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Grete Hermann's ethical philosophy of physics

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Grete Hermann in the countryside, circa 1932. (Courtesy of the © Archives of Social Democracy, Photo Collection, 6/FOTA029916, Friedrich Ebert Foundation, Bonn, Germany.)

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The case of a pioneering woman physicist and philosopher illustrates that we must look beyond hagiography to gain an accurate picture of the history of quantum physics.

If you've heard of the German physicist and philosopher Grete Hermann, it's probably because of her long-forgotten critique of John von Neumann's 1932 proof that hidden-variable theories explaining quantum mechanics are impossible. As the tale goes, Hermann authored a 1935 article in a German philosophical journal refuting the proof,[1] just to see that work largely ignored by physicists and philosophers for more than 30 years. It was only rediscovered, according to that telling, after John Bell published a 1966 paper refuting von Neumann's proof along similar lines.[2] Had Hermann's work not "remained a dead letter," as the philosopher Léna Soler wrote in 2009, "the history of the interpretations of quantum physics would certainly have been very different."[3]

But that's not the full story. The claim that Hermann found fault with von Neumann's no-hidden-variable proof warrants further investigation. Moreover, the singular focus on Hermann's refutation of von Neumann's argument obscures her broader contributions to philosophy, mathematics, and physics—particularly the important connections between philosophy and quantum physics that she first identified. Hermann's case exemplifies how the glorification of popular historical figures makes it difficult to accurately and comprehensively understand the history of quantum physics.

A SOCIALIST AND ANTIFASCIST

Born on 2 March 1901 into a bourgeois family in the northern German city of Bremen, Hermann grew up attending a coeducational school, which was extremely rare at the time. She graduated in 1920 and obtained her teaching certification for primary and middle schools in 1921. She began studying mathematics, physics, and philosophy at the University of Göttingen, where she became the first doctoral student of another trailblazing woman in science: the mathematician Emmy Noether. Hermann graduated in 1925 with a dissertation on the theory of polynomial ideals.

At Göttingen, Hermann regularly attended the seminars of the neo-Kantian philosopher Leonard Nelson, whose work would influence—or, more accurately, provoke and stimulate—her for the rest of her life. Neo-Kantianism was a multifaceted philosophical movement that emerged in Germany in the 1860s. Its adherents generally agreed that a return to Immanuel Kant's 18th-century philosophy would bolster arguments against materialism, mechanism, Darwinism, and scientism. By the early 20th century, it was the dominant strain of philosophical thought in Germany. Nelson's school of neo-Kantianism emphasized the importance of the philosophy of science.

Hermann joined the *Internationaler Sozialistischer Kampfbund* (ISK; International Socialist Militant League), a small organization Nelson had founded with the German educational reformer Minna Specht in 1925. After Nelson's death in 1927, Specht and the journalist and politician Willi Eichler took over the leadership of the ISK. The two became Hermann's most important friends and intellectual comrades. Together they attempted to reform and democratize neo-Kantian philosophy in line with Nelson's ideals.

In the late 1920s and early 1930s, the ISK advocated vehemently for resistance against the rising Nazi Party. As part of that effort, Hermann published a series of articles denouncing

totalitarianism and Nazism in the group's short-lived newspaper, *Der Funke* (The spark), under various pseudonyms. After the Nazis took power in 1933, the ISK and its newspaper were banned, and a boarding school affiliated with the organization was occupied by Nazi storm troopers and later confiscated. Although she was not Jewish, Hermann faced persecution in Nazi Germany as an ISK member. Nevertheless, she initially stayed in Germany and remained active in science. She spent time in 1934 discussing quantum theory with Werner Heisenberg and others in Leipzig and was also in contact with physicists and philosophers in Berlin, including Hans Reichenbach, Walter Dubislav, and Kurt Grelling.

At the same time, Hermann and other ISK members helped Specht move the boarding school to Denmark, an action that helped rescue many children of socialist and Jewish families in Germany. It became an important link between underground ISK groups in Germany and the group's leadership in exile. In fear of a German invasion, Specht and the ISK moved the boarding school to the UK in November 1938 with the support of the Quakers. But hopes of rebuilding it there were soon dashed: After the outbreak of World War II, Specht and other German teachers were interned as enemy aliens on the Isle of Man.

Hermann immigrated to the UK sometime at the end of 1937 or in early 1938. She quickly entered a marriage of convenience with a local socialist, Edward Henry, in London in 1938 and automatically received her UK citizenship, which thus protected her from wartime internment. (The two divorced in 1946; because of the marriage, her writings were variously published under the names Grete Hermann, Grete Henry, and Grete Henry-Hermann.) In exile, Hermann and Specht assumed leading roles in the Union of German Socialist Organizations in Great Britain, an umbrella group for left-leaning German émigrés in the UK. Hermann helped the group plan for the reorganization of the educational system in a liberated postwar Germany.

After returning to her home country in 1946, Hermann joined the Social Democratic Party, helped establish a trade union for teachers and researchers, was involved in protests against nuclear weapons, and dedicated her efforts to educational reform. In 1950 she was appointed as a full professor of mathematics, philosophy, and physics at the *Pädagogische Hochschule Bremen* (Bremen Teacher Training College) and stayed in that position until 1966. She also served as deputy director of the institution and supported efforts to transform it into a university. (It would eventually be integrated into the University of Bremen between 1971 and 1973.) During her time in Bremen, Hermann turned down several offers from other universities so she could concentrate on teaching and philosophical research.

From 1961 to 1978, Hermann also served as the chair of the Philosophical-Political Academy, an organization established to promote Nelson's philosophy, and helped supervise the publication of his collected works. Connecting philosophy with political and societal issues, the academy advocated for open democratic education according to the ideals that Hermann had sought to realize along with Specht and others. Hermann died in her birth city of Bremen on 15 April 1984.

GRETE HERMANN (LEFT) AND MINNA SPECHT (RIGHT) in March 1933, taking records from the International Socialist Militant League's boarding school to a safe in Kassel, Germany, to hide them from the Nazi regime. (Courtesy of the © Archives of Social Democracy, Photo Collection, 6/FOTA029541, Friedrich Ebert Foundation, Bonn, Germany.)

CRITICISM OF VON NEUMANN

Von Neumann's proof appeared in his famous 1932 book *Mathematische Grundlagen der Quantenmechanik* (*Mathematical Foundations of Quantum Mechanics*).[4] It attempts to show that it is mathematically impossible for deterministic physical theories—so-called hidden-variable theories—to underlie the fundamentally indeterministic quantum mechanics. An unpublished manuscript from 1933 indicates that Hermann began pondering the proof shortly after von Neumann's book was published.[5] She developed her ideas further in discussion with Heisenberg during her 1934 stay in Leipzig before publishing them in 1935.

In the article, Hermann points out that von Neumann's proof would stand or fall on the assumption that the expectation value of a sum of physical quantities is equal to the sum of the expectation values of both quantities. The linear additivity of the expectation values is an assumption that holds for simultaneously measurable quantities, which are represented by commuting Hermitian operators. But what about quantities that are not simultaneously measurable—in other words, those whose operators do not commute? Hermann claims that von Neumann's proof, which was based

on a specific assumption about expectation values, was too restrictive.

Hermann also argues that von Neumann's proof was based on a logical fallacy termed by philosophers as *petitio principii*—it presupposed an assertion to be proven as true. Because he believed that the hypothetical existence of hidden variables would allow for dispersion-free states, von Neumann attempted to show that a coherent quantum mechanical system has no such states. In dispersion-free states, expectation values coincide with eigenvalues. But eigenvalues are generally nonadditive. As a result, von Neumann concluded that hidden-variable theories are impossible.[6]

But as Max Jammer, the well-known Israeli historian and philosopher of physics who was born in Germany, pointed out to Hermann in a 1968 letter, it is one thing to argue that von Neumann based his proof on certain unnecessarily limiting assumptions; it is another to accuse the proof of circularity. Von Neumann used the case of pure quantum states to motivate the axiomatic requirement of linearity, but not for the purpose of deriving it.[7]

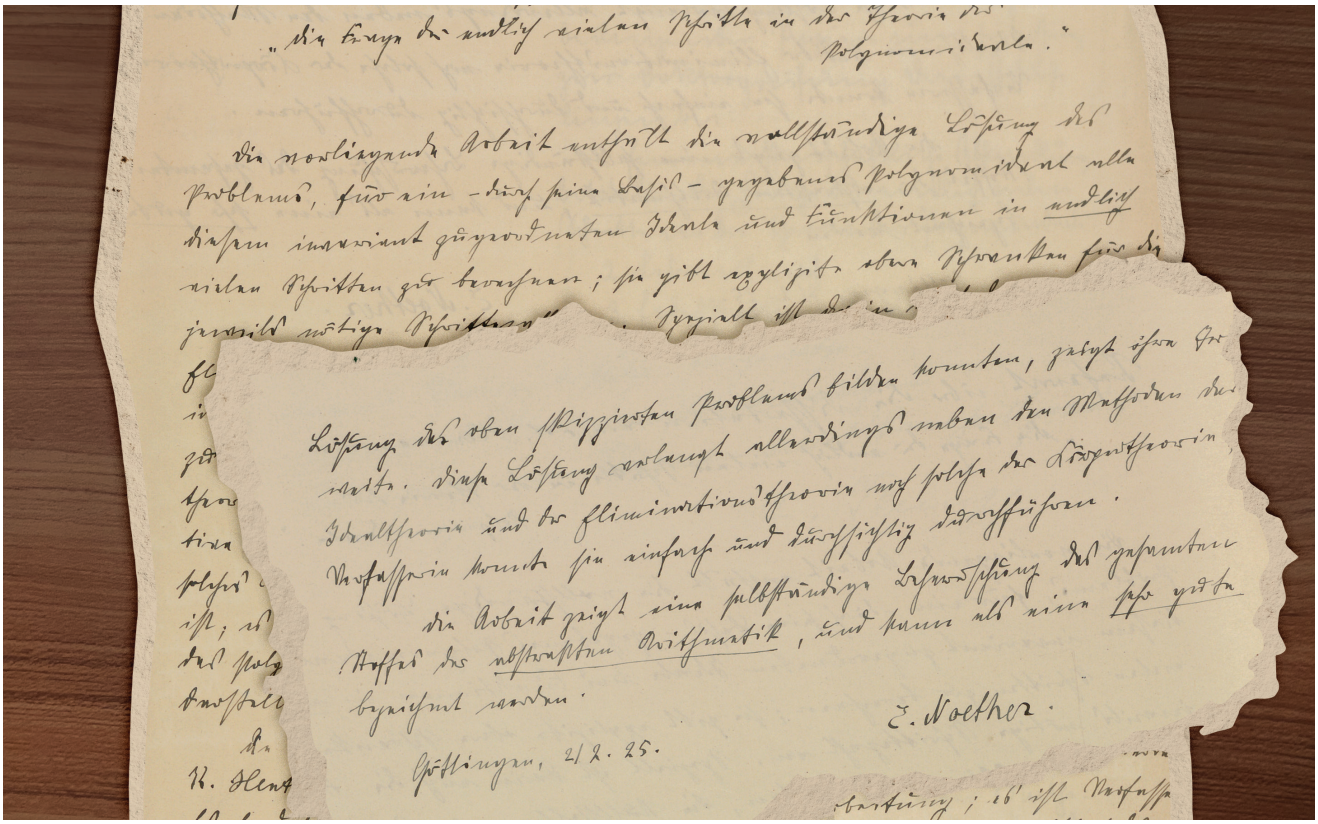
Jammer wrote to Hermann while researching his classic 1974 book *The Philosophy of Quantum Mechanics*, one of the first English-language works to detail the history of quantum interpretations. The book includes a detailed comparison of Hermann's interpretation with Niels Bohr's relational conception of quantum states.[8] But in that section, Jammer unfortunately declines to mention her response to his letter, in which she conceded that he may be right and stated her willingness to set aside her criticism of the proof as circular.

The key point of her criticism, Hermann wrote to Jammer, was not to point out a logical fallacy in von Neumann's proof but to call attention to the overly hasty conclusion he drew from his result. The Hungarian polymath had argued that "all ensembles—even homogeneous ensembles—have dispersion," which therefore negated causal explanations.[9] Hermann considered that claim to be misguided. Quantum mechanics allows statistical predictions about the relative frequency of outcomes when the same experiment is repeated many times. Thus she argued that the principle of causality is not necessarily negated by quantum mechanics. Quantum indeterminism, on the other hand, sets limits as to the precision of the predictability with which physical quantities, such as the position and momentum of a particle, can be measured simultaneously. It is thus the relational and contextual conception of quantum states that contradicts the determinism of classical mechanics.

THE INFLUENCE OF PHILOSOPHY

In a recent overview of the history of quantum mechanics, physicists Robert Golub and Steven Lamoreaux argue that Hermann "was defending the philosophical tradition that causality was a

EMMY NOETHER'S EVALUATION of Grete Hermann's doctoral thesis, which were handwritten in an old form of German cursive, dated 2 February 1925. Noether gave Hermann the highest possible grade, concluding that the dissertation demonstrated "independent mastery of the entire field of abstract arithmetic." (Courtesy of the Göttingen University Archive, Math.-Nat. Prom., file 15.)



necessary constituent for any scientific view of the world."[10] In that reading, Hermann is presented as a neo-Kantian philosopher who tried to defend Kant's conception of causality as a necessary condition of the possibility of experience.[11] Philosopher Erik Banks draws attention to the fact that "in consideration of what Hermann will say later about causality, she only means that in a given context, an interpretive causal *analogy* becomes possible within which the *two given positional measurements* can be ordered together" (italics in the original).[12]

Indeed, in a previously unpublished 1951 manuscript, Hermann says clearly that "we can no longer share Kant's conviction that critical philosophy must succeed in completely liberating the rational moment of knowledge from the empirical and grasping it *a priori* in synthetic judgments." According to Hermann, the classical version of the causal principle fails because of the erroneous "presupposition that physics gives us an objective, uniform model of natural events."[13] In that respect, Hermann's view of causality was in fact an objection to Kant and the traditional ideal of the objectivity of causality.

Like nearly all neo-Kantians of her time, Hermann contrasted Kant's philosophy with new developments in physics to gain a better understanding of both contemporary physical research and its philosophical foundations. Unlike many of those contemporaries, her reading was also influenced by Nelson, who understood and practiced philosophy as a socialist, non-Marxist way of life. But Hermann's views evolved during her lifetime, and the more she began distancing herself from Nelson's intellectual ideas, the more she turned to an approach guided by an open and democratic philosophy.

Bohr introduced the concept of complementarity into quantum mechanics in 1927 to characterize the wave and particle models not as contradictory views but as supplementary to each other—even though the continuous and discontinuous pictures of atomic phenomena simultaneously exclude each other. Along similar lines, he argued that causality and space-time localization were similarly complementary, as were certain conjugate variables, such as position and momentum.[14]

Unlike many of her contemporaries, Hermann did not claim that the quantum mechanical conception of complementarity could be extended and transferred to other areas of scientific research. On the contrary, she believed that the idea of complementarity was older than quantum mechanics and that Bohr's achievement consisted in applying the principle to physics. In Hermann's reading, the principle of complementarity was closely related to what the 19th-century philosopher Ernst Friedrich Apelt termed "splitting the truth."[15] Apelt used the metaphor of a split to describe an activity that separates something into two pieces. The result of the split was a cut—or at least something close to a cut.

Heisenberg used a similar metaphor to distinguish between the quantum object to be measured and the measuring apparatus. For him, the object–instrument divide was a clearly defined tool to limit the applicability of classical notions—for instance, position or momentum—to micro-

A PORTRAIT OF LEONARD NELSON taken circa 1922. (Courtesy of the Göttingen State and University Library, Cod. Ms. D. Hilbert 754, Bl. 12, Public Domain Mark 1.0.)

LEONARD NELSON (LEFT) AND MINNA SPECHT (RIGHT) on a walk circa 1920. (Courtesy of the © Archives of Social Democracy, Photo Collection, 6/FOTA007784, Friedrich Ebert Foundation, Bonn, Germany.)

THE MASTHEAD of the first issue, dated 1 January 1932, of *Der Funke* (The spark), the International Socialist Militant League's newspaper. The subtitle translates to "Daily Newspaper for Justice, Freedom, and Culture." (Courtesy of the Archives of Social Democracy, Friedrich Ebert Foundation, Bonn, Germany.)

physical phenomena. Bohr, among others, understood the so-called Heisenberg cut as a feature of complementarity between the observed system and the observer. Today the Heisenberg cut is often described in terms of quantum entanglement, which is broken when the entangled particles decohere because of interaction with the environment.

FREE WILL

Crucially, Hermann argued that Heisenberg's cut can be used as a device to uncover a fundamental mistake Nelson made when analyzing human actions in relation to physical processes. Using the causality of physical processes as analogy, Nelson had claimed that when someone acts deliberately—namely, for a reason—the deliberate act is caused by the reason that prompted it.

As Hermann pointed out, the fact that we are guided in our actions by reasons and values does not mean that we are completely determined by them. Furthermore, human beings, as agents, can make their own actions the subject of observation and reflection. For that reason, Hermann argued, we can make ethical decisions and act morally. That capacity is both a right and a duty. Anyone who claims that free will could be verified or falsified by the results of physical research thus turns physics into "physicalism" because they ignore that social and quantum interactions are different. She formulated the following thought experiment to make the point clear:

> Let us therefore assume that there is no reason why a radium atom decays right now and not in 100 years, or why a quantum of light hits a photographic plate at one point and not at another. This would not at all mean that the radium atom had the freedom of ethical decision to determine when it wanted to decay, or that the light quantum chose the place of its impact based on ethical considerations. Human freedom, i.e., the freedom of choice, has by no means been proven possible by the acausality of atomic processes. For the people whose ethical decision we are asking about are not atoms or light quanta. And, on the other hand, quantum physical objects do not make ethical decisions.[16]

Hermann's critique of Heisenberg

An episode from Grete Hermann's correspondence with Werner Heisenberg during the 1930s encapsulates her ethical worldview. In 1936 the Nazi regime was rearming the German military and had recently reoccupied the demilitarized Rhineland. Both actions were clear violations of the Treaty of Versailles. Still based in Germany, Hermann was planning a philosophy conference to be held in Heidelberg that September and had invited Heisenberg to participate. On 9 July 1936, he wrote to her stating that he would not be able to attend because he had been called up to the German army for required training at the same time as the conference. Although he was sorry to miss it, Heisenberg informed Hermann that through his army training he was "looking forward to being forced to fundamentally change my external life thoroughly in this way."

Hermann was shocked by that response and told Heisenberg what she thought of it: "You leave it up to authorities to direct the shaping of people's lives and worldviews—in this case, yours as well—through external or internal coercion." Heisenberg, who would go on to assume a leading role in the German nuclear project during World War II, rejected Hermann's appeal to take responsibility for his actions. As he wrote, that "would only make sense, after all, if one set oneself the task of changing the world politically, which only seems possible to me as an alternative to science." But for Hermann, strictly separating ethics and science was unacceptable, indeed irresponsible.[18]

MINNA SPECHT'S 75TH BIRTHDAY PARTY on 22 December 1954. At the head of the table, far left, is Willi Eichler. Specht is second from left and Grete Hermann is second from right. (Courtesy of the © Archives of Social Democracy, Photo Collection, 6/FOTA029560, Friedrich Ebert Foundation, Bonn, Germany.)

There's a conceptual lesson to be learned from Hermann's critical analysis: Whenever a transfer of specific technical and physical circumstances to social interactions takes place—and vice versa—we should remember not only that science generates knowledge but also that scientific research and knowledge construction themselves are socially constituted.

FROM PHYSICS TO ETHICS AND POLITICS

Hermann's critique of Nelson points to a crucial insight into understanding her intellectual motivation: Neither physics nor philosophy but rather politics was the driving force in her thought. In fact, Hermann's publications on philosophical issues relating to quantum mechanics make up only a tiny fraction of her writings, most of which focus on ethics and politics.[17] Because those writings were only published in German and are not easily accessible digitally, they have so far been largely ignored by Anglophone scholars.

Her case illustrates why we should be cautious about overly simplified representations of groundbreaking figures in the history of science. Hermann is typically portrayed as a forgotten pioneer of quantum mechanics and another female scientist who failed to gain recognition for her discovery of an error in von Neumann's impossibility proof. But it turns out that her work was in fact never fully forgotten, although her contributions failed to be widely recognized by Anglophone historians and philosophers of science. Moreover, the focus on Hermann's refutation of the no-hidden-variable proof arguably distracted scholars from examining the overarching theme of her intellectual work: that science and ethics are inseparable.

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