as philosopher* or Bernal’s *Science in history*.\(^{147}\) In his publications, Rosenfeld presumed that his readers were well-acquainted with the vocabulary and lines of thought in Marxism, which, however, was probably rarely the case as he was mainly addressing a general physics audience. Thus, since the majority of obituaries and shorter biographies by his colleagues and friends do not mention this side of him, it seems that these people were probably unable to understand his references to Marxism and therefore did not appreciate or recognize them. In addition, Rosenfeld seems not to have been very outspoken about Marxism beginning around the time he took a position in Copenhagen. Consequently, it was more or less unknown that he was a Marxist among his Danish colleagues of that time.

\(^{147}\) Pannekoek (ref. 34); Bernal (ref. 41).
Léon Rosenfeld’s Marxist defense of complementarity

ABSTRACT

The Belgian physicist Léon Rosenfeld (1904–1974) has been called “the clarifier” of Niels Bohr’s ideas in quantum mechanics. He had a unique connection to Bohr as his close collaborator from 1930 until Bohr died in 1962. However, although he is considered Bohr’s spokesman, he had his own characteristic way of articulating Bohr’s views. In particular, Rosenfeld added a dialectical-materialist layer to Bohr’s ideas in certain contexts. Despite Rosenfeld’s open profession of Marxism, the literature has generally avoided discussing its relevance for his work and activities. This paper suggests some reasons why and investigates Rosenfeld’s combination of Marxism and complementarity, which his colleague and friend Wolfgang Pauli metaphorically denoted by the equation “Rosenfeld = √Trotsky × Bohr.” Rosenfeld’s particular views appear anomalous to the frequently expressed stereotypes of both Marxism and complementarity. The paper concentrates on the role Marxist philosophy played in Rosenfeld’s fierce defense of complementarity from the late 1940s through the 1950s and the reception his campaign was accorded at the Niels Bohr Institute in Copenhagen and elsewhere.

KEY WORDS: Léon Rosenfeld, complementarity, Marxism, dialectical materialism, idealism, Copenhagen Interpretation of quantum mechanics, Niels Bohr, philosophy of quantum mechanics