Grete Hermann: Mathematician, Philosopher and Physicist

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Introduction

The first time I came across the name of Grete Hermann was in a lecture on the foundations of quantum mechanics[1]; the professor briefly mentioned her name while speaking of von Neumann's proof of the impossibility of hidden variable theories and the discovery of its "silly assumption"[2] made by John Stewart Bell. Grete Hermann, a German philosopher and mathematician, had noticed the mistake many years before Bell.[3] The unusual presence of a woman, and moreover, not a physicist, but rather a philosopher and mathematician, immediately struck me. For the first time in my study of the history of quantum mechanics I encountered a young female mathematician playing an important role in the development of the field and in the discussion of its philosophical implications. Her different background and education helped her take an original perspective on the philosophical problems of quantum mechanics. After further readings, I felt that the study of this woman and her ideas would be fruitful, not only for the interesting details it could add to the history of quantum mechanics, but also as a philosophical reflection on the basic principles of physical theories. To summarize, it could constitute a case of historical and philosophical significance, worthy of further investigation.

With my inquiry, I will highlight the fruitfulness of Grete Hermann's ideas; therefore also indicating that further research into her work might prove worthwhile. Her importance lies not solely in the discovery of a mistake[4] in the proof of one of the most prominent mathematicians of her time[5], as her endeavors went much further in scope and deeper in content. The scope of her work is not restricted to her field of expertise; mathematics. Rather, Hermann went further in investigating the philosophical problems originating from the development of the new physical theories. And similarly, the contents of her research started on a technical mathematical level and developed to broader, ambitious questions about the existence of causal relations in nature. As a consequence of the wide scope and content of Grete Hermann's work, it is not possible to situate her within one discipline and, rather, her body of work rests on the intersection between philosophy,

[1] "Foundations of Quantum Mechanics", NS-HP428M, Wintersemester 2010-2011 at Utrecht University. The classes were given by Jos Uffink.
[2] John Bell in an Interview to Omni (May 1988) in Mermin (1993), p.88.
[3] Cf. Bell (1966).
[4] As it will be shown in Chapter 2 von Neumann made an unjustified assumption when describing hidden variable theories. This assumption does not invalidate the proof, but limits the universality of its conclusions. I here generally call this choice of an unjustified assumption "a mistake", although it's not properly an error.
[5] John von Neumann had been called "the last of the great mathematicians" Dieudonne (1981). In 1926 he published the Mathematische Grundlagen der Quantenmechanik, where he established the mathematical framework for quantum mechanics; here his proof of the impossibility of hidden variable theories that Hermann (and Bell) would discover to be wrong.

physics and mathematics. The three disciplines are strongly interrelated in the elaboration and expression of her ideas.

It is probably also due to such interrelation between different fields of study, and the difficulty assigning the work to one field, that her contribution ended up being neglected and forgotten by these fields.[6] Therefore, for the sake of clarity, I will try to artificially restore the initial separation between the three fields in order to point out Hermann's contributions to each field individually. Grete Hermann's achievements are mainly in three fields: physical science, or better the foundational study of quantum mechanics, philosophy and mathematics. In physics, by analyzing the philosophical problems of quantum mechanics, Hermann proposes a solution to the problem of causality and with it to the so called "measurement problem". [7] According to Kant, causality is a necessary condition of our understanding. The new quantum theory appeared to contradict that because of the probabilistic character of predictions it was able to make. In order to dismiss this claim, Hermann undertakes a critical discussion of the meaning of causality in quantum mechanics and in Kant's oeuvre. Along with her defense of Kantian philosophy, she proposes a new interpretation of causality, at the same time making a conceptual analysis of the term; separating it from predictability and announcing that we have to give up the requirement of an absolute knowledge of the situation. These proposals are worth studying for their originality and for being ahead of their time.

The considerations Hermann makes of the basic principles of quantum mechanics are guided by her adherence to Friesian philosophy; a philosophical school that originated in the 19th century from an empirically based reinterpretation of Kant that has been largely neglected in the history of philosophy. In philosophy, Hermann contributed to the development of Friesian philosophy and her case enables the possibility of shedding some new light on this little studied philosophical school. Finally, she dedicated her first academic years to mathematics. Here, she also made important contributions, such as her search for an algorithm for computing primary decomposition of

[6] Grete Hermann has been mainly ignored by historical studies covering each of the three fields. In mathematics, notwithstanding her relation to the famous Emmy Noether, her proposal has been neglected. Similarly, her considerations in physics and philosophy are generally unknown to both a wider and an expert audience. Only recently have some studies on her political ideas and on her work in the foundations of quantum mechanics appeared (e.g. Soler(1996), Soler(2009), Miller (1996), Fischer (2005), Seevinck (2002)). For the reasons why Hermann has been ignored so long see the conclusion of this thesis.

[7] The measurement problem in quantum mechanics is understood as the fact that when a measurement is performed, a definite result will be found out. This creates a problem since the wave function has a probabilistic aspect until the measurement is performed. Many different answers have been proposed, such as the collapse of the wave function through the interaction with the measurement instrument. However, the problem and the philosophical questions connected to it (what is the ontological status of the wave function before the measurement?) are still open. See Krips (2008).

polynomials[8], which has been considered an important pioneering contribution to computational algebra.[9]

From the study of her research in the three disciplines arise many aspects worth of investigating further; I will focus here on three questions in particular: (1) is Hermann's interpretation of causality a promising proposal for the understanding of quantum mechanics and is it in some way relevant to today's views? (2) How did Friesian philosophy influence the elaboration of her ideas? And can Hermann's work constitute a philosophical and historical contribution to it? (3) Do Grete Hermann's life and work have an historical interest in themselves? Can the study of her life and work help us understanding the history of ideas and development of quantum mechanics better and at the same time answer the question of the contingency of her specific situation, i.e. why was she so long ignored?

To answer these questions I will use a threefold methodology. I will analyze the historical, philosophical and physical aspects of her work and life in order to better comprehend and reflect on the interdisciplinary nature of Hermann's work. On a historical level, a study of the primary sources was necessary to properly grasp Grete Hermann as a historical figure, in turn leading to a re-evaluation of the critical studies on her. Philosophically, the confrontation with other views and philosophical convictions, in particular with Friesian School, turned out to be beneficial in order to understand Hermann's original contributions to philosophy and the role this played in the elaboration of her ideas. And last, but not least, on a physical level, the main focus of this thesis is the evaluation of her answer to the fundamental question concerning the role of causality in quantum mechanics.

The study of the literature across the above three levels of analysis was limited by the scarcity of works, which, when considered in light of all her accomplishments, reveals the need for further studies. Unfortunately, there are not many critical studies on Grete Hermann's work[10] and most of the primary sources are neither translated in English[11] nor easily accessible.[12] After her death, Hermann had been nearly forgotten. The marginal interest she actually did receive can be

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[8] Cf. Herzenberg (2008), p. 5.
[9] Hermann(1926).
[10] The sole critical comments on her work before 1974 can be considered the reviews on Die naturphilosophischen Grundlagen der Quantenmechanik, like the very positive one made by von Weiszäcker and Strauss. Cf. Von Weiszäcker (1936).
[11] In this thesis I strived to always present the reader with an English translation, the original in German is to be found either in the footnotes (for short quotes) or in the appendix.
[12] Only Hermann's Die naturphilosophischen Grundlagen der Quantenmechanik and Die Überwindung des Zufalls (critical observation on Nelson's foundation of ethics as a science) are available in libraries in the Netherlands. For the rest, all primary sources are only available in Germany and some of them could only be found in Hermann's archive in Bonn (PPA).

credited to Max Jammer, who described the pioneering importance of her work in his extensive study of the history of quantum physics. [13] From Max Jammer's brief but attentive comments on Grete Hermann[14], there has been a slow revival of interest in her work and in the following years some initial critical studies appeared.[15] However, none of them presented the English speaking reader with a general overview of Grete Hermann's work and ideas; most of them only concentrated on some biographical details or on some of her specific contributions.

This thesis aims to be an extensive work on Grete Hermann, and a first step toward a deeper understanding of her work. I will endeavor to highlight the importance of Grete Hermann's work by considering her work into a wider context and by comparing her ideas to the ones of relevant people of her time. In addition, the epistemological contributions of Grete Hermann are chosen as the main perspective of this study, since these constitute, in my opinion, the most interesting part of her work. Indeed, it is in the epistemological studies that Grete Hermann elaborates her most original and significant contributions to the philosophy of science by proposing her own interpretation of causality and its role in quantum mechanics. Other aspects, such as Hermann's ideas on politics and ethics as well as on mathematics, are only briefly mentioned here in order to provide context and aid in the comprehension of her work. However, since these are not directly relevant to the three central questions, further studies are necessary for a full elaboration.

An answer to the three focal questions, on the philosophical, physical and historical value of Grete Hermann will be presented in the concluding chapter of the thesis, and the preceding chapters will pave the way towards this conclusion. The first chapter will focus on Grete Hermann as a historical figure, and focus on her life as a whole. The temporal aspects (life and personal experiences) provide the context for the timeless ones, such as her thoughts and ideas, whose examination will begin in the second chapter which is dedicated to the examination of her main work on the foundations of quantum mechanics Die Naturphilosophischen Grundlagen der Quantenmechanik.[16] In order to better comprehend the importance of this work, and Hermann's epistemological ideas in general, two other chapters will follow. The understanding of the philosophical context of Hermann's ideas will be elaborated in the third chapter, while the forth will pursue a study of Hermann's ideas of causality by comparing them with the ideas of some of the fathers of quantum mechanics, such as Werner Heisenberg and Carl Friedrich von Weiszäcker.

[13] Jammer (1974), p. 208-209.
[14] Before writing on Hermann, Jammer exchanged several letters with her and she reacted positively to his understanding of her proposal, stating that it could not have been explained better. Cf. PPA (1/GHAJ000010)
[15] E.g. Soler (1996), Soler (2009), Seevinck (2002), Herzenberger (2008).
[16] Hermann (1935).

All this research will result into a wider contextual acknowledgement of Grete Hermann’s importance and why she deserves more attention. This thesis shows the importance the study of Hermann’s work can have for historians, philosophers and physicists (and, indeed, for whoever might be interested). Much is therefore to be achieved, let us thus begin.

1. Understanding Grete Hermann

"ein Milieu wie es sich in Göttingen bietet" [17]

Letter from Leonard Nelson to David Hilbert, Mein Glaubensbekenntnis,

29. December 1916.

The mutual relationship between life and ideas is evident in Grete Hermann's life; her political and philosophical ideas influenced most of her choices in life; and vice versa, the experiences she had altered her understanding of politics and science. Grete's life would be interesting in its own right from a historical perspective, since she was an active, emblematic protagonist of her times. A woman, educated in mathematics and philosophy, who dedicated her life to the application of socialist ideals, is both unusual, and emblematic of the great changes of the 20th century. From her life we can gain many insights to what had been called "the short century"[18]; from the movement of resistance to the national socialist regime, to the socialist involvement in educational structures and the academic conditions for women.

Although there are many aspects of historical interest this biography could raise, the main focus will be on the biographical data that might help us understand her thought on natural philosophy and quantum mechanics, while other details will only be outlined. The aim of this chapter is to set the stage for Grete Hermann's ideas, to glance at the era she was living in and at the events and people who influenced her. In these pages we will encounter the main intellectual protagonists of her life, from Nelson to Heisenberg, and get a sense of the role her philosophical conviction played in her decision making. The chapter will endeavor to furnish all the elements that might be useful for further analysis of Grete Hermann's ideas.

A renewed investigation of both the primary and secondary sources has been chosen as the most fruitful method to tackle the complexity of Hermann's life; because of the scarcity and the superficiality of most biographical notes on Grete Hermann, a personal attentive study and interrogation of the primary sources constitutes the nucleus of this study. The study of the personal archive[19] contributed both to the evaluation of the present biographical notes on the subject, and

[17] "a milieu such as the one offered in Göttingen" Letter from Leonard Nelson to David Hilbert, Mein Glaubenbekenntnis, 29. December 1916 in Peckhaus (1990), p.125. (author's translation).

[18] or "the age of extremes". See Hobsbawn (1994).

[19] Hermann's Nachlass is kept in the Archiv der Sozialen Demokratie (AdSD) in the Erbert Stiftung in Bonn.

also unearthed new relevant events in her life, providing a new perspective on her life, and background for her ideas.

1.1. Early years

Grete Hermann was born on the 2nd of March 1901. The first year of the new century, a century that would see the German population involved in two wars, which for the first time enveloped the majority of the world. It was an age of extremisms, of ideas and ideologies that could change the political status quo: it was an age of dramatic change. Grete was one of the unfortunately forgotten protagonists of this century of tensions, who, while expressing the spirit of the time, also contributed to it with her own original ideas.

Born in Bremen in a middle class protestant family, she was the first girl following the birth of two boys, which made her father very happy[20], and after her three other girls followed. The father, Gerhard Hermann, was a tile merchant and sailor; her mother devoted much time to her religion. The young Grete appeared from childhood to be an especially thoughtful girl. Her sister, Maria Smolling, recalls her as a serious girl, never playing with dolls, reading most of her spare time, and able to narrate wonderful stories.[21] She started doubting the existence of God from a young age; she expressed her first doubts on religion when in 1914 she was confronted with the start of the First World War, and saw the ineffectiveness of her mother's prayers in comparison. Although Grete had a critical attitude towards religion (that later caused her to leave the church), her mother never found her behavior disrespectful and still believed in Grete's fundamental christianity. Her father also appears to have been a pious man; he gave up his bourgeois life in order to get closer to God, a decision that Grete later commented upon in the following way: "In 1921, after a spiritual search and difficult times personally, my father decided to break with the bourgeois life. He left my mother his business and everything he owned, and he wandered around as an "itinerant preacher" - as he called himself - with long hair and beard, woolen jacket, short trousers, and galoshes. When not wandering he lived alone meditating. " [22]

Both parents valued education highly; they encouraged their children toward study and critical thinking; the children had a separate room for doing their homework and "Ich dressiere

[20] Cf. Maria Schmolling, "Erinnerungen aus der Kindheit an meine Schwester Grete Henry Hermann als Versuch einer Beantwortung eines Fragebogens" (February 1993), in AdSD.
[21] Cf. Ibid.
[22] Hermann (1953), p. 180. (author's translation).

meine Kinder mit Freiheit!”[23] (I train my children with freedom) was the father’s educational motto. Grete went to the Gymnasium (Standard German high school), which at the time was still rather uncommon for girls[24]. Official documents show that she completed the exam to become high school teacher in 1921[25], but she seems not to have worked as such until later years. In fact, after graduating from school in 1920 she enrolled for the study of philosophy and mathematics at the University of Göttingen, where her two brothers[26] also studied.

Grete grew up during the dramatic years of the First World War, protected by good economic conditions and the love of her family. These years would always stay in her mind, and she would maintain a close relationship to her family her entire life. It is in these years that she experienced for the first time the power of knowledge and education.

1.2. A young mathematician in Göttingen

The Göttingen, where the young lady decided to move in order to study mathematics, was at the time Hilbert’s Göttingen. It had been an important centre for mathematics before, with Gauss and Riemann as main protagonists, and when in 1921 Grete entered the department of Mathematics it was centered around David Hilbert’s charismatic figure and his programme. The normal view if his porgamme was the endeavour of “einer Neubegründung der Mathematik durch den Nachweis ihrer Widerspruchsfreiheit mit Hilfe einer zu diesem Zwecke aufgebauten Beweistheorie.“[27](a new foundation of mathematics supported by the proof of its internal consistency, thanks to a theory of proof constructed for this specific purpose). However, a look into the social and intellectual context, leads to a different definition of his programme. [28] Hilbert can be seen as the central figure in the faculty of mathematics, trying, and partially succeeding, to direct the philosophy department towards his own interest, which he did first with the selection of Husserl, and then with the professorship of Leonard Nelson. He was aware of the important role philosophy would play in the elaboration of his axiomatic method; philosophy could offer at the same time a useful tool for the clarification of the meaning of mathematical symbols, and justification for the axioms. Nelson’s philosophy, or critical mathematics, represented an example of the systematic and mathematically

[23] Hermann (1953) , p.198.
[24] Cf. Venz; only 20 years earlier the woman who became her teacher, Emmy Noether, had not been allowed to enter the gymnasium. It is also interesting to note that all the official school documents were pre-structured for boys, and in her case they had been overwritten with female particles.
[25] „Zeugnis der Lehrbefähigung für Lyzeen“ (3.3.1921) in AdSD.
[26] One became after 1945 professor of mathematics in Marburg. Cf. Miller (1995), p.12
[27] Peckhaus (1990), p. 2.
[28]Cf. Ibid.

oriented philosophy that Hilbert wished for. The Hilbert programme in a broader sense was not limited to mathematics, but settled on an interdisciplinary ground, including philosophy and physics, and assigned to the relation between mathematics and critical philosophy a particularly crucial role. [29] It had been Hilbert (together with Klein) who in 1915 invited Emmy Noether to Göttingen and it was Hilbert again who interceded numerous times to ensure a professorship for Leonard Nelson.[30] Both Nelson and Noether had been accepted in Göttingen University thanks to Hilbert, and both became guiding intellectual figures for Grete. Thus, indirectly, Hermann became part of Hilbert's project. Consequently, her work also starts from the intersection of mathematics and critical philosophy and could be considered as part of Hilbert's interdisciplinary programme. She had only little direct contact with Hilbert, since she only followed a class of his in the first years of her study in mathematics. [31] Her attention was soon captured by Emmy Noether's work. Grete became her first doctoral student, graduating with a dissertation on Die Frage der endlich vielen Schritte in der Theorie der Polynomideale, which is considered an important pioneering contribution to computational algebra. [32] In Emmy Noether she found intellectual and emotional support; the two appear to have had a positive and close relationship - as fondly recalled by Hermann in her memoirs she could always count on Noether's support.[33] More controversial and temperamental was the relationship of Grete Hermann with the other important intellectual figure in her life that she met in these same years, Leonard Nelson. Her brother had taken Nelson's class a year before and had been annoyed by Nelson's dogmatism; nevertheless, he suggested him to Grete. In 1921 she followed Nelson's seminar on The typical thought errors in philosophy ("typische Denkfehler in der Philosophie") . Although initially fascinated by his way of thinking, she was skeptical towards his "eingebildet" (arrogant), authoritative attitude and the numerous rules which were imposed on the class[34]. Nonetheless, in the Winter of 1921/1922 she was again sitting in the benches of his class on "Übungen über Religionsphilosophie" (philosophy of religion). She admired Nelson's critical thinking and especially his method[35], though at the same time was scared by the

[29] "den Zusammenhang zwischen Mathematik und Philosophie zu pflegen, darin habe ich jeher einen Teil meiner Lebenaufgabe erblickt" in Peckhaus (1997), p.8.

[30] More is to be said about Hilbert's interceding in favour of Nelson. To what had been called the „Nelson's affair"we will return later in chapter 3.

[31] Lecture on set theory in winter 1923-1924. Cf. Vorlesungsbescheingung (28.4.1925), in AdSD.

[32] Cf. Herzenberg (2008), p. 5.

[33] Cf. Hermann(1985).

[34] Nelson's rules were punctuality, regular participation and the fact that the discussion had to go on until late at night. Grete Hermann expresses her critical thoughts on these rules, but also expresses a complete approval of his last rule; namely „die Aufforderung dich nie aus Furcht vor Blamage vom Antworten abhalten zu lassen". (the encouragement to never detain from answering because of fear of disgrace) Cf. G. Hermann (1985), p .180.

[35] Nelson's philosophical method was, following Fries, the regression to principles (cfr.chapter 3). It's unclear whether Grete is here referring to his philosophical method or his method of teaching philosophy (the Socratic Method, "he

results this could bring. [36] A strange fear captured her, when confronted with the dilemma of having to choose between Nelson's philosophical method, in which she believed, and the security and hope of religious representation. In her own words the dilemma was: "The fear that Nelson might have been right and that my confrontation with him would have lead me to the alternative (dilemma): either I had to give up the hope in a worldview consistent with the religious life and consequently draw disagreeable ethical consequences or to betray the method of philosophy. As long as I at the time knew about it, I was convinced of the certainty and necessity of this method."[37] Overcoming this fear thanks to Nelson's philosophy[38] was a fundamental step in her life, and most of her philosophical work can be seen as an elaboration of this single step. However, it took her some time to undertake this important step. First she avoided Nelson's classes and then she moved for a year to Freiburg University, where she studied with the theologian Karl Barth, and only in 1924 did she return to Nelson's seminars. As she deepened her study of the work of Friedrich Fries, Nelson's teacher, her fear faded away; Nelson supported her and after many vicissitudes[39] she passed her final exam under his supervision. The collaboration between the two could now begin; Nelson asked Grete to supervise the critical edition of his works[40] and she accepted, yet not without the original hesitation. The critical study of Nelson's work kept her busy until the last years of her life, yet even in the final agreement with Nelson's ideas, she never lost her initial critical attitude toward the Friesian philosopher.

1.3. Politics, education and exile

The encounter with Nelson was also fundamental in Grete Hermann's life from a personal and political perspective. In 1917 Leonard Nelson founded the Internationale Jugendbund (IJB), a political union whose guiding principles stemmed from Nelson's understanding of socialism. The Bund found it roots in Kant's philosophy and proclaimed freedom and equality, and in particular the

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encouraged his pupils to do their own thinking and introduced the interchange of ideas as a safeguard against self-deception" Nelson (1949).

[36] Cf. G. Hermann, Erinnerungen an Leonard Nelson in AdSD.

[37] Ibid.

[38] „Durch Nelsons Herausforderungen habe ich es allmählich gelernt, mir Schritt für Schritt den Mut zur Wahrheit zu erkämpfen, der dazu gehört, sich einer als zwingen anerkannten Denkmethode nun auch rücksichtslos im eigenen Denken anzuvertrauen“ Ibid. (author's translation)

[39] Nelson wasn't allowed to sit for the Staatsexamen.

[40] Nelson(1975).

belief in the power of human reason[41], as its central tenets. The members of the IJB were also active in the labour unions of the SPD (Sozialdemokratische Partei Deutschlands, The Social Democratic Party of Germany). When in 1925 the SPD stopped this collaboration, Nelson made the decision to create his own party: the ISK, internationale sozialistische Kampfbund. Similarly to the IJB, in this party the lifestyle of its members was regulated by strict rules: the members were required to be vegetarian and show respect for animals, they had to leave the church, abstain from alcohol, and live following the socialist beliefs, such as egalitarianism and the construction of a social ownership. Given these strict rules it is not surprising that the number of members remained small, never exceeding 300 people, but it could boast around 1000[42] external supporters (amongst them even Einstein). Many women were members of the party[43]. One of them was Minna Specht, close friend of Grete Hermann, and "right-hand woman" of Willi Eichler, who took the leading role after Nelson's death.

Grete avoided joining the ISK until after Nelson's death in 1927, again because she feared his authoritative style; she was determined to always only follow her own ideas. After joining, the ISK became a fundamental part of her life, determining some of her most important decisions. She soon started writing in the socialist newspaper "der Funke", and working in the adults' and children's school in Walkenmühle. The school was founded by Leonard Nelson and now directed by the pedagogue Minna Specht, adherent to socialist ideals of education. This did not last long; when in 1933 Hitler came to power, he intensified his fight against the socialist movements and in March 1933 the school in Walkemühle[44] was closed. The ISK had been prepared to work and fight illegally, and in those years all its efforts were directed towards active resistance of Hitler's regime.[45] Nevertheless, there were limited possibilities for resistance in Hitler's Germany; in the end of 1933, the ISK's leader Willi Eichler had to flee. Grete also decided to leave Germany in 1936, first moving to Denmark, where Minna Specht together with Gerard Heckmann had re-started the Walkenmühle children's school in Östrupgård. The school suffered from several problems, such as the isolated location and the illnesses of several students, and it was finally closed in 1937.[46] From there, Grete moved first to Paris and then to London. London was at the time the main centre for political refugees, nucleus of many ISK's members from Germany, and here Willi Eichler had

[41] Cf. Lemke-Mueller (1997), p. 12.
[42] This is the estimation of Lemke-Mueller, a member of the party (Lemke- Mueller (1997) p.13)
[43] Cf. S. Miller (1995).
[44] School financed by offers, personal contribution of the members, and by the generosity of some rich merchants such Hermann Roos and Max Wolf, cfr. Venz, p. 15. The educational duties constituted a fundamental part of Nelson's philosophical ideas brought into practice.
[45] Cf. Lemke- Mueller (1997), p. 15.
[46] On the educational system and the history of the Walkemühle school see Ziechmann (1970).

founded the "Union Deutscher Sozialistischer Organisationen in Grossbritannien". Grete was actively involved in the political work of the ISK during which she possibly met Eduard Henry; they married, but had no children. There is little known about him, possibly he was a member of the party as well, as her social life revolved around the group.[47]

1.4. Back home: the final years

It is likely that it was mainly convenience (to obtain the safety offered by an English citizenship?) that convinced Grete to marry, because as soon as the war ended she got divorced from Eduard Henry and returned to Germany. However, from now on she kept the surname Henry.[48] She moved back to her hometown, Bremen, and during those years she got intensively involved in the education of the new German generation. Firstly, she participated in the founding of the "Pedagogische Hochschule", of which she became the director.

From the memories of a student at the school we can get exactly the sense of chaos, reconstruction and belief in a better future that could be achieved through education that teachers and students at the time shared. "We were lucky that she came in this chaos! She could prop us up anew. Please consider: hunger, cold, undernourished until becoming ill, with a family destroyed from the bombs or the division. Every one of us was weighed down by different experiences of the war at the front, at home or during exile and found himself in a broken worldview in search (of something).[...] We were all so different in our personal experiences, opinions, beliefs and mistrusts. Grete Hermann took us all seriously, so as we were. […] Grete Hermann was the embodiment of tolerance and limpid authenticity. She formed us through being our example. She was self-determined, rationally self-determined.“[49]

Although at school she was teaching mainly physics and mathematics, her own research involvement with these subjects appears to have stopped with her self-imposed exile to Denmark, and the subsequent death of Emmy Noether. During the first years in Copenhagen she kept regular contact with important physicists and mathematicians, such as Werner Heisenberg (whose involvement in Hermann's story we will see later), Carl Friedrich von Weiszäcker, (student first of Heisenberg and then Bohr) Paul Bernays, (a close collaborator of Hilbert) and Pascual Jordan. However, the volume of letters became lessened over the years, and no letter concerning matters of philosophy or physics can be found after 1937. Her life at that point was mainly revolving around

[47] Cf. Hezenberger(1998).
[48] Cf. Hoennecke (1995), p. 28.
[49] Ibid , p. 28-29 (author's translation).

her political and educational mission. In 1953 she published Nelson's work on which she had been working since the early twenties with Minna Specht and published an article about The Significance of Behavioural Study for the Critique of Reason in the journal Ratio.[50] She became a member of the SPD and worked together with Willi Eichler on the Godesberger Programme.[51] She was part of the PPA and active in its Erziehungsprogramm. As Minna Specht got seriously ill, Grete moved back to her hometown Bremen, where she took care of her dear friend and colleague until Minna's death in 1961. It is in Bremen that Grete also died, on the 15th of April 1984, at the age of 83.

The limited works on Grete Hermann currently available state this: Grete Hermann's interest in the epistemological matters concerning quantum mechanics and the nature of causality slowly waned in favor of her political ideas and personal life, between the start of the second world word and 1984. [52] These works depict a new Hermann (or Henry-Hermann) returning back to Germany, who had forsaken the epistemological problems for her political, social and educational engagements.

However, it can be seen now that this view is inaccurate. While it is true that Hermann's political and pedagogical engagements increased during the war and became a main part of her life in post-war years, it is not true that she relinquished her interest in the philosophical challenges brought about by quantum mechanics. In fact, an attentive analysis of Grete Hermann's archive brought to light new documents that show this. Contrary to what is generally known, reading through Grete's letters in the last years of her life, we discover that she still cultivated ideas and an interest in the subject. In 1956, Grete expressed in a letter to her old friend Carl Friedrich von Weiszäcker the wish to continue and further her work on quantum mechanics. [53] She then requested leave of absence from the school and explained her project to join him for a year at the Max Planck institute (either in Munich or in Stuttgart depending on where he would have been). After she received permission from the school, she wrote another letter to von Weiszäcker where some more precise plans were made, even though Weiszäcker sounds busy and less enthusiastic about the

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[50] Hermann (1973).

[51] The Godesberger Progam, was the program followed by the SPD (sozialdemokratischen Partei Deutschlands) between 1959 and 1989. Grete Hermann and Nelson's collaborators were particularly important for the elaboration of the ethical foundation of this program. Statements of the program like "der Demokratische Sozialismus […] will keine letzten Wahrheiten verkünden, und zwar nicht aus Verständnislosigkeit oder Gleichgültigkeit gegenüber den Weltanschauungen oder religiösen Wahrheiten, sondern aus der Achtung vor der Glaubensentscheidungen des Menschen, über deren Inhalt weder eine politische partei noch der Staat zu bestimmen haben.", have been clearly diktated by the followers of Nelson's ethical socialism, and have been influential in the history of SPD. Cf. Albers (2001).

[52] When the last letter to Werner Heisenberg in AdSD is dated.

[53] „Mir geht es darum, die Ansätze, dich in früheren Ansätzen gewonnen habe, grundsätzlich zu vertiefen und damit zu überprüfen" letter to Weiszäcker, 30.06.1956 in AdSD.

project. No other information could be found about this project and whether she joined him at the Max Planck institute to renew her study on the philosophical problems of quantum mechanics. From the lack of further documents, or of any result of this possible year of study, it could be guessed that she had never fulfilled her wish to continue working on the philosophical foundations of quantum mechanics. A reason could have been the illness of her friend Minna and the numerous responsibilities she had in her home town at the time. It would have been really interesting to study Hermann's mature thoughts on the philosophy of quantum mechanics, how her ideas evolved and how they could be linked to her more mature political and philosophical ideas. However, the discovery of these letters already sheds a different light on the development of her interests and ideas, and we see that claiming Grete Hermann was completely disinterested in epistemology in the post-war years is inaccurate.

Though a deeper investigation of Hermann's biographical data and personal experiences as a protagonist of her time could provide valuable material for other historical studies, the work here provides the historical ground necessary to start answering the three questions on the historical, philosophical and foundational importance of Grete Hermann posed herein. From the description of her biographical data the first historical question of "who was Grete Hermann?" has been answered, with some new information added to the existing literature. Here have been mentioned aspects and events, such as her encounters with Nelson and Heisenberg, and her critical temperament, that are relevant to the philosophical question (is Hermann's interpretation of causality fruitful? How does her work relate to the development of philosophy and its relation to science?). Unfortunately, we are not able to read Hermann's last views on the philosophical problems of quantum mechanics, however, in her early works there is still substantial material present for consideration on both physical and philosophical grounds.

2. The Foundations of Quantum Mechanics in the Philosophy of Nature

> In vielen Theilen ist seine Untersuchung bis zur Vollendung gediehen, in andern müssen wir ihn verbessern, und in mehreren ihm die fehlende Vollendung zu geben suchen. Dieser letzte Zweck aber noethigt uns, seine Arbeit einer gänzlichen Umarbeitung zu unterwerfen, zuletzt einzig„ weil er die Natur des inneren Sinnes des Bewusstseyns und der Reflexion nicht richtig erkannt hat, wovon sich die Folgen bis ins Einzelste über das Ganze verbreiten.*"*54

In 1935 the publishing house Öffentliches Leben already active in the publication of Friesian works[55], published Die naturphilosophischen Grundlagen der Quantenmechanik (the foundations of quantum mechanics in the philosophy of nature) by Grete Hermann[56]. It was only later acknowledged that this essay contained the discovery of the circularity in von Neumann's proof of the impossibility of hidden variable theories. However, that was only a minor part of the essay. In fact, in this first work of epistemological character, Grete Hermann did not at all restrict herself to only discovering a mistake (i.e. making an unnecessary assumption) in the work of one of the greatest mathematicians of her time. Rather, the majority of her work was devoted to questioning the nature of causality, the meaning of quantum mechanics for the theory of knowledge, and its relationship to classical mechanics.

Unfortunately, the paper was not widely read, and only a shorter version was later republished in "die Naturwissenschaften." Only the main line of argument of the essay is left in this abridged version, while many other important aspects, such as the relation to Kantian philosophy, and the disproving of von Neumann's proof, are completely left out. This abridged version is the only part of Hermann's reflections on the foundations of quantum mechanics that had the fortune to be translated in 1999 into English[57] (by Dirk Lumma as he was still a graduate student at the Massachusetts Institute of Technology), but was only published in a minor journal.[58] Therefore, even to the few who had the fortune to read the translation, some of the richest and most thought-

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54 Fries over Kant. Fries (1967), Bd 4. 105 ff. In Bonsiepen (1997)

55 "öffentliches Leben" published in the same period, for example, was the second edition of "Neue oder Anthropologische Kritik der Vernunft" by Jakob Friedrich Fries. What is remarkable is that Hermann's work on quantum mechanics is considered as part of the work of the Friesian school. The interaction between Fries' ideas and Hermann's work will be discussed at length in chapter 3.

56 An identical copy was published in the same year also in "Abhandlungen der Fries'schen Schule, Neue Folge, 6, pp. 69-152.

57 While a complete, detailed translation, had been made into French. See Soler(1996)

58 The Harvard review of philosophy is an annual journal edited and published by undergraduate philosophy students at Harvard University.

provoking parts of the essay are still concealed. [59] This chapter will try to fill the gap by giving a detailed analysis of the complete essay, restoring the initial unity of the work and evaluating the parts that were left out in the abridged version. In the course of this analysis, the relevance of the paper, in which Hermann's disproof of von Neumann's theorem and her interpretation of causality is presented, become evident. In no other work did she express in such detail and depth her ideas on the subject. Therefore, this essay has been chosen as the focal point for discussing Hermann's ideas on physics and epistemology.

In the initial remarks added to the first edition, Grete Hermann stresses, in true Friesian spirit[60], the mutual dependency of physics and philosophy and how it would be possible to bridge the existing "entfremdung" (alienation) between the two fields. She then thanks Professor Heisenberg for his "willingness to discuss the foundations of quantum mechanics"[61] and for the help he provided to her subsequent studies. Here, some historical background would be useful. Heisenberg was working as a Privatdozent[62] in Göttingen between 1924 and 1927, where Hermann was at the time a teacher assistant for Leonard Nelson, and working on her dissertation under the guidance of Emmy Noether. In this context, the young mathematician-philosopher might easily have had contact with one of the founding fathers of a theory that was shaking our basic assumptions about nature, and appeared to contradict the Kantian category of causality - an aspect of particular relevance for Hermann as a philosophy student.

Hermann was deeply interested in the new developments in physics and their mathematical and philosophical implications. If it had not happened before in the corridors of Göttingen university, Heisenberg and Hermann had the occasion to meet and discuss in depth some of the controversial aspects of quantum mechanics in 1934, a year before the publication of her essay, at a seminar in Leipzig[63], where all the main promoters of the theory (from Swiss Félix Bloch to the young Carl Friedrich von Weiszäcker) were also present.[64] Probably, Hermann presented Heisenberg with her demonstration of circularity in von Neumann's impossibility proof, and along

[59] The situation is different for the French reading public as a precise and complete translation of die Naturphilosophischen Grundlagen was made by Lena Soler in 1996. The German public can naturally read the original, but it is not readily available. No translations in other languages are known.
[60] Fries understood philosophy and natural science as standing next to each other. (cf. letter to Apelt in Gregory (2006)). For now I should only mention the influence of Fries' philosophy in Hermann's work. A detailed discussion on Hermann's relation to the philosophy of Fries and Nelson will follow in Chapter 3.
[61] Hermann (1935), p. 2.
[62] Privatdozent or Private lecturer is a title conferred in Germany to people who hold all formal qualifications to become a university professor but are not one yet, and work independently for the university.
[63] Leipzig was in these years becoming, along with Copenhagen, one of the most important centres for the new physics.
[64] Cf. Soler(1996), p. 13., Heisenberg (1971).

with it they discussed the philosophical foundations of quantum mechanics. After the conference, they carried on the debate long distance, sending each other letters for many years. This dedication to Heisenberg firstly suggests that Hermann highly regarded him, and secondly, she did not consider her discovery and ideas to be in strong opposition to the ideas of the father of the uncertainty principle. Likewise, Heisenberg devoted some decades later a chapter in his book Physics and Beyond to the discussion of Grete Hermann's ideas.[65]

2.1. Is it possible to overcome the limits posed by quantum mechanics?

Hermann starts tackling the epistemological problem connected with the theory of quantum mechanics with the following description of the situation at the time:

> "Modern physics, in its bold and successful advance, shook positions considered by classical physics untouchable foundations for the study of nature. To these positions critical philosophy, with its a priori foundations of experience, gave an explanation and meaning from the perspective of the philosophy of nature. It is said that experience decided the situation; the achievements of physics in this century are celebrated as the important victory of experience over any preconceived opinion. This is viewed as a liberation from the prejudices which covered empirically based hypothesis in the shining but deceptive clothing of eternal truths. EINSTEIN explained that he was forced by the facts to recover the concepts of space and time from "the Olympus of the a priori", to repair them and set them back in a state in which they could be useful again. The exponents of quantum mechanics claim that a corresponding correction must be made to the law of causality."[66]

This is the problematic situation Hermann's starts with: in its development quantum mechanics had presented mankind with astonishing results, unimaginable from the long accepted perspective of classical mechanics; already with Einstein's theory of relativity, the concepts of space and time had lost their absolute meaning. With quantum theory, the possibility of a Laplace demon (i.e. of a complete determinate causal description of the world), has to be given up. These

[65] The discussion between Heisenberg, von Weiszäcker and Hermann as described by Heisenberg will be analyzed at length in chapter 4.
[66] Hermann(1935), p. 7 (author's translation).

probabilistic aspects of quantum mechanics challenge the Kantian understanding of causality as necessary condition for our experiencing the world.

Laplace's thought experiment was representative of the principles classical mechanics was built on. If we imagine a demon[67] who has a complete knowledge of the world, this demon given the laws of nature and the knowledge of the initial conditions would also be able to give a perfect prediction of all future events. Although the existence of the demon could have been theoretically possible in the classical framework, since the development of quantum mechanics it became an unrealistic dream. Together with this renunciation of an unlimited possibility of predicting every future event starting from its causes, also absolute causal relations get into problems. In fact, in this case the category of causality as a necessary condition for human understanding seems to fail. For Grete Hermann, this became first evident with the "dualisms experiments", by which she meant all the experiments showing a wave-particle duality, such as the double-split experiments; light quanta which, when for example asked to pass through a double-slit present both a corpuscular and a wave like behavior, as a consequence the classic distinction between radioactive processes (with the movements of small particles) and wave processes no longer applies. "The particle picture and the wave picture are merely two different aspects of one and the same physical reality"[68], states the complementarity principle as enunciated by Niels Bohr. [69]

Since the wave and the particle constitute two mutually exclusive aspects of the same event, a complete description of one state independently from the other is not possible. While in classical physics it is possible to measure quantities independently from each other, and the results of one measurement will not interfere with the results of the second one, this is no longer possible in quantum mechanics. In the state function we have the expression of the mutual dependency of quantities. The particle and the wave description are complementary to each other and one cannot be described without the other; they limit each other. Therefore, it is not possible to determine exactly both characteristics of the quantum behavior as a particle or a wave (position and momentum) at the same time, since determining one would interfere with the value of the other.

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[67] Laplace himself used the word 'Intelligence', the word 'demon' was a later addition. Here Laplace's description of the "demon though experiment": "We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes". Laplace (1951)p. 4.

[68] Jammer (1974), p. 68.

[69] More about Bohr's view on complementarity in Faye (2008).

Heisenberg gave a mathematical (quantitative) expression of these limits in the predictions of quantum processes through his uncertainty principle ($\Delta x \, \Delta p \geq \frac{\hbar}{2}$): there will always be an uncertainty or indeterminacy[70] of at least one half of ħ, the reduced Planck constant ($\hbar$ = h/2π), in the determination of position (x) and momentum (p) of an atomic process.

This is the situation Hermann is confronted with, and the question she starts asking (and was part of an active debate about at the time) is whether or not it is possible to overcome these limits in the description of quantum events ("sind die Schranken überwindbar?"). Are the limits in the predictability intrinsic to the nature of the very small world, or is the probabilistic aspect only an expression of our lack of knowledge, and Laplace's Demon still imaginable? Would the proof of insurmountability of these limits then dismiss the principle of causality?

The questions which Hermann is asking are connected to the issue of whether quantum mechanics is complete or not, and whether other causes or characteristics, which would explain the indeterminate aspects of quantum mechanical results (i.e. the existence of hidden variables), should be sought. " What prevents us believing that through the expansion of physical knowledge new formulas and rules will be developed, which, together with the current formal approach, will make precise predictions possible again?"[71] This would open the way to the research of hidden causes, which would then allow a determined, not probabilistic, description of the situation.

The possibility of other hidden characteristics, capable of explaining the statistical predictions of quantum mechanics, has often been proposed as a way to avoid giving up on the classical understanding of causality. With the hypothesis of these hidden causes, the probabilistic character would be considered as arising only due to our lack of knowledge (epistemological probability), and as such no rethinking of the category of causality would be necessary. The causality principle would remain inviolate; we simply do not know enough. At first, one would expect that Hermann, a follower of Friesian Kantianism, would carry on this argumentation to protect the Kantian category of causality, but as we will see, she takes a different route in defense of the Kantian causality principle.

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[70] Heisenberg himself used the terms Ungenauigkeitsrelationen and Unbestimmtheitsrelationen, which would be more properly translated in 'inaccuracy relations' and 'indeterminacy relations', respectively. Cf. Hilgevoord, Uffink (2001).

[71] Hermann (1935), p.19 (author's translation).

2.2. Mathematical argumentation: the refutation of von Neumann's impossibility proof

As explained in the introduction to the paper, Hermann's aim is not a critique on a physical level but on a philosophical one, where the physical knowledge can be a "wertvolle Anregung und Befruchtung der philosophischen Arbeit"[72] (valuable stimulus, and fertilization of, the philosophical work). She does not believe that the causal principle can be dismissed, nor defended, on an empirical level, as this would contradict the a priori character of causality claimed by Kant.[73] With this conviction, she proceeds to show how mathematical and statistical arguments have failed to defend the causality principle and consequently, that only philosophy can answer the question of whether it is possible to overcome the limits in the predictability of quantum mechanics.

First, she addresses the statistical arguments, which describe an absence of the individuality of particles, and consequently also the impossibility of them possessing individual characteristics (Merkmale). By contrast, Hermann underlines that, while it is true that systems can be considered as a group of indistinguishable particles following a statistical behavior, in which two particles can be swapped without changing the behavior of the system, this does not exclude the possibility that in looking at the particles individually, they may present determinate characteristics. Similarly goes her refutation of arguments derived from the interpretation of the wave-function as a probability function, second, and third, of Dirac's theory of "Maximalbeobachtungen"[74]. All these proposals do not offer a clear answer to the question whether it is fruitful to look for further hidden causes. Last, but not least, this is also the case with the greatly awarded von Neumann's proof of the impossibility of hidden variable theories. Grete Hermann shows a flaw in this proof, and concludes that notwithstanding the fact that the mathematical formalism has been standing the test of time and can therefore be accepted as a valid mathematical description of nature, it cannot be deduced that further undiscovered relations with a different mathematical formulation are not possible.[75] The mathematical formalism alone is not able to answer the question of whether the limits in the predictability of quantum mechanics are insurmountable or only there due to our lack of knowledge.

Von Neumann's impossibility proof was the generally accepted formal answer to the question of the existence of hidden variables, and Hermann proceeded to show it is unsound. In

[72] Ibid., p. 9.
[73] For Kant, the concept of cause had to "either be grounded completely a priori in the understanding or be entirely abandoned as a mere chimera", Kant (1787), A91-2/B123-4.
[74] Cf. Ibid.
[75] Cf. Hermann (1935), p.34.

1931 John von Neumann had published in his celebrated book on the Mathematische Grundlagen der Quantenmechanik[76], a proof of the impossibility of theories which, by using the so-called "hidden variables", attempt to give a deterministic explanation of quantum mechanical behaviors. He provided "what seemed to be a bulwark protecting the Copenhagen Interpretation against the claim that determinism could be recovered"[77]. Indeed his theorem constituted a mathematical legitimation of what the majority of physicists already believed, and it was promptly accepted. Only a few scientists challenged the proof in the following years. Subsequent to Grete Hermann, George Temple in 1935 and Hans Reichenbach in 1944[78] questioned its logical grounds. Nevertheless, the fact that from von Neumann's proof it was not possible to deduce the impossibility of all hidden variable theories would not be universally acknowledged until Bell's paper in 1966.[79]

It is interesting to note that Hermann's argumentation does not differ substantially from the one presented by John Bell over 30 years later. He had, however, no idea of her work, which is not surprising, given the unsuccessful story of Hermann's essay, and Bell's inability to read German.[80] In fact, in 1966 Bell addresses his article to the majority of physicists, who still believed that "the question concerning the existence of such hidden variables received an early and rather decisive answer in the form of von Neumann's proof on the mathematical impossibility of such variables in quantum theory". [81] Despite Bohm's creation of a working hidden variable theory, most physicists still believed in the consequences of von Neumann's proof. This shows just how readily and widely accepted the proof was, and is concurrent both with the limited questioning the proof received in the first place, and the fact that Hermann's discovery was unnoticed or ignored for so long – all reflect a tendency towards accepting, rather than questioning, von Neumann's proof.

With a distance of 30 years, both Hermann and Bell identified the same problematic assumption in von Neumann's proof. Von Neumann takes an overly limited definition of hidden variables theories, in which the final conclusion is already entailed. Hermann and Bell both address it in a simple and clear way, with Hermann stating:

> Von Neumann requires that for this expectation value-function Expt(R), defined using an ensemble of physical systems and producing a number for every physical quantity, Expt(R+S) = Expt(R)+ Expt(S). In words: The expectation value of a sum

[76] Von Neumann (1930).
[77] Caruana (1995), p. 8.
[78] Cf. Ibid.
[79] Written in 1964, the paper was not published until 1966, because of a bureaucratic mistake. Cf. Jammer (1974).
[80] Cf. Caruana (1995).
[81] Bell (1966), p. 447. Bell is himself quoting Jauch and Piron.

of physical quantities is equal te the sum of the expectation values of both quantities. With this assumption the proof of von Neumann either succeeds or fails.[82]

Or in Bell's words:

His [i.e. von Neumann's] assumption is: Any linear combination of any two Hermitian operators represents an observable, and the same linear combination of expectation values of the combination. This is true for quantum mechanical states; it is required by von Neumann of the hypothetical dispersion free states also.[83]

Von Neumann, when listing the characteristics of hidden variable theories, assumes that the linear combination of the expectation values equals the sum of the expectation values of the single observables. While this is the case in classical mechanics, it is not necessarily true for all quantum mechanical states. The additivity of expectation values appears at first very reasonable, but with an analysis of the specific case of quantum mechanics, it is not viable anymore. Experiments in quantum mechanics have shown that the measurement of a sum of non-commutative observables is not equivalent to the sum of the separate observations. From this nonadditivity of observations it follows that the additivity of observation values is not trivial at all. Bell demonstrates that not all hidden variable theories respect von Neumann's assumption, and therefore they are not all excluded by his proof.

In von Neumann's postulate, Hermann says, there is an explicit assumption that the subsample is made up of indistinguishable particles, but the hidden variables are exactly what would characterize a difference in that subsample. Von Neumann's proof is a petitio principi: he is assuming that which the proof is meant to demonstrate.

Bell and Hermann reach similar conclusions, Hermann focusing on the circularity, and Bell the arbitrariness, of von Neumann's proof.

"If one - just like Von Neumann - does not give up this step, then one has tacitly assumed the unproven presupposition that the elements of an ensemble of physical systems characterized by φ cannot have any distinguishing characteristics on

[82] Hermann (1935), p. 31 (translation of M. Seevinck).
[83] Bell (1966), p.449.

which the outcome of R is dependent. The impossibility of such characteristics is just the thesis to be proved. The prove thus runs into a circularity."[84]

"Thus the formal proof of von Neumann does not justify his informal conclusion.[…] It was not the objective measurable predictions of quantum mechanics which ruled out hidden variables. It was an arbitrary assumption of a particular (and impossible) relation between the results of incompatible measurements either of which might be made on a given occasion but one of which can in fact be made"[85]

Despite the similarity of the two demonstrations[86], their reception and dissemination in the scientific community at the time, and subsequent influence, differed dramatically. While Bell's proof gave fresh impetus to the discussion on hidden variable theories, and caused a re-evaluation of Bohm's proposal, Hermann's paper was ignored by the scientific community. Bell was aware of the importance his discovery had for the further development of hidden variable theories[87] and published in the well-known Reviews of Modern Physics. Hermann, on the contrary, writes her disproof in small letters, having stated previously that type face texts are only physical and technical considerations that the reader can skip without losing anything in the structure of the argumentation; in addition, in the second version she leaves that proof completely out. From this, it seems evident that Hermann herself did not think highly of the discovery.

It is remarkable that her discovery of the results of Neumann's proof not being acceptable anymore did not lead Hermann to different conclusions, both regarding the importance of her disproof, and the logical implications this had for her own ideas. One of the logical implications of disproving the impossibility of hidden variable theories, is of course that these are again possible. Given this discovery, we could imagine Hermann having elaborated her own alternative to the standard statistical interpretation, continuing on from the discovery of a circularity in von Neumann's proof, developing a new interpretation incorporating hidden variables, and at the same time saving Kant's category of causality. Hermann, however, shifts the discussion to a different level, maintaining, if not the impossibility of hidden variable theories, at least the absence of a need

[84] Hermann (1935), p. 33. (translation of M. Seevinck).
[85] Bell (1966). p. 449.
[86] Bell's paper naturally goes further than Hermann's simplistic proof. He includes the relation to the Jauch - Piron proof and discusses the limits posed by Gleason's theorem.
[87] "Bell's criticism of von Neumann's work prompted Bohm and Bib to construct a hidden variable theory independent of von Neumann's postulate" Jammer (1974), p.312.

for them. This line of thought is probably why Hermann assigned such little importance to her disproof – rather than disproving von Neumann's argument and proposing new consequences, she disproved the argument but agreed with the consequences. Hermann's work did not at all pave the way for hidden variable theories as Bell's proof several years later did, not only because her proof remained unknown, but also because of the theoretical background it is embedded in. Hermann does not use the proof of circularity in von Neumann's theorem as a reason to investigate the possibility of hidden variables further; on the contrary, she uses it to support her view that the question of whether or not one should look for other characteristics cannot be settled on empirical or mathematical grounds. She interprets the failure of this mathematical proof not as a reason to investigate further in the direction of what the theorem tried to negate, but merely as a failure of the use of mathematical reasoning to answer these sorts of questions. The question of the existence of hidden variables, or in Hermann's words, of whether it is possible to overcome the limits posed by quantum mechanics (without dismissing causality), can according to Hermann only be answered on a philosophical level.

2.3. A non-mathematical answer: the relative view

Hermann started her essay with three questions: 1) Is it possible to overcome the limits in the predictability of quantum mechanics? 2) Is it fruitful to look for further hidden variables? 3) Is Kant's category of causality, as a condition for human understanding of the world, dismissed by the new physical theory?

Von Neumann's proof supported a negative answer to the first two questions; however, with her critique of all the existing proofs and the discovery of a circularity in the one presented by von Neumann, Hermann showed that neither his proof nor any other mathematical method can answer these questions. The answer can only be given on a philosophical level. Given the principle of incompleteness of experience (Satz von Unabgeschlossenheit der Erfahrung), according to which our experience is never complete and we can always discover new characteristics, the only reason why the search for other characteristics might be deemed worthless is when the causes are already known ("dass man diese Ursachen bereits kennt"). [88] Based on this, when stating that in quantum mechanics it is not possible to overcome the limits of predictability we are faced with a dilemma: either the causes are known - but if so how could the lack of predictability of precise results in measurements on microphysical objects be explained? - or they are not known, and the search for

[88] Hermann(1935), p. 36.

further, as yet unknown, causes is valid and the limits possible to overcome. A hint for the solution of this dilemma is for Hermann to be found in Bohr's correspondence principle. The principle implies that classical terms are at the basis of the description of quantum mechanics as well as in classical mechanics.[89] In classical terms, when a measurement is taken, the instrument shows the result of the interaction between the measurement apparatus and the object. It follows that this is true in quantum mechanics as well as in classical physics. The existence of such a correspondent description gives the possibility to explain in detail events whose happening was not predictable beforehand. It means, according to Hermann, that all characteristics necessary for determining the result of the measurement are already there. In other words, she gives the only answer which is not in contradiction to the principle of incompleteness of experience - that the results of the measurement process can be explained completely, by going back to their causes, and that therefore the causes are already there.

Initially this answer might seem quite contradictory and strange ("befremdlich"): if the causes are already there why is it not possible to make complete predictions of future events? Hermann indicates that the principle of correspondence together with the uncertainty principle imply that predictions cannot go further than described by the formalism. In quantum theory only a limited description through classical terms is possible, though, through the measurement process it is still possible to go back to a complete description of the state that was not completely determined before. The measurement created a new "Zusammenhang", relation or context (of the observation). The conclusion is that quantum mechanics can give only a partial description of the situation. No complete description, as expected by classical mechanics, can be given, but only a partial one, from the perspective of the observation made by the physicist. Hermann calls this astonishing feature of quantum mechanics the relative view. The knowledge we can get from quantum mechanics is only relative to the context of the observation. This is why complete predictions are not possible, since the description of the situation is "only relative, and relative to the observation, which was only made at the moment of the measurement"[90] it not possible to know it beforehand. Only once the measurement is performed the causes can be reconstructed by the physicist.

Hermann explains the "relative character" of quantum mechanics by means of a thought experiment borrowed from her friend Carl Friedrich von Weiszäcker. Von Weiszäcker[91] asks the

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[89] More in Faye (2008).
[90] Hermann(1935), p. 41.
[91] Von Weiszäcker (1931).

reader to imagine an electron on a plane.[92] It is not precisely determined on which point of the plane the electron is and we use a microscope to determine it: the light deviated from the electron will get back to the microscope and register on a photographic plate. Then, imagine that the microscope only uses a single light quantum. In accordance with the wave-particle duality, the light quantum will on the one hand behave as a particle colliding with the electron and on the other hand as a wave, getting back to the microscope according to the laws of optics. Yet, if we put a photographic plate at the same distance as the microscope's image plane, therefore at the distance from which the wave starts, we will be able to determine the exact position t of the electron. However, in the impact between the electron and the light quantum, the initial impulse will have varied, and as such it will no longer be possible to determine it precisely. In the second case, we put the photographic plate in the focal plane instead of in the image plane of the microscope. In this case the photographic plane will present a sharp image, showing the exact direction from which the light entered the microscope. Given that the impulse of the light quantum was already known, the variation of the impulse of the electron could also be known. However, in this case the exact point of contact will be indeterminate. Although there is no difference in what happened with the electron in these two cases, the different experimental settings (different positions of the photographic plane) will produce different results.[93]

This thought experiment gives a visual representation of the relative character of quantum mechanics, and this means in Hermann's words that "dass man, je nachdem, wie man sich Kenntnis von dem beobachteten System verschafft, oder, wie wir dafür sagen können, je nach dem vorliegenden Beobachtungszusammenhang , für dasselbe System und für den gleichen Zeitpunkt - nämlich für das Elektron zur Zeit unmittelbar nach dem Zusammenstoß mit dem Lichtquant - verschiedene Wellenfunktionen erhalten kann."[94] If we had placed the photographic plate in a different position, we would have come to a different description of the same situation. The existence of these different, mutually exclusive descriptions, shows that depending on how we observe the situation, we can derive different wave functions. The knowledge of the situation we

[92] This thought experiment in some aspects resembles Wheeler's delayed choice experiment. (See Wheeler 1978). It might refer to "Heisenberg's microscope", where Heisenberg, who was von Weiszäcker's teacher, tries to deduce the uncertainty principle from a simple situation in classical optics. (See Heisenberg 1931).

[93] If no photographic plate is put at all, then we will be confronted with a third, different situation. In this case the wave function will represent a linear combination of the wave function of the electron and of the light quantum, consequently it will not be possible to describe them singularly but only in relation to each other. Cf. Hermann (1935), p. 45.

[94] Ibid., p. 45.

gain is therefore relative to the context of observation (Beobachtungszusammenhang). [95] As a consequence it is not possible to give a universal description of the situation, but only a context-dependent description. In this way Hermann claims to have answered her first two questions: the limits in the predictions of quantum mechanics are in principle insurmountable, not because of a mathematical proof that is negating the possibility of other causes or characteristics, but simply because all the causes are already known. Therefore, the dream of a Laplacean demon has to be given up, and the search for hidden variables has to be deemed futile. This relative view is initially difficult to accept, because it contrasts with the classical description we are used to, wherein the context of observation is irrelevant. However, given the correspondence principle, and the indeterminate character of quantum mechanics, the relative view presents a complete, although only perspective-dependent, description of the situation.

From this thought experiment we have learned that even though the event cannot be predicted beforehand, once a measurement is performed, all necessary causes appear to be already there and the result can be explained completely. This leads to the third unanswered question about causality: is causality as a pure concept of understanding - i.e. allowing us to get from subjective judgments or judgments of perception to universal judgments of experience - still tenable in quantum mechanics?

2.4. Is the causality principle dismissed?

A second substantial part of Hermann's essay on the Foundation of Quantum Mechanics in the Philosophy of Nature is dedicated to the analysis of the problematic aspects of quantum mechanics from the philosophical perspective.[96] In it, Hermann tries to answer her third question, formulated as: What are the consequences of developments of quantum mechanics for the theory of knowledge? Is the claim that quantum mechanics dismissed Kant's category of causality correct?

The first chapter concluded with two claims which seem to oppose each other. First, Hermann claims that the limits of the predictability of future events posed by quantum theory are insurmountable in principle. Secondly, that all events, no matter whether described in a quantum

[95] "Beobachtungzusammenhang" is translated by Lumma in "framework of observation". However, I here prefer the more literal translation "context of observation". More on the "relative view", as expressed by some modern supporters, in the conclusion.
[96] In specific, the perspective Hermann's chooses is the Philosophy of Nature of Fries and Kant. Chapter 3 is dedicated to the further clarification of this concept. For now it will suffice that she is analyzing the consequences quantum mechanics has for philosophy, and in particular for Kant's and Fries' critical philosophy.

mechanical framework or a classical one, necessarily follow from a cause. The two claims seem to contradict each other. On the one hand it is stated that there is an intrinsically indeterministic character in any event, limiting the causal conclusions we can draw from any starting situation, but on the other hand it still holds that for every event it is possible to find a cause ("für jede Erfahrung eine Ursache"[97]). A way out of this contradiction is traced by Hermann in a critical analysis of the principle of causality (Kausalgesetz- causality law or principle). Generally the principle of causality is understood as the fact that every event has a cause, and from this it follows that given a cause, a future event can be predicted. Hermann warns the reader that the generally accepted view of the principle of causality is in fact a mixture of two different concepts: predictability and causal relation. The fact that every time – at least in classical mechanics – we have a causal relationship we can also make a prediction of the result does not imply that casual relationships and the possibility of predictability are the same. Unpredictable events can still have a cause. Hermann calls the first principle - that nothing happens without a cause – the causal law, or principle (Kausalgesetzt). The second principle is that of predictability (Vorausberechenbarkeit), and it identifies the possibility of predicting future events based on the causal relationships among them. The causal connection can then be proven from the fact that future events can be predicted.

Now, quantum mechanics relies only on the first principle, the causal principle, while the second, predictability, is no longer valid; it is not possible, as demonstrated before, to give a precise prediction of future events on quantum scales. Once the difference between these two principles, which were scrambled under the big umbrella of the law of causality, is realized the contradiction between the two initial statements disappears. "Formulated independently of its criterion of applicability, the law of causality states that nothing in nature happens which is not brought about in all its physically determinable characteristics by previous events, that is, which does not succeed them with necessity. In this sense, gapless causality is not only consistent with quantum mechanics, but is demonstrably presupposed by it."[98] Given an initial quantum mechanical system, it is not possible to give an unequivocal prediction for its future states, but after having known the results (which were, impossible to predict beforehand with certainty, as described in the uncertainty principle) it is possible to reconstruct backwards the causal chain that determined them. The causal chain will be then reconstructed retrospectively and completely.[99] Like in the case of the microscope, the fact that the event was unpredictable did not mean that no causal relation

[97] Hermann (1937).
[98] Lumma (1999), p. 42.
[99] Cf. Soler (1996), p. 339.

determined it; once the light quantum is captured on a photographic plate, the position or the impulse of the electron can be described by determining their causes.

Kant explained his concept of causality in the Critique of Pure Reason[100] when speaking about the second analogy of experience. For Kant the determination of the temporal sequence of perception is one of the fundamental elements of objective experience. With the analogies of experience, he tries to show how this temporal sequence can ground objective experience. The three analogies reflect the three different varieties of temporal sequence: persistence, succession and simultaneity. In the second analogy he discusses the problem of objectivity of causality. He formulates the "principle of temporal succession according to the law of causality" in the second edition of the critique in the following way: "All changes occur according to the law of the connection of cause and effect."[101] The connection between two perceptions in time, Kant says, is not a direct experience, but it's a product of the "synthetic ability of our imagination". In order to show that causality is a pure concept of understanding, he needs then to show its being necessary as well.

Kant distinguishes between two kinds of appearances, the view of a house and of a ship going down the river. In the case of the ship, differently from the case of the house, he shows that the order of the perceptions is determinate and could not be inverted. From this example he concludes that in the case of the house the succession is subjective, while the succession of the ship sailing down the river is objective, as it is the succession of events of the object and not as of our subjective perceptions. Therefore, what he here identifies as the main characteristic of causality, as a universal and necessary of our experience, is its being irreversible. However, the causality law, like as all the analogies, has to be considered mainly "regulative", concerning only the structure of the relation between perceptions.

Returning to Hermann, by distinguishing between true causality (i.e. every effect has a cause) and predictability, she can still consider Kant's description of causality as a regulative fact of experience valid. In quantum mechanics it is still possible to indicate a cause for every event; this process is irreversible and once happened it could not have been differently. Thus, causality as the necessary and universal condition for our experience remains safe thanks to Hermann's interpretation.

[100] Kant (1787).
[101] Kant (1787), B 233.

The last part of Hermann's essay on the philosophical foundations of quantum mechanics is then dedicated to the relation between Kantian transcendentalism and quantum mechanics. Hermann's conclusion is that the Kantian category of causality has not been refuted by the discoveries of quantum mechanics; on the contrary, there is a convergence between quantum physics and critical philosophy that might even reinforce the strength of transcendental idealism.

There are three major parallels between quantum mechanics and Kantian philosophy, or, more exactly, Kantian philosophy as interpreted by the Friesian school:

1) In the same way Kant's categories constitute the theoretical basis for the interpretation of experience, the classical terms, as determined by Bohr's correspondence principle, determine the intelligibility of quantum theory. It is decisive that quantum mechanics remains intact exactly in the basic terms that mediate between experience and knowledge. ("The fact that quantum mechanics is conservative in exactly that aspect for which it has often been praised for overcoming, is decisive here. Despite the revolutionary changes of quantum mechanics, the fundamental concepts which mediate the passage from experience to knowledge, have been left untouched."[102])
2) As shown in Hermann's essay, quantum mechanics does not contradict at all Kant's view on causality, but on the contrary, it supports it. The central reasoning of the Kantian view, constructed on Newtonian science, is still valid for post-Newtonian science.
3) Kant (although here Hermann mainly means Fries) has underlined the relative character of knowledge. The categories should not be understood as absolute patterns for the order of our experience, but more as an arbitrary attempt to order and limit the immensity of nature. "Die Kategorien […] geben insofern als blosse Analogien den Leitfaden zur Interpretation der Wahrnehmung" (the categories, as purely analogies, constitute the guidelines for the interpretation of experience). We can derive the same lesson from quantum mechanics: what we can know about nature is only a part, a relative view. In quantum mechanics we cannot have an absolute knowledge of the situation, but only the experience and understanding relative to the context of our observation.

[102] Hermann (1935), p. 78 (author's translation).

"Knowledge of nature is given to us not as completely determined by its internal characteristics, but only as relations, which are insofar indissoluble as it is not possible to derive from them a clear and self-contained foundation."[103]

Grete Hermann's epistemological considerations do not stop at the acceptance of these insurmountable limits to our knowledge, but go further in considering other kinds of knowledge. Hermann does not take the relative view as a negative restriction on our possibility of knowing but, on the contrary, as a positive way to understanding the probabilistic aspects of quantum theory. In the concluding chapter of the essay "Die Spaltung der Wahrheit", she points out that the situation in quantum mechanics and critical philosophy confronts us with the fact that we cannot have a universally valid view of reality, but that different, equally correct views are possible. This creates room for ethics and aesthetics. Since the truth is "gespaltet" (split), different kinds of truths are possible, and with it different views of the world, different kinds of knowledge. The circle is closed; although the essay is on very technical aspects of the foundations of quantum mechanics, Hermann fits it within a wider, systematic picture. This wider system stems from Fries' system of critical philosophy, as explained in detail later in chapter 3.

2.5. The merits of the essay

Lena Soler, in her critical review on The Foundations of Quantum Mechanics in the Philosophy of Nature highlights the many important merits of the essay, such as her being ahead of its time, first by studying the relationship between quantum mechanics and Kantian philosophy, then by discovering a mistake in von Neumann's impossibility proof, and finally by her dual training both as philosopher and mathematician which allowed her to engage in deep discussion with Heisenberg and other important physicists.[104]

First of all, it is important to note the fact that this was a pioneering work[105] in the study of the relations between quantum mechanics and Kantian philosophy. If sometimes philosophers have been accused of "coming late", of giving a late response to the big changes happening in science, here it is definitely not the case. Hermann, trained as a mathematician and fascinated by philosophical reasoning, had all the necessary skills to tackle the problem of the epistemological

[103] Ibid., p. 75.
[104] Cf. Soler (2009)
[105] Chronologically Hermann was one of the first, together with Cassirer and Kojève, to examine the consequences of quantum mechanics for Kantian philosophy. Cf. Ibid. p. 330.

consequences of quantum mechanics and did not hesitate in doing so. However, we should keep in mind that when she speaks of transcendental idealism or critical philosophy, what she refers to is not Emmanuel Kant, but Friedrich Fries and Leonard Nelson. A more detailed analysis of the philosophical relationship between Kantian philosophy and quantum mechanics, as interpreted by Hermann, Heisenberg, and von Weiszäcker, will be presented in chapter 4.

What is important for me to underline here, is the significant role the mutual relationship between science and philosophy plays in Hermann's essay and in her other works. In order to understand this, a deeper look at the meaning of philosophy of nature, which is the privileged philosophical perspective chosen by Hermann, is needed. This, entered into in chapter 3, will extend the understanding of the interplay between philosophy and science (in both Hermann's work and in general), and at the same time allow a fresh look at the largely misunderstood Friesian school.

The second, uncontroversial, value of the essay is the simple proof of an error in von Neumann's "impossibility proof". Even if not recognized at the time, this is definitely a clear example of a formal discovery of its circularity, which can be compared with the well-known proof Bell presented circa 30 years later. We could imagine how the history of quantum mechanics may have been different, how hidden variable theories might have been developed already in the 40s, and of a different enthusiastic reaction to Bohm's theory. However, I will not pursue a counterfactual history[106] in this thesis. What is more interesting here is to get to a better understanding of how history developed, and attain a better grasp of its minor facets. In her essay, although largely ignored, Hermann elaborated a disproof of von Neumann 30 years before Bell, and this constitutes an important part – even if lacking immediate effects – of the history of quantum mechanics. In conclusion, some hints of why Grete Hermann's work has been so long ignored and what in the history of ideas changed when Bell's work had been warmly welcomed, would add some interesting reflections to this complex story.

A third aspect, that I want to make clear here, is the positive solution Hermann offers to what has been called "the measurement problem". In fact, Hermann's reinterpretation of the law of causality does not only save Kantian transcendental categories, but also offers an explanation of why quantum mechanical results have a statistical aspect, and how this might be explained on a physical level. In addition, her ideas may have some similarity with some other proposals elaborated much later, such as the one of Carlo Rovelli. In the concluding chapter of this thesis will

[106] Counterfactual history is a way of looking at history by asking the question "What if"(counterfactual). It is claimed that the relevance of the counterfactual situation shows the importance the fact had and its causal connection with other events. An example of counterfactual history is Hawthorn (1991).

I will present further considerations on Hermann's solution of the measurement problems and I will look at what it can add to the contemporary debate.

Many other research questions may emerge from the reading of the "Foundations of Quantum Mechanics in the Philosophy of Nature", and this thesis tries to answer some of them, while indicating the road to answers for the others. What we have seen is a work of intense collaboration between science and philosophy leading to some important results, to the clarification of which, the rest of this thesis is dedicated.

3. Understanding "Naturphilosophie"

The previous chapter provided a detailed analysis of Hermann's essay The Foundations of Quantum mechanics in the Philosophy of Nature[107]. Yet, to better grasp the full novelty and power of Hermann's ideas, it is necessary to delve further into the history of philosophy and science. Consequently, this chapter will provide the historical contextualizing necessary to fully appreciate Hermann's philosophical position and method. As it was previously mentioned, Hermann states in the introduction of her essay that she aims to analyze the basic principles of quantum mechanics. Specifically, the consequences for Kant's causality principle; not from the view of physics, but from a specific philosophical perspective, that of philosophy of nature.[108] Philosophy of nature, from the German "Naturphilosophie"[109], is for Hermann, the only perspective capable of providing answers to the philosophical problem of foundations of quantum mechanics. Although she states that she is grounding her work on philosophy of nature, no explicit definition of philosophy of nature can be found in her essay on the foundations of quantum mechanics (nor in her other published works). Thus, what Hermann means by philosophy of nature, remains a pertinent question for the readers. This chapter begins by taking up that question. Once explained, it will lead us further into the study of some, largely neglected, philosophers of nature; namely Friedrich Jakob Fries and Leonard Nelson. Additionally, a comprehensive study of Fries and Nelson will shed light into the historiography of philosophy as it pertains to philosophy of nature as well as Hermann's position in it. Consequently, an understanding of Hermann's use of philosophy of nature adds to the comprehension of both the importance of her work, and its place in the history of philosophy.

First of all, Philosophy of Nature is not a term easy to define. "The network of ideas, methods and attitudes it is supposed to represent is best understood in terms of the ideas, methods and attitudes of individuals. There is probably no single individual who could usefully and accurately be subscribed as a typical *Naturphilosoph.*"[110] Carl Siegel, professor at the University of Vienna and scholar of German history of philosophy, in his 1913 history of the German Philosophy

[107] Hermann (1935)
[108] Cf .Ibid. (1935), p. 9.
[109] Naturphilosophie, philosophia naturalis, and Philosophy of Nature are here used as synonyms, although this is not without problems. It should be noted that, generally, the German 'Naturphilosophie' is associated with the Romantic view of nature, while 'philosophia naturalis' is commonly used to describe the studies of nature before the scientific revolution.
[110] Gower (1973), p. 302, note 16.

of Nature (Geschichte der Deutschen Naturphilosophie[111]) tried to indicate some common guidelines and changes in all these different ideas and attitudes. It constitutes of a general history of the German philosophy of nature from the modern time onwards, in which Siegel wants to show a continuity line connecting all philosophers of nature. In order to do so, Siegel first distinguished between two kinds of philosophy of nature in Germany from modernity onwards: (1) the critical philosophy of nature and (2) the metaphysical philosophy of nature.

The critical philosophy of nature (kritische Naturphilosophie) takes the natural sciences as its object of study and engages in a logical inquiry of its foundations, methods and aims. Scholars of this type of critical philosophy of nature include Fries, Kant and Mach. On the other hand, the philosophy of nature as elaborated by German philosophers such as Leibniz, Goethe and Schelling can be called metaphysical. The metaphysical philosophy of nature takes nature itself as its object and introspection (Selbstbeobachtung) as its method of choice.[112] Despite their difference in content and methods, there is no absolute separation between these two views on the philosophy of nature, with some scholars contributing to both fields. For instance, both Kant reflecting on nature, and Goethe peering into the study of the natural science, contribute to both critical and metaphysical philosophy of nature.

Grete Hermann when speaking about Naturphilosophie is referring to what Siegel called "critical philosophy of nature", and in particular to the work of Jacob Friedrich Fries, that she had come to know through the work of his student Leonard Nelson. As described in the first chapter, Hermann was immediately fascinated by the way Nelson was carrying philosophical discussions and she decided to take the philosophy of nature elaborated by Fries as the privileged perspective to analyze natural science, and in particular the philosophical problems concerning the understanding of causality in quantum mechanics. As detailed later in this chapter, Hermann takes many elements of Fries' and Nelson's, philosophy of nature and creates original developments of her own within the field. However, to show the original contribution of Hermann, it is first necessary to briefly review the main features of Fries' and Nelson's philosophies, with a focus on the aspects relevant to Hermann's work. After this first brief review, Hermann's position on philosophy of nature and the influence Friesian philosophy had in the development of her ideas will be examined highlighting the philosophical and historical value of her proposal. At the same time this study contributes to the

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111 Siegel (1913)

112 "Die metaphysisch gerichtete Naturphilosophie […] versucht sie die hier neben der Sinneswahrnehmung zur Verfügung stehende andere Quelle der Erfahrung , die Selbstbeobachtung, mittel Analogieschlüssen auch für anderen Gebiete der Natur zu vertreten." (Siegel (1913), p. VII). Siegel's description of the method of metaphysical Philosophy of Nature is questionable. Especially regarding Schelling's and Leibniz' philosophy.

history of philosophy, as proposing a re-evaluation of Friesian philosophy and its importance in the development of science.

3.1. Fries' Philosophy of Nature

Fries was born the son of a cleric of ancient nobility in Moravia, and after some years at the seminary he enrolled in the law faculty in Leipzig. Soon, his interest in philosophy prevailed and he gave up his law studies. By 1796, he was living in Jena, listening to Fichte's lectures on philosophy at first but was soon attracted by the natural sciences, in particular chemistry. However, it was Kant who largely inspired his philosophical spirit. In fact, the precision and clarity of Kant's philosophical system had impressed Fries in his early years, when he was studying at the theological seminary, and now attracted all his devotion. The reading of Kant was one of the reasons why after a period working as a tutor in Switzerland he returned to Jena and decided to pursue a career as a philosopher and university professor (mostly of physics and mathematics)[113].

Most of his life Fries searched for a philosophical argument that was comparable in clarity and precision to the proofs of geometry, and he thought to have found one such in the work of Immanuel Kant. Fries found in Kant a source of both inspiration and critique. From the first encounter with Kant's writings, Fries' philosophical work can be seen as a psychological revision of Kant's thought. In the Neue oder anthropologische Kritik der Vernunft, Fries explains that he is trying to carry out an extension of Kant's ideas in a program that he called "propaedeutic of general psychology". [114]

Fries' reworking of Kant can be divided into three main steps[115]; first, he tried to show that Die Kritik der reinen Vernunft has to be considered as a branch of empirical psychology, and not a propaedeutic to philosophy, as Kant had presented it. Since for Fries the objects of observation are contents of our mind, it is in our mind that the starting point of any study of knowledge is to be found. The critique of reason is therefore, according to Fries, a work in general psychology. Second, a precise description of the relationship between empirical and general psychology is required. As a final step, he poses the basis of a new anthropological (or psychological) critique of reason, in which the psychological aspect is taken as the starting point that Kant had overlooked. The three

[113] This biographical paragraph mainly based on Gregory (2006), Gregory (1983). and NDB (vol V).
[114] Cf. Gregory (2006).
[115] Cf. Pulte (1999)and Pulte (2006).

steps leading to the acknowledgement of a psychological basis in Kant's critique of pure reason constitute the center of Fries' philosophy. [116]

Kant had divided the organic from the inorganic world. He understood the organism as being accidental, which means that it could not be captured by natural laws and that the intervention of reason was necessary. This created a decisive separation between the organic and inorganic world and what we can know about it. Fries, who in tune with the romantic Naturphilosophie of Schelling[117] believed in the unity of nature, overcame this division and considered both the organic and inorganic as being empirically based and intelligible without the intervention of reason.[118] He recognized two types of processes in nature: indifference and cyclic processes (Kreislauf). Matter in contact was acting by indifference, while the cycle was the typical process of organisms. The movement of the solar system, for example, was a cycle (Kreislauf) which had an elliptic form.[119]

From this revision Fries' makes of Kant's critique of pure reason stem many consequences, such as a new concept for science. Fries "dynamized" and expanded Kant's concept of science[120]. Actually, Kant accepted as genuine sciences[121] only those which rested on a priori concepts (physics and mathematics), and consequently excluded from the realm of science the ones likes biology and chemistry, because of their mainly empirical basis. Contrary to this, Fries, in developing a psychological revision of Kant and enlarging the use of mathematics, accepted other fields into the realm of science. For example, chemistry is considered a science by Fries, because even though it starts from empirical observations it uses in large part a mathematical description. This expanded concept of science is possible because Fries develops a new methodology of science, and at the same time opens the realm of proper sciences in an empirical direction.[122]

Similarly to the revaluation of the general definition of science, Fries widened Kant's perspective in mathematics as well. He studied the new developments in the foundation of mathematical physics, and was the first German philosopher to speak of a "Philosophy of Mathematics". He elaborated a meta-theory of mathematics, and considered the problem of origin and foundation of mathematical knowledge.[123]

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[116] Cf. Ibid.
[117] On the relation between Fries and Schelling see Gregory (1983).
[118] For Fries, an organism was not only what was alive, but more broadly everything which was changing in cyclical form. The living organism, therefore, was seen as only a specific part of the organic world.
[119] Cf. Gregory (1994) and Gregory (1995).
[120]Cf. Ibid.
[121] Kant enumerates three necessary conditions for "science proper": 1)mathematicity, 2)apodicticity, 3)systematicity. "Science proper" has to be grounded on a priori judgments. Cf. Kant (1786).
[122] Cf. Pulte (2006).
[123] Cf. Pulte(2006).

For these reasons, Fries' proposal has been considered a "scientifically adequate"[124] continuation of Kant. He opened up the possibility for many developments in science that were dismissed by Kant, such as chemistry and biology and gives much attention to the mathematical foundations of physics. Fries' concept of science and his openness to different disciplines constitutes the ground on which Hermann, a mathematician, educated in philosophy as well, considered the relation between philosophy, mathematics and natural science. Fries' concept of science, and correspondent openness to different disciplines, constituted the ground on which Hermann considered the relationship between philosophy, mathematics and natural science.

However, Fries' elaboration on Kant, and the possibilities it offered for both philosophy and science, have been forgotten.[125] Siegel stated that " there is only one thinker who can claim to have pursued Kant's philosophy of nature in the most rigorous way, and as well with precise examination. This thinker is J. F. Fries."[126] But with the exception of Siegel and a few others, Fries' work received little attention by the history of philosophy.[127] This adverse reception of Fries, accused of psychologism by his contemporaries[128], and subsequently largely ignored, can be explained[129] by the prevailing puristic attitude in the history of philosophy. As well as, by the inductivism in the history of science. In the 19th century, purism prevailed in philosophy, meaning that all the attention was given to pure philosophy and that philosophy and science were treated separately. At the same time, in science an inductivist attitude defined a closure of science towards relevant philosophical developments; science had at the time adopted a largely internal focus. Unfortunately, Fries' work was based on both science and philosophy, and consequently mutually exclusive attitudes in both fields at the time led it to be ignored. Naturally not all historical studies of the 19th century can be categorized as inductivist or purisistic and already in the 19th century appeared some integrated histories of science in which Fries began to be considered; such in the mentioned work of Siegel, or works by Whewell and Mach.[130] The tension and exclusivity between science and philosophy at the beginning of the 19th century, led to the creation of an isolated view of philosophy opposing this division, that later culminated in logical positivism. Fries in many respects can be understood as an neglected forerunner of these ideas; indicators of continuity between Fries'

[124] Ibid. p. 102.
[125] Cf. Geldsetzer (1999), Pulte (1999), Bianco (1980) and later in this chapter.
[126] Siegel (1913), p.118. (author's translation).
[127] Geldsetzer (1999) stresses that in the historiography of philosophy, Fries has been generally referred to only restrictively to three aspects: 1) the alleged physchologismus, 2) kantianismus and 3) his antisemitismus. Bianco (1980) points out that the studies of Fries have been mainly apologetic or polemic.
[128] Cf Sachs-Hombach (1999).
[129] Mainly in Pulte (1999).
[130] Mach (1883), Whewell (1837).

philosophy and logical positivism include the use of logic and analysis of language as philosophical methods, and the choice of natural science as a research subject.[131]

In recent years there has been a reversal in the attitude towards Fries. Historians and philosophers of science tried to look at the importance of Fries ideas in their context without assuming any partisan perspective. As Fries' work provided the grounds for Grete Hermann's ideas in philosophy of nature, an analysis of Hermann's work in turn contributes to the re-evaluation of Fries. Fries' dynamizing of Kant, his parallel work on philosophy and science, and his expansion of the concept of science played indeed a central role in Grete Hermann's work, as it will be shown later.

3.2. Nelson's case

Grete Hermann was exposed to Friesian Philosophy thanks to her encounter with the German philosopher Leonard Nelson. Although Nelson had been an earnest follower of Fries' ideas, his work is not a pedantic reproduction of them. Contrary to what was asserted in the refusal of his first dissertation proposal,[132] he actively revisited Fries' work by amplifying and criticizing it in many ways. Nelson studied Fries' works for many years and extended Fries' natural philosophy in several respects, such as the relationship between critical philosophy and the contemporary developments of mathematics, and its ethical and political consequences. In a way, Nelson's relationship with Fries reflects Fries' relationship to Kant.[133] They both try to carry on a renewal of their teachers, by pursuing an in-depth understanding of their works, and at the same time confronting the teacher's philosophy with contemporary advancements in science. It is by trying to follow Fries' understanding of philosophy of nature (science and its development as the object of study) that Nelson engages in a long term dialogue with David Hilbert. The discussion carried on between Nelson and Hilbert on the relationship of philosophy and mathematics is an important indicator of the intellectual background against which Hermann's elaborates her ideas. Nelson's life

[131] Cf. Pulte (1999).

[132] His first dissertation thesis was refused because it was considered to be not "an independent work, but mainly deputizing Fries's thoughts" (keine selbstaendige Arbeit [...] sondern vor allem Friessche Gedanken vertrete) in Peckhaus (1990).

133 Although Kant was a famous philosopher at Fries time, Fries was almost unknown when Nelson "discovered" him. "Just as Felix Mendelssohn-Bartholdy (to whom Nelson was related through his mother's family) rediscovered Bach's forgotten masterpiece, "The Passion According to St. Matthew", so Nelson rediscovered the forgotten writing of a forgotten philosopher, J.F.Fries (1773-1843), whose work had fallen into oblivion by a coincidence of adverse cultural and political circumstances, namely, the crushing effect of post-Kantian philosophical mysticism – as cultivated by Fichte, Hegel, Schelling – and the police state of Metternich." J. Kraft (1948), p. xi.

and his encounter with Hilbert, therefore, play a key role in Hermann's subsequent study of philosophy of nature.

Nelson was born in 1882 in Berlin to a family of Jewish lawyers, and could boast having Felix-Mendelssohn-Bartholdy and Du Bois-Reymond as his relatives. He first studied philosophy, psychology and theoretical physics in Heidelberg and Berlin, then, he moved to Gottingen where he worked until his premature death in 1927.[134] In Gottingen, Nelson was surrounded by both a climate fertile for the development and spread of his ideas and a hostile academic establishment, which obstinately opposed his professorship. For instance, in 1921, when Hermann first attended Nelson's seminars, he was still busy with trying to secure his position at Gottingen University and was not allowed to examine her for the Staatsexamen.[135] It was only thanks to the personal intervention of David Hilbert that in 1916/1917 Nelson could finally get his 'Habilitation'. Some time before, in 1896, during his early reading of Fries, Nelson had understood that his own mission in philosophy was not only the development and defense of his own system, but also the diffusion of his ideas, through which he could bring to practice his philosophical convictions. This pedagogical drive led Nelson to found schools and political movements like the IJB (founded in 1918, which in 1925 became the ISK), and the school in Walkemühle, both following the same political and educational socialistic ideals. In 1903, shortly after he had started studying in Göttingen, he had founded together with the philosophers Alexander Ruestow, Carl Brinkman and Heinrich Goesch, the "Neue Fries'sche Schule" (New Friesian School).The mathematicians Gerhard Hessenberg, Otto Meyerhof and Kurt Grelling soon also joined the New Friesian School.[136] Nelson, of not yet twenty years[137] – who had already the charisma and influence that will later characterize him – convinced the older and more influential mathematician Hessenberg and the psychologist Kaiser, to support the publication of Nelson's earlier project ,the Abhandlungen der *Fries'schen Schule.* The journal aimed at propagating Fries' interpretation of Kant as the epistemological ground for a "Philosophy of Natural Science". Despite the initial personal and

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[134] For the biography mainly following Peckhaus (1990).

[135] Staatsexamen were the final exams for the philosophy study. Hermann graduated in 1925 with a thesis on transcendental idealism. After many difficulties, Nelson was allowed to examine her but only under the control of Ach. Cf. Hermann, Erinnerungen an Leonard Nelson in ASD.

[136] Over the single members see Peckhaus (1990). p.132 ff.

[137] "mit einem ungewöhnlichen philosophischen Unternehmen trat ein kaum zwanzigjähriger Göttinger Student, Leonhard Nelson, an den Verlag heran: einer neuen Folge der „Abhandlungen der Fries'schen Schule" [..] Es war nicht möglich, ihm den abenteuerlich erscheinenden Plan auszureden, und da er zweifellos ein außergewöhnlich fähiger Mensch war und auch zwei schon ältere Gelehrte, den Mathematiker G. Hessenberg und den Physiologen K. Kaiser gewonnen hatte, wurde das Unternehmen 1904 begonnen, noch ehe der geistige Vater das Doktorexamen bestanden hatte" So describes the editor Ruprecht the first publication of the journal, in Peckhaus (1990), p.151.

political success of Nelson's ideas, his academic carrier had a "schleppende Verlauf"[138] (sluggish progression), since Husserl and the majority of the professors of the philosophy department opposed him, and his Habiltation proposal was repeatedly rejected. Only in 1919 did he receive the professorship for the Extraordinariat fuer systematische Philosophie, and from that moment on, and until his premature death in 1927, he was engaged in propagating and elaborating on Fries' ideas.

As mentioned in the biographical notes in the first chapter of this thesis, Nelson and Hermann did not have an easy relationship, and Hermann's feelings towards Nelson were a mixture of both admiration and fear. What immediately captured her attention, and served as the primary basis for her support of Nelson's school was his "method of philosophy, of whose certainty and necessity I was convinced."[139] In the biographical chapter the question is left open whether she is here referring to his general way of reasoning in Philosophy, to his effective way of conducting philosophy classes (he stressed the importance of punctuality and critical thinking and of many little rituals, such as having discussions until deep in the night), or to what he called "the Socratic method". In fact, these three aspects cannot be entirely separated from each other in Nelson's work and they probably all played a role in enlisting Hermann's interest in the method.

In his lecture on The Socratic Method, Nelson clearly explains what he understands philosophy and its method to be. "The function to be performed by the philosophical method is nothing other than making secure the contemplated regress to principles, for without the guidance of method, such regress would be merely a leap in the dark and would leave us where we were before – prey to arbitrariness."[140] The philosophical method consists of the regression to the principles; it works regressively from the consequences back to the reason and discards all other unnecessary characteristics from the original judgment. This process does not bring new knowledge (since it is deductive), but causes a transformation; through reflection dark, confused judgments are transformed into clear concepts. Philosophy, therefore, consists of the application of this method, and it will have as a result the sum of all the universal rational truths discovered with this reflective method. However, how is it possible to teach this method, Nelson asks himself. He points out that only the history of philosophy can be effectively communicated by instruction, whereas the art of philosophizing must be acquired through practice – however, he does believe that such practice can benefit from guidance. This guided practice is what he calls the Socratic Method, and it provides the examples on how to perform the regression to principles. According to Nelson, "The Socratic

[138] Cf. Ibid.
[139] "...Methode des Philosophierens, von deren Sicherheit und Notwendigkeit ich überzeugt war", Hermann (1953), p. 180 (author's translation).
[140] Nelson (1949), p. 9.

Method consists of freeing instruction from dogmatism; in other words, in excluding all didactic judgments from instruction."[141] In other words, the student of philosophy can only learn how to ascertain principles if he or she is standing on his or her own two feet and not being limited by any imposed dogmatic judgments.

This method is faced by what Nelson calls the general problem of education: how is it possible to teach a method which is itself opposing any authority? He solves this by following Socrates' example, wherein the teacher does not provide answers, but only helps students in formulating their questions, and in not being afraid to doubt. Even if students get scared when confronted with all their doubts, or in a so-called "benumbed"[142] situation, the Socratic teacher does not help the students, but lets them find their way through reasoning back to the first principles. This does not involve proposing a solution or answer, but only indicating the way to what Socrates called the "ars maieutica", the art of midwifery. [143] In theoretical reasoning, as well as in his political activities, we see the importance Nelson, in contrast to Fries, places on education. His example concerning the importance of pedagogic methods was followed by Hermann, both in its theoretical reasoning and practical implications. This can be seen in her pedagogical engagement in the Walkemühle school, and in her critical reasoning about Nelson's work. The Socratic Method is for Nelson something peculiar to philosophy. In philosophy, the principles are wrapped in obscurity, and in contrast to mathematics, they are not easy to grasp. Nelson underlines the fact that in mathematics, the basic principles are grasped more easily and are not wrapped in obscurity, like in philosophy, and therefore the regression is not even necessary. In this manner, he explains his opinion on mathematics and its relationship to philosophy: "The brilliant development of the science of mathematics and its universally acknowledged advance are explained by the fact that its principles - ignoring for the moment the problems of axiomatics - are easily grasped by the consciousness. They are intuitively clear and thus completely evident, so evident that, as Hilbert recently remarked on this same platform, mathematical comprehension can be forced on everyone."[144] In giving a description of how mathematics works its way to the first principles, Nelson mentions David Hilbert's programme of a new axiomatization of mathematics as 'the'

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[141] Nelson (1949), p.10.

[142]" I consider," says Meno to his teacher Socrates, in the dialogue bearing his name, "that both in appearance and in other respects you are extremely like the flat torpedo fish; for it benumbs anyone who approaches and touches it. . . . For in truth I feel my soul and my tongue quite benumbed and I am at a loss what answer to give you" [Plato (1924), 297].

[143] "My art of midwifery is in general like theirs; the only difference is that my patients are men, not women, and my concern is not with the body but with the soul that is in travail of birth", explains Socrates in Plato's Theaetetus (149a-151d)

[144] Nelson (1949), p.7.

paradigmatic example for the discipline. Indeed, Nelson understood his own work as the philosophical foundation for Hilbert's mathematics, and as an alternative to the logicism of Frege and the conventionalism of Poincarè.[145] Nelson's position was an elaboration of Fries' critical philosophy, and from Fries he inherited two key positions on the relationship between mathematics and philosophy. First, he wanted to pursue the Friesian dream of the construction of a philosophy based on a rigorous scientific method, such as the one used by mathematics and natural sciences.[146] Second, Nelson elaborated on Fries' concept of "kritische Mathematik" (critical mathematics) as a philosophically grounded method for mathematics. By "kritische Mathematik," Fries understood the study of mathematics as using the method of the regression to principles and the analysis of concepts. Critical mathematics had both the task of indicating, and of questioning, the validity of basic principles (or axioms).[147] While David Hilbert was concerned with constructing an axiomatic system that would offer a new foundation for mathematics, Nelson's critical mathematics, questioning the validity of basic principles or axioms, laid the foundations for a fruitful collaboration with David Hilbert.

When he first encountered Nelson, Hilbert was one of the most influential professors in Göttingen's mathematics department, itself one of the foremost European centres for mathematics at the time. The academic success in mathematics did not satisfy Hilbert, and he was trying to widen his influence and interests into the philosophy department, as he was convinced that through philosophy he could gain important insight he could use in his axiomatic formulation of mathematics. Hilbert found in Nelson what he had not found in Husserl or in other philosophers: Nelson was not only a man with "a pleasant knowledge of the new mathematics, that, particularly the young mathematicians, do not seem to posses very often"[148], but his grasp of philosophy fitted perfectly in Hilbert's programme reforming mathematics. In fact, the famous mathematician and the young philosopher seemed to share their ideas and aims regarding the relationship between philosophy and mathematics. This common interest between Hilbert and Nelson is visible in a long letter (of 47 pages!) Nelson wrote to Hilbert under the title "Mein Glaubensbekenntnis."(my confession of faith). The letter might as well have been entitled "Unser Glaubensbekenntnis," (our confession of faith) as the expressed beliefs demonstrated considerable overlap with those of

[145] Cf. Peckhaus (1990) .

[146] "unsere Philosophie auf ebenso strenger wissenschaftlicher Methode beruht wie die Mathematik und die Naturwissenschaften" programme „abhandlungen Fries'schen Schule", in Peckhaus (1990), p.151.

[147] An example of critical mathematics is Nelson's and Hessenberger's "Bemerkungen zu den Paradoxien von Russel[l] und Burali-Forti". A critical study of it in Bernays (1928).

[148] "eine erfreuliche und gerade bei den jüngeren Philosophen keineswegs immer vorhandene Kenntnis der neueren Mathematik" Peckhaus (1997), p. 4 (author's translation).

Hilbert's.[149] Nelson starts the letter, dated December 1916, offering thanks to Hilbert for his help, without which he would have never achieved his aims (and his position).[150] As underlined earlier, Nelson was finally able to become a professor and succeed in his goals thanks to Hilbert's help, and it is, therefore, to Hilbert that he writes the letter describing his beliefs.

While Hilbert's role was crucial in the development of Nelson's career, Nelson played an equally important role for Hilbert. This is stated by Hilbert in a letter to the minister, where he claims (overstating, to convince the minister to consider Nelson for a position at the university): "Without Nelson I can't carry on an important part of my life's programme. Without Nelson I'm nothing in the faculty."[151]. While Nelson's interest in enlisting the help of the great mathematician is easily understandable, Hilbert's interest in Nelson's philosophy is a bit more intriguing. What exactly did Hilbert find interesting and useful in Nelson's work? Why was the world-renowned mathematician so eager to find a position for a young philosophy student who was studying an outdated philosopher, and had soon established several enemies in the philosophical community?[152]

One can better comprehend the convergence between Hilbert's and Nelson's ideas by examining the development of Hilbert's programme. In 1903, after the publication of the antinomies in logic and set theory (Mengentheorie) by Frege and Russell, Hilbert went through a "philosophische Wendung" (philosophical turn).[153] As a consequence of this philosophical turn, he revised his programme by inserting logic and set theory as disciplines where an axiomatization was also necessary. It was in Nelson that he found the philosophical justification for this project. There were two parts of Nelson's critical mathematics that could be seen as reflecting Hilbert's proposal: (1) the identification of axioms and (2) the analysis of these axioms, whose validity and origin were analyzed through the philosophical method. Correspondently, Hilbert's work was divided in three areas: the mathematical, the logical and philosophical. The mathematical task was to formulate the systems of axioms and to prove their independence. The duty of logic was to ensure that the systems of axioms were free of contradictions. Finally, philosophy would carry out a clarification of

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[149] Peckhaus (1997) argues that the title was handwritten by Hilbert.

[150] " Und ich hätte auch später nicht einmal dies Ziel erreicht, wenn nicht Sie mir damals Ihre Hilfe hätten zu Teil werden lassen", Cf. Ibid., p. 3.

[151] „Ich kann ein[en] wichtigen Teil meines Lebensprogamms nicht durchführen ohne N[elson]. [...] [Seine Berufung ist Kulturtat 1sten Ranges: Reformation des Geistes des Professorentums] Ohne N[elson] bin ich Nichts in der Fakultät" Peckhaus (1990), p. 224 (author's translation).

[152] Nelson had two long-winded disputes with some supporters of Neo-Kantianism, such as Hermann Cohen and Ernst Cassirer. In Ibid. p. 197.

[153] Cf. Ibid.

the concepts used and would try to find a foundation for the axioms. Thus, the combination of philosophy and mathematics played a key role both in Hilbert's and Nelson's programme.[154]

As a consequence of his convictions about the mutual relationship between mathematics and philosophy, Hilbert tried to make Göttingen a centre not only for mathematics, but also for philosophy. However, his interest in philosophy was defined by his goal of reformulating mathematics, which consequently required a reformulation of philosophy. The main difference between Nelson's and Hilbert's beliefs in philosophy and mathematics consisted in the fact that for Hilbert, mathematics and philosophy were not on the same level, but philosophy was at the service of mathematics. On the contrary, Nelson saw the work philosophy could do for mathematics in providing the grounds for mathematical research – but rather as a collaborator as opposed to subservient.

Even if Hilbert and Nelson were looking at philosophy and mathematics from different angles, they agreed that the collaboration between mathematics and philosophy would lead to the advancement of both subjects. It is from this mutual relationship between mathematics and philosophy that Hermann's ideas developed. Initially educated as a mathematician at the same university in which Hilbert was carrying on his programme, she directly encountered Leonard Nelson - the main living endorser of Friesianism and supporter of critical mathematics. Thus, the mutual relationship between philosophy and mathematics, as pursued in the mutual collaboration between Nelson and Hilbert, has to be taken as the intellectual background on which her ideas developed.

[154] "insbesondere den Zusammenhang zwischen Mathematik und Philosophie zu pflegen, darin habe ich von jeher einen Teil meiner Lebensaufgabe erblickt" in Peckhaus (1997), p. 8.

3.3. Hermann's Philosophy of Nature

"Durch Nelsons Herausforderungen habe ich es allmählich gelernt, mir Schritt für Schritt den Mut zur Wahrheit zu erkämpfen, der dazu gehört, sich einer als zwingend anerkannten Denkmethode nun auch *Rücksichtslos im eigenen Denken anzuvertrauen."*[155]

Grete Hermann, in „Erinnerungen an Leonard Nelson."

After the above description of Fries' and Nelson's critical philosophy, it is clear that when Hermann is speaking about natural philosophy she is referring to the natural philosophy as elaborated by Fries and Nelson. Fries based his philosophy on a revision of Kant; by assigning a different role to experience and organism, he elaborated a new concept of science, which included disciplines that were left out by Kant. Nelson then carried out a revision of Fries' work, with a particular focus on the relationship between mathematic and philosophy. This allowed him to engage in a close and mutually beneficial collaboration with David Hilbert. In addition, Nelson philosophy went hand in hand with his political and educational ideas. It was while trying to propagate his ideas that he met Hermann and initiated her to the Friesian school. However, the precise influence of Friesian philosophy of nature on her work remains uncertain. The following section addresses this, and in so doing completes the picture of Hermann's use of, and position within, natural philosophy.

It is my contention that the influence of the Philosophy of Nature of Fries and Nelson is evident in three main aspects of Hermann's work, particularly in her essay on the foundations of quantum mechanics. These three areas are (1) her understanding of philosophy, (2)the method she used for pursuing her research and (3) her choice of subjects to investigate. In fact, in her study of the foundations of quantum mechanics in the philosophy of nature, Hermann is analyzing the developments of natural science (in one case analyzing quantum mechanics, in another essay relativity theory) as the Friesian school advocated. Thus, the way she understands philosophy – as having to look at the contemporary developments of natural science - is defined by her Friesian background. Secondly, the method Hermann uses to carry out her research on the philosophical foundations of quantum mechanics is characterized by the analysis of concepts (for example in the case of causality she points out how the term is in fact constituted by two different meanings), and the step by step reasoning through deduction to the basic principles.

[155] Hermann (1953), p. 182.

This regression to principle is also of Friesian origin, and prominently present in Nelson's work. As Fries and Nelson wished, she writes a philosophical work trying to follow a method as rigorous as the scientific method, and to apply natural science to philosophy, and philosophy to natural science. The third aspect of influence from Friesian philosophy is the choice of the subject. Hermann chooses to look at quantum mechanics and its relation to transcendental idealism, which is, needless to say, a topic of chief interest for any follower of Kant's ideas, including Fries and Nelson. As stated by the author herself, her aim is not a critique of the physical theory. In fact, although a revision of physics is possible, this would not solve the problem of causality,[156] for which only philosophy of nature can adequately provide answers.

Given these three factors and the references to Fries by Hermann, her work on the foundations of quantum mechanics is evidently grounded in Friesian philosophy of nature. However, Hermann's work is not a mere replication of Fries' and Nelson's ideas, she goes further than her teachers, widening Friesian philosophy by expanding its realm of study and by softening its absolutism (especially regarding Nelson's philosophy).

First of all, the choice Hermann makes to look into quantum mechanics and its consequences for the Kantian category of causality, while in line with Friesian philosophy, adds new aspects to it. Since Friesian philosophy is based on Kant's philosophical system, the problem of validity of Kant's categories is an argument of chief importance for Friesian philosophy. An analysis of the newest developments in quantum mechanics and its implications for Kant's category of causality, reveals that Hermann carried out a widening of the interests and objects of study of Friesian philosophy. As described above, Friesian natural philosophy, up until Hermann, had been mainly concerned with mathematics, and its relation to philosophy or critical mathematics. Fries had widened Kant's conception of "proper science" to include chemistry, but had still chosen mathematics as the paradigmatic methodology, and consequently elaborated a first meta-theory of pure mathematics. Similarly, Nelson had been dedicated to the study of mathematics and to the solution of the antinomies. While Fries had devoted some little attention to the new developments in physics, as carried out by Euler and Lagrange, his follower Nelson disdained the changes in physics. Nelson believed, like an old-school Kantian, that Newton's mechanics was the only possible physical theory and that the problems of quantum mechanics and the theory of relativity would end up explained and formulated as classical mechanical problems.[157] On the contrary,

[156] Cf. This thesis p. 8,9.
[157] Cf. Heckmann (1953).

Hermann, although coming from a mathematical background, sees in the new physical theories an important contribution to epistemology and philosophy of nature. She looks into the consequences of quantum mechanics (and of physical theories in general) for the philosophy of nature, and in this way she enlarges the Friesian perspective. Friesian philosophy, under Hermann, is now not looking at mathematics, but also a new perspective, entailing the incorporation of the newest developments in physics, is introduced. The relationship between mathematics, philosophy and physics is central to Hermann's reflections, and thus as a consequence of her work, Friesian philosophy of nature and its realm of study are expanded.

The other original development of Hermann's philosophy, with regard to Friesianism, is her softening of the absolutist aspects in Nelson's philosophy. In a letter to her friend and political colleague Gustav Heckmann she writes: "I want to understand how to free Nelson's philosophy from its misleading absolutist demands, and through which modifications to the kernel of his philosophy this can be achieved and in turn made valid."[158] In this sentence the position of Hermann towards Nelson's philosophy is condensed, with which she has been involved since 1925, when Nelson asked her to collaborate in the edition of Vorlesungen ueber Ethik.

Fries distinguished between theoretical and practical natural philosophy. Theoretical philosophy was researching the existence of things, while practical philosophy of nature was concerned with their goals. After Fries, Nelson understood theoretical philosophy as the method of axiomatics, and took Hilbert's system as the example to follow for "exact science", and at the same time identified practical philosophy with ethics. In both realms, Nelson wants to find the way back to fundamental principles (Axiomen) that once discovered must be accepted by everyone. Nelson believed in the universal validity of reason (Vernunft) and understood his mission in leaving nothing, in both physics and ethics, to chance ("vom Zufall entziehen"). For Nelson, anyone confronted with an answer that is indicated by reason must see it as the only possible solution. This position tends to absolutism and dogmatism, which is exactly what his philosophical method endeavored to liberate us from. Hermann is aware of these tendencies in Nelson's philosophy, and, thus looks to modify his theory.

In both realms Hermann manages to free Nelson's philosophy from these absolutist colors, without falling into relativism but preserving the role of rationality (Vernunft). In Die Überwindung des Zufalls[159] she shows how, by using the same methods as Nelson, we should get to a different

[158] "ich möchte verstehen, durch welche Modifikationen der Wahrheitskern der Nelsonschen Philosophie von irreführenden Absoultheitsansprüchen befreit werden und sinngemäß geltend gemacht werden kann „ Ibid. p. XI. (author's translation).
[159] Hermann (1985).

conclusion, namely that reason and sense experience (Vernunft und Sinnlichkeit) always work together in every ethical judgment. Although rationality still plays a major role, justice is given to experience and to the possibility of different ethical and political judgments. Similarly, the absolutist aspects are left out of the other part of Friesian philosophy, the theoretical philosophy of nature. Here Hermann accepts the indeterministic aspects of physical theories, without having to dismiss the Kantian categories of understanding. Quantum mechanics may not provide precise predictions, yet it still maintains a rational causal structure. Both in physics and in ethics, and without negating the role of reason, Hermann restores an element of indeterminacy that Friesian and Nelsonian philosophy lacked.

After this brief overview of the philosophy of nature, and in particular of the philosophy of nature of Fries and Nelson, Hermann's work can be regarded from a wider perspective, allowing for a deeper understanding of her philosophical ideas. First of all, the meaning philosophy of nature has in Hermann's philosophy is now clear. Hermann used the Friesian philosophy of nature as a privileged perspective for her study of modern physics, and this stands out in three main aspects of her work; her understanding of philosophy, the method of pursuing her research, and her choice of the subject and her understanding of philosophy. Secondly, although she chose to follow a specific philosophical school, Grete Hermann's philosophical ideas were not a mere reproduction of Friesian philosophy of nature, but made valuable and original contributions to it. For instance, it has been noted that Grete Hermann pursued a widening of the Friesian perspective on an interdisciplinary level, and at the same time lessened some of its absolutist tendencies. Finally, this study of Hermann's use of philosophy of nature, and her contributions to it, supplements the recent studies of Friesian philosophy of nature, in re-evaluating this long neglected school.

4. Understanding Causality

4.1. Conversation with Heisenberg

Heisenberg describes his first encounter with Grete Hermann with the following words:

> " We were offered a special occasion for philosophical discussions one or two years later when the young philosopher Grete Hermann came to Leipzig for the express purpose of challenging the philosophical basis of atomic physics. In Göttingen, she was an active member of the circle around the philosopher Leonard Nelson, and thus steeped in the neo-Kantian ideas of the early-nineteenth-century philosopher and naturalist Jakob Friedrich Fries. One of the requirements of Fries' school and hence of Nelson's circle was that all philosophical questions must be treated with rigor normally reserved for modern mathematics. And it was by following this rigorous approach that Grete Hermann believed she could prove that the causal law – in the form Kant had given it – was unshakable. Now the new quantum mechanics seemed to be challenging the Kantian conception, and she had accordingly decided to fight the matter out with us"[160]

More than 30 years later he dedicated an entire chapter of his book to the philosophical discussion they had on that occasion, acknowledging both the depth of the discussion, and the fact that its topic was still of contemporary interest. He entitled the book Physics and Beyond: Encounters and Conversations, since what he tried to do was to reconstruct, as accurately as memory allowed him, some important conversations related to atomic physics he had in his life, from philosophical to political topics. The conversation between Heisenberg, Hermann and Friedrich von Weiszäcker, the focus of the chapter, is about the relation between quantum mechanics and Kantian philosophy.

Through a brief analysis of this conversation some remarkable aspects will come to light, such as the fact that Hermann's discovery of circularity in von Neumann's disproof is not mentioned, and the dissimilarities between Hermann's ideas as described by Heisenberg and what we can read directly in her published work. To comprehend the challenging aspects of this conversation, it is useful to pursue a comparison with other works, wherein the protagonists of the

[160] Heisenberg (1971), p. 117-118.

discussion also express their ideas on the relationship between quantum mechanics and Kant's philosophy. Heisenberg's ideas, as expressed in Recent Changes in the Foundation of Exact Science, and von Weiszäcker's philosophical view, as described in Zum Weltbild der Physik, together with the already presented work of Grete Hermann will enlarge our perspective of this conversation. By juxtaposing Heisenberg's and von Weiszäcker's positions with Hermann's ideas of causality, both the traditional and the novel aspects of her ideas will become evident.

Heisenberg starts the recollection of his conversation with Hermann and von Weiszäcker by describing the young philosopher Hermann (he does not mention that she was also, and mainly, a mathematician), appearing worried about the consequences quantum mechanics might have for Kantian philosophy, and in particular for the category of causality. Looking at it from a Kantian perspective she does not believe that the causal law can be disproven by experience. Since it is an a priori category of understanding, it is causality itself that determines experience, and cannot be disproven by it.[161] In addition, without causal law there would only be an indistinct flow of sensations, and therefore no science. For these and other reasons, an empirical disproof of the law of causality seems impossible to Hermann.

Heisenberg replies to her critique by showing through a practical example how this is actually the case in quantum mechanics. For instance, when we look at the process of atom decay, such as of Radium B, he says, the new theory does not provide an explanation of why a certain atom decays at one moment, or why it emits an electron in one direction rather than in the other. Consequently, the idea of causality as determinant of every experience seems not to be valid in this case. Hermann's reply is surprising – as long as we keep in mind her argumentation against the possibility of finding other causes; she proposes to look at other, maybe hidden, causes. "The mere fact that no cause for a certain effect has yet been discovered does not mean that no such cause exists."[162] Heisenberg's answer is that the theory is complete and that there is no reason to believe that other causes exist.

This answer leads Hermann to a "dreadful" dilemma: on the one hand quantum theory is incomplete (because we can only make statistical predictions), on the other the theory is considered to be complete (since no other determinants have to be found. And if they were found they would end up in conflict with other experiments). At this point von Weiszäcker enters the conversation by pointing out that looking at radium b as a Ding an sich, the Kantian expression for a 'thing in itself', is the point of confusion. He believes that from quantum mechanics we can learn only to work with

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[161] Cf. Ibid., p.118-119.
[162] Ibid. p. 119.

the observations and that the observation does not say anything about the Kantian Ding an sich. Grete Hermann immediately corrects him by explaining the Kantian division between ‘Ding an sich’ and ‘physical object’: ‘Dinge an sich’ have a negative regulative function; they cannot be known. While physical objects, even if not visible, are deducible from experience. In addition, physical objects, like Radium b, but also like tables and stars, are necessary for objective science, since we would not be able to go further than experience without them. For Kant, the categories are necessary for the creation of these physical objects, and therefore no objective science is for Hermann possible without them. Von Weiszäcker picks up her remark on the problem of objectivity, and opines that in quantum mechanics, we are confronted with a new method of objectivising perceptions. Every perception refers to a different observational situation and consequently it is not possible to give an objective description as in classical physics. Following von Weiszäcker’s argument, Kant’s categories are not completely overthrown, but relativized. All experience is still expressed in classical terms, and therefore, it respects the Kantian categories. It has, however, lost its absolute meaning. In quantum mechanics, Kantian categories can only have a limited application. In fact, it is the case here that different, equally correct, perspectives of the same situation are possible. Uncertainty, which in classical physics has been considered as a synonym for ignorance, is now considered a grounding principle of quantum theory, and no more a sign of lack of knowledge. As a grounding principle, uncertainty cannot be refuted without this leading to contradictions.

At this point, Heisenberg describes Hermann as being very unhappy with the turn of the conversation. She had, he states, come to Leipzig in the hope of either refuting the indeterministic character of quantum mechanics, or finding Kant “guilty of a serious philosophical lapse.” Hence, the last question she poses is whether this “relativization” of Kant is equivalent to the giving up of a secure common ground for knowledge. To this von Weiszäcker boldly replies that Kant’s categories represent knowledge, and this will never change. However, as with Aristotle’s laws of the lever, that newer developments of knowledge provide more insight than the old, these do not necessarily invalidate the old. For von Weiszäcker, the Kantian a priori is still valid, but has now only a restricted, relativized, application - a new concept of understanding is brought about with quantum mechanics. “This reply, based on Bohr’s teaching, seemed to satisfy Grete Hermann to some extent, and we had the feeling that we had all learned a good deal about the relationship between Kant’s philosophy and modern science”[163], Heisenberg concluded with these words his recollection of the conversation with Grete Hermann and Carl Friedrich von Weiszäcker. We know, however, that the

[163] Ibid. , p. 124.

discussion of the problematic law of causality in quantum mechanics and its relation with critical philosophy did not end here for Grete Hermann. She elaborated further many of the concepts considered in this encounter.

4.2. Remarks

There are at least three aspects of this conversation that are important for the present study. First, it is interesting to note that, here again, the unjustified assumption in von Neumann's impossibility proof, which at the time Hermann had already discovered, is not mentioned at all. Both Heisenberg and Hermann neglect this aspect and focus only on the debate regarding the causal principle. Although they make the same choice for the subject of the conversation, the reasons why Hermann and Heisenberg left out of the discussion von Neumann's disproof, may have been different. Hermann's motives for neglecting her disproof have already been discussed, but it is worth considering why Heisenberg did the same.

The second aspect, worthy of further investigation, refers to the comprehension of Hermann's thought itself, and its evolution. Heisenberg depicts a young philosopher, who is proposing to look into hidden causes as a solution to the apparent contradiction of the causal law. This picture of Hermann is in contrast with her ideas as expressed in later years. In fact, from what can be read in Hermann's published work, she firmly negates the usefulness of looking for further hidden causes, and all her arguments are directed to showing the completeness of quantum theory. These observations lead to the supposition that she either changed her mind during this discussion with Heisenberg and von Weiszäcker, or that Heisenberg had false memories or misunderstood her remarks. It is my contention that both suppositions are partly true. In the already examined work on the foundation of quantum mechanics Hermann poses the question of whether we should look for other causes; she uses this question as the starting point for her research of the consequences the new theory has for Kant's causality law. At the same time, the same question is a guiding question for the reader, so that she or he is slowly directed to her conclusions. Consequently, since it is proposed as a guiding question, and all her research is presented as an attempt to give it a clear answer, I believe that she cannot have been a determined supporter of hidden variable theories at the time she met Heisenberg in Leipzig. She was probably also not a supporter of hidden causes, as Heisenberg depicts her – maybe for reasons of simplicity – but discussing their possibility.

The third topic, to which the rest of this chapter focuses on, is the relativization of Kant. In the conversation both Heisenberg and von Weiszäcker are depicted as proposing not to completely give up Kant's a priori as a necessary condition for our understanding, but only to relativize its application. This is in many respects similar to Hermann's proposal of giving up the absolute character of knowledge. Therefore, the study of Heisenberg's and von Weiszäcker's ideas will help us understand in what aspects Hermann might have been influenced by, and herself influenced, the two physicists, and in what other way she might have elaborated on her own original proposal.

4.3. Heisenberg and Kant

In the lecture Recent Changes in the Foundation of Exact Science[164] delivered in September of 1934, Heisenberg again expressed his ideas on the relationship between Kantian philosophy and quantum mechanics, but in a more structured form. He first highlights the recent developments in natural science, and then identifies the schism between the classical description, and the mathematical formalism peculiar to quantum mechanics. While in quantum mechanics questions about nature are expressed in the same classical terms as in classical physics and one enquires about objects in space and time, the mathematical formalism of quantum mechanics presents answers in terms of wave-functions, in a multidimensional configuration that is not easy to interpret. This, for Heisenberg, leads to the necessity of drawing a line of distinction between the measuring apparatus and the object of observation.[165] The existence of the dividing line is seen in the statistical relationship, where the effect of the observer causes an uncontrolled disturbance in the region of the dividing line, demonstrating at the same time the limits of the application of classical terms, and their connection (not contradiction) with the quantum mechanical description.

These transformations in the foundation of exact science have, according to Heisenberg, some clear effects on philosophy. On the one hand Kant's categories and forms of intuitions are no more absolute; space, time and cause are not seen as independent from experience. On the other hand, they, and in particular the causality law, are preserved as the premise for any objective science. How is this possible without contradiction? Heisenberg claims to solve the apparent contradiction by stating that "Physical theories can have a structure differing from classical physics, only when their aims are no longer those of immediate sense perception, i.e. only when they leave the field of common experience dominated by classical physics. It is in this way that modern physics has more accurately defined the limits of the idea of the a priori in the exact sciences, than

[164] Heisenberg (1934).
[165] Ibid.

was possible at the time of Kant."[166] Kant's a priori still constitutes the condition for experience in classical physics. However, classical physics has only a limited application in the new science, which eschews immediate experience in order to understand the microphysical world. This leads to a demarcation line that has to be drawn between the classical and statistical description, between the object of description and the process of measurement, and this line is determined by the disturbance of the measurement processes.

This demarcation line constitutes the limit of the application of a classical description and at the same time limits Kant's a priori as a condition for knowledge. Heisenberg compares the situation with the belief that the earth was flat. For long time before Columbus' travel it was generally believed that the earth was flat, and people were looking for the end of the world. With Columbus' discovery it was proven that the earth was round and therefore the search for the end of the world did not make sense anymore. Similar is the situation with quantum mechanics, where there are no limits in the application of rational thought, but there are limits to kinds of thoughts, in questions, that become now, as the search of the world's end after Columbus' discovery, meaningless. Through focusing on the demarcation line between the classical and the quantal description and the uncontrolled disturbance determined by the measurement process, Heisenberg answers Hermann's question on the fear of giving up, together with Kant's categories, the possibility of objective knowledge. Objective knowledge is for Heisenberg not dismissed, but rather limited to certain questions that can be asked if one is after a meaningful answer. Although Heisenberg gives an answer to the problem of causality in quantum mechanics, he is aware that this is a controversial one (e.g. how to exactly determine the demarcation line?) and that there is yet much to be said on the relationship between quantum mechanics and Kantian philosophy, therefore he concludes by expressing his wish of further thoughtful discussions of it. [167]

4.4. Von Weiszäcker's view

The other protagonist of the discussion is the young Carl Friedrich von Weiszäcker. Although a physics student, he is described by Heisenberg as growing "unusually animated whenever our talks impinged on philosophical or epistemological problems."[168] The philosophical aspect of quantum mechanics always attracted von Weiszäcker's interest and in Zum Weltbild der

[166] Cf. Ibid.(1934), p. 21.
[167] Cf. Ibid., p. 21.
[168] Heisenberg (1971), p. 117.

Physik[169] he delves into the philosophical problems of the new Weltanschauung in length and expresses his own opinion about the relationship between Kantian philosophy and quantum mechanics.

For von Weiszäcker it is not true that quantum mechanics has lost the Anschaulichkeit (picturability)[170] and the causal character of classical physics: picturability and causality still constitute fundamental methodische Hilfmitteln (methodological tools) for the new theory, since this is still expressed in classical language. Nevertheless, picturability and causality are not part of the worldview presented by quantum theory, and cannot be seen as absolute characteristics of any physical theory. There is one main characteristic that according to von Weiszäcker is lost by quantum mechanics and this is the possibility of an objective knowledge, of " the making objective" of perceptions (Objectivierbarkeit). The "Objectivierbarkeit" of nature, which was presupposed by classical physics, claims that the result of a measurement does not depend on the conditions in which it is determined. In von Weiszäcker's words: "There is one thing that we can't do anymore: we can't assemble the intuition fragments and the causal connection to one in itself being nature. Rather, what complementary side of nature we see all depends on our freely chosen experimental setups and the knowledge of one contents excludes the knowledge of the other one."[171] This means that in quantum mechanics the object cannot be defined without referring to the context of observation and consequently to the observer.

How does this relate to Kant's philosophy? Kant postulated the existence of the Ding an sich, thing in itself, that cannot be perceived through experience but only through reason, as a necessary base for his philosophy. The concept of the Ding an sich gets into problems, for von Weiszäcker, when dealing with the microphysical invisible world. For instance, when speaking about atoms, it is not possible to give any definition of their characteristics, since they are not absolute and vary according to what is measured. There is no clear division line between things that we experience and things that we do not, and thanks to complementarity, we can bring to light the different opposing characteristics of the same atom. Hence, for von Weiszäcker, Kant did not

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[169] Von Weiszäcker (1976).

[170] Anschaulichkeit is a term difficult to translate in English. It is generally translated as "picturability" or "visualisability". From the very beginning, it has been largely discussed whether quantum mechanics was visualizable or not. For a critical view on the relation between visualisability and intelligibility see de Regt (2001).

[171] "Wir können nur eines nicht mehr: die einzelnen Anschauungsfragmente und Kausalketten zum Modell einer an sich seienden Natur zusammenfügen. Vielmehr hängt es von unserer frei gewählten experimentellen Anordnung ab, welche der zueinander "komplementären" Seiten der Natur wir zu Gesicht bekommen, und die Kenntnis eines Sachverhaltes schließt die Kenntnis des dazu komplementären Sachverhaltes aus" Von Weiszaecker (1976), p. 86. (author's translation).

consider enough the participation of the "will" (Willens), the human interaction, in his construction of the empirical world.[172]

Von Weiszäcker concludes that regarding the a priori these are presupposed (Voraussetzung) by quantum mechanics, but they do not constitute one of its inherent parts (Bestandteil), as Kant claimed. In quantum mechanics the Kantian categories end up to be logical rules, determined by facts and experiments, rather than the necessary conditions for understanding. Like Heisenberg, his ultimate opinion is that Kant's categories need not be totally given up, but relativized. It is not possible to take the Kantian a priori conditions as universally valid criteria for looking at the world, in the same way in which it is not possible to look at the world independently from the context of observation. However, the Kantian a priori still constitute an important part of the elaboration of any physical theory, as part of its methodological tools. Von Weiszäcker's opinion, as presented here, is similar in its main features to that recalled by Heisenberg about the conversation with von Weiszäcker and Grete Hermann. He still believes that Kant's a priori are not dismissed but relativized, and understands the concept of Ding an sich as not applicable to the world of the quanta. This view of the Ding an sich, is, as Hermann already pointed out, a misunderstanding.

4.5. Grete Hermann on causality

In his memories Heisenberg depicts Hermann as a little Socrates continuously asking questions, and speaking at length only when she feels the need for the clarification of a term (the Kantian Ding an sich). Although Hermann, like her teacher, Leonard Nelson, was fond of Socrates' question oriented method, as is evident in her later writings, it seems clear she did not only want to interrogate Heisenberg, but also defend her own opinion on the topic; she may have either decided to not express it boldly, or Heisenberg neglected some aspects in bringing the conversation back in his mind. Her ideas on the causality principle, and on the epistemological consequences of quantum mechanics, are given voice mainly in four essays, all written after this conversation. These essays are: Die Naturphilosophischen Grundlagen der Quantenmechanik[173], Die Bedeutung der modernen Physik für die Theorie der Erkenntnis[174], Über die Grundlagen physikalischer Aussagen in den älteren und den modernen Theorien[175] and Die Kausalität in der Physik[176].

[172] Cf. Ibid. p. 106.
[173] Hermann (1935).
[174] Hermann (1937a).
[175] Hermann (1937b).

In the already analyzed Die Naturphilosophischen Grundlagen der Quantenmechanik, published less than a year after the conversation with Heisenberg and von Weiszäcker, the opening line of questioning is similar to the one in the discussion with the two physicists. Namely, does quantum mechanics require a revision of causality? (In the discussion described in Physics and Beyond the starting question is: is quantum mechanics challenging the Kantian conception of causality?). Soon, however, the question is reformulated in a more precise fashion as: "are the limits in the predictability of quantum mechanics insurmountable in principle?" Hermann announced that that question cannot be answered on a mathematical or physical level, but only on a philosophical one.[177] Through her philosophical study she pointed out that there should be made a division between the insurmountability of the limits in the predictability and the dismissal of the law of causality. Quantum mechanics, in Hermann's opinion, only requires the giving up of precise predictability, but not of the causal law that nothing happens without a cause.

In other words, the first question is answered with a no (no, no revision of Kant's causality principle is necessary), while the second one is answered positively (yes, the limits are insurmountable). The reason why it is no longer possible to give an exact description of future events in quantum mechanics is for Hermann, that it can only give a description relative to its context of observation.[178] This poses limits to our knowledge of the situation that is not possible to overcome. It means that with quantum mechanics the absolute character of knowledge, that was taken for granted in classical physics, is lost, and that instead of an objective description of nature, only a representation which is relative to the context of observation is possible. "Instead of such a unitary and objective description [i.e. that of classical physics] we have representations which only depend on the single context of observation; they lose their applicability with a new observation and can be substituted by it."[179] She concluded by showing that, contrary to what was presupposed by the initial question, there is a strong similarity between critical philosophy and quantum mechanics. Kantian philosophy, therefore, is more confirmed than threatened by the developments of the new science.[180]

The problem of causality in quantum mechanics is also addressed in two later essays. In Die Bedeutung der modernen Physik für die Theorie der Erkenntnis, which was written some years

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[176] Hermann (1948).
[177] Cf. Chapter 2 in this thesis.
[178] Cf. Hermann (1935).
[179] "An die Stelle einer solchen einheitlichen und objectiven Naturbeschreibung treten Darstellungen, die nur relativ zum jeweiligen Beobachungszusammenhang gelten, bei neuen Beobachtungen ihre Anwendung verlieren und durch neue Beschreibungen ersetzt werden" Hermann(1935), p. 58-59. (author's translation).
[180] See chapter 2.

earlier but only published in 1937, and in Über die Grundlagen physikalischer Aussagen in den älteren und den modernen Theorien, also published in 1937, but taking a broader perspective. In these, Hermann looks at the epistemological implications of not only quantum mechanics, but of modern physics in general; from Maxwell's theory to the theory of relativity. Moreover, the first of the two essays, which won the Avenarius Preis[181], was an answer to a question of epistemological character, namely: "Welche Konsquenzen haben di Quantentheorie und die Feldtheorie der modernen Physik fuer die Theorie der Erkenntnis?"(What consequences do quantum theory and field theory have for the theory of knowledge?) [182] Hermann traced the history of classical physics, noting how the presupposition that space and time would reflect the real nature of objects received first a blow by Maxwell's theory and then fatal wounding by the theory of relativity and quantum theory. However, stated Hermann, it is not necessary to change either the causal law or the space-time concepts, but only the absolute character of the observation of nature. Hermann's answer to the implications modern physics bears for the theory of knowledge is that the modern theory forces us to a renewed study of Kant. In fact, Kant's a priori as conditions for our experience stay intact, and it is stressed that Kant (or better Fries) had already envisaged the limits of knowledge and that in the Antonomienlehre[183] (the theory of antinomies) he had shown that knowledge of nature is not in itself true.

The epistemological problems connected with quantum mechanics, and in particular an overview of the problem of causality, is presented by Hermann in her 1948 essay over Die Kausalitaet in der Physik. Here, once again, she opposed the common view that quantum mechanics had by then shown the connections in atomic processes are not causal. Her answer is that, first of all, due to the principle of incompleteness of experience (Satz der Unabgeschlossenheit der Erfahrung), it is not possible to say that a process is not causal, as the causes may always be found (here she used the principle of incompleteness of experience to argue differently than in the Foundations of Quantum Mechanics in the Philosophy of Nature). Next, although we do not know the causes and it makes sense to look for them, the formalism of quantum mechanics provides a complete description, excluding the need for other causes. Moreover, following Heisenberg's teachings, there is a "cut" between the classical description and the one in quantum mechanics. This cut coincides with the situation in which there is a transition from the classical description of, for

[181] In a letter even Heisenberg congratulates her for winning the prize (AdSD)
[182] Vorwort, in Hermann (1937a)
[183] In the transcendental dialectics Kant introduces four antinomies, or cases, in which by following reason we get to contradictory results. The results are in contrast which each other, but equally rational. This illustrates the limits of knowledge.

example, the instrument to the quantum mechanical behavior of the event studied. The “cut” is not determined objectively, it is not possible to determine the place of the cut without uncertainty. For these reasons, claims Hermann, it is not possible to find other causes - all the causes are already there, but only recognizable after the experiment is performed.[184] Consequently, in the case of the double-slit experiments, neither a subjective nor an objective interpretation can describe the situation completely[185]. The solution is for Hermann seen in a relative interpretation of quantum mechanics that still upholds the causality principle, but gives up on the requirement for an absolute description. In this essay, contrary to the previously analyzed ones, Hermann critically reviews the position of other important physicists interested in the same questions of great philosophical importance, such as the here analyzed views of Heisenberg and von Weiszäcker, but also those of Pascual Jordan and Hans Reichenbach.

The discussion of Jordan’s interpretation of quantum mechanics, suggesting a connection between the non-causality of quantum mechanics and the internal freedom of the human being, is a stimulus for Hermann to delve into what ethics should learn from the new developments in physics. Again she assumes a Nelsonian-Friesian perspective and states that freedom is not chance. In any case, Jordan’s position is not tenable, because a non-causal world would not furnish any explanation of freedom or free will, since these do not simply mean that there are no causes. Conversely, what we can learn for Hermann from quantum mechanics is that it is possible to give a causal description which is not completely mechanical. With quantum mechanics we have to give up the possibility of Laplace’s demon, of a completely determined description of natural events, but still causal explanations are possible. What has to be given up is the search for an absolute description. Similarly in ethics, Herman claims, in her previously mentioned critical tone towards Nelson’s ethics[186], that absolute truths should be given up. The loss of absolute truths does not mean, however, that everything is left to chance. On the contrary, the non-absolute character of ethics leaves space for self-determination (Selbstbestimmtheit); a freedom of choice that does not leave everything to chance. Aware that to ethics and physics correspond two different descriptions of reality, she concludes by stating that: “If even the physicists cannot describe their objects in an unequivocally determined classical model, but can only describe and understand their objects as relative to each context of observation, then there is yet more space left for varied understandings of our own surrounding life, along with the causal explanations provided by physics. “[187]

[184] Cf. Hermann (1948), p.377.
[185] For more about this argument see Chapter 2.
[186] For Hermann’s revision of Nelson’s ethics see Chapter 3.
[187] Hermann (1948), p. 382 (author’s translation).

4.6. Encounters and Conversations

Now that we have analyzed Heisenberg's and von Weiszäcker's views on the developments on causality in quantum theory and its relation to Kant's philosophy, Hermann's proposal appears on one hand supported by the position of the two physicists, and on the other some important original features of her personal interpretation stand out.

Grete Hermann follows the interpretation of quantum mechanics as detailed by the Copenhagen interpretation, and in particular by Heisenberg and Bohr. She believes that the indeterministic aspects of the theory are inherent to the nature of atoms, and that no other causes that could explain their probabilistic behavior as due to a lack of our knowledge, are possible. However, she does not accept this position without first critically challenging it, as presented in the Foundations of Quantum Mechanics in the Philosophy of Nature. Here, she first shows that there is no, and cannot be any, mathematical argument explaining the limits in the predictions of the new theory, and that these limits can be explained only on a philosophical level. Hermann follows Heisenberg in seeing a "cut" between the measured object, described through quantum mechanics, and the measurement instrument, expressed in classical terms."It appears that a peculiar schism in our investigation of atomic processes is inevitable"[188], she agrees with Heisenberg; the cut, as a passage between the classical and the quantum mechanical description, is arbitrarily determined, since it depends on when and where the measurement has taken place. This cut introduces an element of unpredictability in the new theory. No matter how much new information we get, predictions of the behavior of atoms will always be of a limited certainty.

Nevertheless, Heisenberg, Hermann and von Weiszäcker agree that this does not mean that the Anschaulichkeit of any physical theory, and the causal principle lose their validity. In fact, thanks to Bohr's correspondence principle these characteristics of classical physics, that were thought to be part of any physical theory, still hold in quantum mechanics. The requirement, due to Bohr's principle, of a correspondence between the terms in which classical mechanics and the new physics is described, not only shows a fundamental continuity between the two theories, but also allows for the new theory to be visualisable (Anschaulich), and the causal connection to be still a feature of any scientific theory. However, with the cut, the classical concepts have only limited application in quantum mechanics, and the limit imposed in their application to the passage to the microphysical world creates an insurmountable indeterminacy. The three, Heisenberg, von

[188] Heisenberg (1974.), p. 15.

Weiszäcker and Hermann, agree that this does not warrant a total dismissal of the Kantian concept of causality as a category of our understanding. They believe that causality still holds as an important feature of any scientific theory, but it has lost its absolute character and only a relative description is now possible. All three stress the importance of the "relative" view in quantum mechanics as opposed to the "absolute" one presupposed by classical mechanics.

Although they all agree in these points, Hermann's interpretation differs from the judgments Heisenberg and von Weiszäcker make of Kant. Both physicists propose a relativization of Kant, with Heisenberg stressing that, as when the earth has been discovered to be round, only certain types of questions now make sense to be asked, and von Weiszäcker arguing that the Kantian Ding an sich is not possible in quantum mechanics, because of the complementarity between the wave and the particle behaviors in atomic processes. For the two physicists Kant's a priori are still valid, but only as pragmatic tools for the understanding of nature, they cannot be considered anymore as constituting elements of our experience. "Modern Physics has changed Kant's statement about the possibility of synthetic judgments a priori from a metaphysical into a practical one. The synthetic judgments a priori thereby have a character of relative truth."[189]- "Science progresses not only because it helps to explain newly discovered facts, but also because it teaches us over and over again what the word 'understanding' may mean"[190], so express Heisenberg and von Weiszäcker their opinions according to Heisenberg's recollections. Unlike the two physicists, Hermann does not recognize any necessary revision of Kant. She states that the critical philosophy, of Kant, Fries and Nelson, instead of being dismissed by quantum mechanics, finds in it further support and appealing structural similarities.[191] Even with the great changes in modern physics, Kant's categories, viewed through Frisian philosophy, are for Grete Hermann still constitutive of our knowledge of nature, and the universally valid structure of science. Causality has no limited application; it should be distinguished, however, from its false twin, predictability.

How is it possible that Grete Hermann's view differs so much from the one of the two physicist and that she does not see any problem for the Kantian a priori losing their absolute character? Hermann, through Fries' study of Kant, had already been through a revision of Kant's a priori, and saw in his Antinomienlehre[192] the proof that Kant himself did not claim an objective

[189] Heisenberg (1958), p.82.
[190] Heisenberg (1971), p.124.
[191] As explained in chapter 2.
[192] In the critique of pure reason, Kant presents four situations in which it is possible to argue rationally and get to opposite contradictory conclusions. The four antinomies that were presented for Kant to show that is not possible to judge about things which do not start from the empirical experience, are used by Hermann to point out the limits of

meaning for his categories, but understood them only as fundamental relations to our experiences. Similarly in Kant, or better in the interpretation of Fries and Nelson, the Antonomienlehre had shown that the knowledge of nature is not true in itself. In other words, according to Hermann the consequences of quantum mechanics for the Kantian a priori have been anticipated by the Friesian critical study of Kant, and therefore the latter philosophy finds great support in the new physical theory.

Hermann's interpretation of the implications quantum mechanics bears for Kant's category of causality has herein been analyzed from various different perspectives. The comparison of Heisenberg's and von Weiszäcker's opinions shed some light on some common ideas they share with our philosopher-mathematician, but also on some original aspects of Hermann's interpretation. The critical and contextual study of the conversation between Heisenberg, von Weiszäcker and Hermann, as recalled by Heisenberg himself, has been worthwhile not only for this aspect, but also for the insight it offered into the evolution of Hermann's thought, and the reception of her disproof of von Neumann's theorem.

From such perspectives, we can see that Hermann's original contribution to the problem of causality in quantum mechanics is not only that she was one of the first to analyze the consequences of quantum mechanics for the theory of knowledge, particularly Kant's philosophy, but that she goes further by integrating Fries' philosophy of nature. Thanks to her analysis, highlighting both that Kant's category of causality had been unnecessarily linked with predictability and that in quantum mechanics, the description of a system can only be context-dependent - Kant's category of causality appears to be supported by quantum mechanics, rather than dismissed as generally believed to be. Finally, Hermann draws some ethical parallels from her analysis of the situation in physics: in the same way quantum mechanics shows us the impossibility of absolute knowledge, in ethics, it is possible to look for self-determination free from absolute values.

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knowledge. For Hermann, we can only have a relative view on nature, which is nevertheless still determined by the a priori categories.

Conclusion

> In physics, the move of deepening our insight into the physical world by relativizing notions previously used as absolute has been applied repeatedly and very successfully.[193]

Before summarizing the results of this research, it is worth having a brief look at two last questions. These questions are: 1) Why was Grete Hermann's discovery of a wrong assumption in von Neumann's impossibility proof ignored for so long? 2) What is the relationship between Hermann's ideas and more contemporary work in quantum mechanics?

In the following two paragraphs I try to give an answer to both these questions. These answers are given in the form of a hypothesis, however, and have to be taken as new perspectives and suggestions for further research. Since these are more subjective ideas, they are not part of the thesis itself, but are left for the conclusion. My claims will constitute the final part.

A first suggestion: why was Grete Hermann ignored for so long?

A question which arises naturally when reading of Hermann's life and work is why was her work, and in particular her discovery of a circularity in von Neumann's proof, has long been ignored? An early acknowledgment of Hermann's discovery would have changed the history of quantum mechanics and increased the development of alternative theories making use of hidden parameters. Understanding the reasons why Hermann's work was neglected for so long can contribute to understanding the development of science at the time, as well as interestingly demonstrate how individuals and contingencies influence the development of science in general. I agree with previous studies of Hermann, in that there is not any singular reason why Hermann's work was so long neglected, but rather that a number of factors, of varying importance, contributed. However, in my opinion one aspect was particularly relevant; this aspect was not considered by previous studies of Grete Hermann.

A list of reasons that has been presented in the literature until now reads like this[194]: 1) she was a woman, in a time in which women were still not well received in the scientific community (e.g. her teacher, Emmy Noether, whose achievements have been proclaimed worldwide, never

[193] Rovelli (2009), p. 17-18.
[194] Herzenberg (2008), Seevinck (2002).

received a professorship) 2) she was young and without influential connections 3) she came from a different background: she had not studied physics, but philosophy and mathematics 4) she was a political outsider and dissenter 4) von Neumann was at the time very highly regarded, and his ideas rarely questioned[195] and 5) Bohr and Heisenberg had some interest in preserving the belief in the results of von Neumann's no hidden variables proof, since it supported their ideas. The arguments behind these posited influences seem reasonable and strong – however in addition to these first five reasons, other, less convincing, causes have also been considered: 6) Hermann was writing in German, in a world where English was gradually becoming the language of choice in Academia. There was no English translation of Von Neumann's work for a long time, and Hermann's work as well was only available in German[196] and 7) that Hermann published only in minor journals. These last two reasons hold less ground in my opinion, since, first of all, German was still the language of choice at the time, and it was only gradually replaced by English. At the time, the most important and well known works in physics were still written in German.[197] Secondly, it is not accurate to say that Hermann published only in minor journals, since Hermann published in 1935 her summary of Die Naturphilosophischen Grundlagen der Quantenmechanik in die Naturwissenschaften. This journal, founded by the Kaiser Willhem Society in 1913, could not only boast an important tradition but also important physicists, such as Einstein, Planck and von Laue having published in it.

Although it seems evident that these factors had their role in the scientific community's longstanding ignorance of Hermann's work, I claim that one of the most relevant reasons has been overlooked in previous discussions on the matter. In my opinion, a primary reason is to be found in Hermann's personality and work, as she did not actively pursue the wider dissemination and understanding of her discovery. First of all, she published the critical analysis of von Neumann's proof written in small font, having earlier stated that anything in such a font could be readily skipped. The discovery of an unnecessary assumption in a proof of one of the most important mathematicians of the time is presented by Hermann just as a footnote in her philosophical considerations. Secondly, in later editions of the paper, the disproof is simply left out, stressing again the insignificance Hermann ascribed to it. She seems to be either unaware, or unwilling to highlight her discovery. Either way, the result of her critique to von Neumann's proof only served

[195] "The truth, however, happens to be that for decades nobody spoke up against von Neumann's arguments, and that his conclusions were quoted by some as the gospel. There must be some magic in his arguments that could fool people into believing that his definition of hidden variables theory would be the only correct one rather than the obviously inappropriate one" in Belinfante (1973).

[196] Recently a French translation of the Naturphilosophischen Grundlagen der Quantenmechanik has been made (by Lena Soler), unfortunately, there is still no English translation available.

[197] Just as an example Heisenberg's "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen", where he started posing the basics of matrix mechanics..

to show how it was impossible to answer the problem of the completeness of quantum theory on a physical level, and why a philosophical analysis was necessary. What Hermann particularly wanted to show is that quantum mechanics could still be seen as causal and complete, without having to assume some hidden causes. Thus, her discovery did have the role of guiding her research for hidden variable theories, but played an only minor part in her philosophical arguments.

Given the relative triviality and obscurity Hermann assigned to her disproof, it seems less surprising that it is also left out in Heisenberg's published memories of Hermann. [198] Unfortunately, we cannot know whether Heisenberg neglected her discovery, or whether she did not even mention it to him because it seemed unimportant compared to her philosophical concerns. If the latter were the case, it would make the 5th posited reason (Heisenberg's satisfaction with the results of the proof) less important, or rendered irrelevant. Furthermore, the limited interested that Hermann assigned to physics can be seen in her decision to turn away from it with the outbreak of the Second World War, and become instead mainly dedicated to the application of her political ideals. While in 1935 she was discussing her ideas with the founding fathers of the newest physical theory and did not shy away from confronting them with the most challenging philosophical questions, in the following years her contact with the world of physics became scarcer. Although it has been shown that her interest in physics was maintained for many years[199], her direct engagement in the development of quantum mechanics certainly became less with time. It is, therefore, my opinion that the main reason Hermann was so long ignored was because of her own choices. Whether in making these choices she consciously sought to diminish the dissemination and importance of her discovery, it is not possible to answer yet. Although other factors, such as her being an outsider to physics, a women, socialist and philosopher, all probably played their role in determining that her discovery was to be ignored, it seems undeniable that her own choices had the lead role to this outcome.

[198] See Chapter 4.
[199] Cf. Chapter 2.

A second speculation: the relation of Hermann's ideas to contemporary developments

The second question which may arise in the reading of Hermann's work is, what is the relation of Hermann's ideas to contemporary developments?

In 1935 Hermann published Die Naturphilosophischen Grundlagen der Quantenmechanik, a long ignored work, which has been here shown rich with fruitful insight and suggestions. In this essay, written by young Hermann while she was studying under the guidance of philosopher Leonard Nelson and mathematician Emmy Noether, a new interpretation of quantum mechanics that Hermann called "relative" was proposed. She stresses that with quantum mechanics it is no longer possible to acquire absolute knowledge of the situation (the Laplacean demon), but only relative knowledge, which depends on the context of the observation. This is because quantum theory had been shown at the same time to be based on the same terms as classical physics, yet to have a limited application of these. While in classical mechanics physical properties could be measured independently from each other, this seems no longer possible in quantum mechanics - the physical characteristics appear interrelated. Thus, for example, it is not possible to measure the position of a particle without interfering with its momentum (Bohr's complementarity principle). In addition, the state function, which entails all the information about the system quantum theory presents us with, can only give probabilistic predictions of the evolution of the state. How are we to interpret these various problematic aspects? Hermann questioned the consequences quantum theory would have for the Kantian category of causality, answering that quantum mechanics is complete, and that the search for hidden causes is futile, as the causes are already clear. Depending on the context of observation we can get to different descriptions of the same event. This is what Hermann calls a "relative" interpretation of quantum mechanics.

Many years after Hermann's "relativity" proposal, there is still discussion of relative views in quantum mechanics.[200] Carlo Rovelli[201], in particular, proposed the consideration of all physical variables, such as the state or the outcome of a measurement, as relative to an observer, which can be a living, as well as inanimate object. From this perspective he poses some postulates, from which he tries to derive the interpretation of quantum mechanics in the same spirit as Einstein did with the theory of relativity. Consequently, he claims that quantum theory is complete, and resolves the apparent contradictions of the measurement problem. "The core idea is to read the

[200] See for example Rovelli (1996), Rovelli, Laudisa (2009), Bitbol (2007).
[201] In Rovelli (1996).

theory as a theoretical account of the way distinct physical systems affect each other when they interact (and not of the way physical systems "are"), and the idea that this account exhausts all that can be said about the physical world."[202] This same fundamental idea is also shared by other relative interpretations, for example those proposed by Bitbol[203] and by Everett.

I suggest that Grete Hermann could be considered a forerunner of these interpretations. In accepting the relative view, Rovelli has to deny the absolute character of physical knowledge, exactly the way Hermann had done many years before. Although guided by different philosophical concerns (Hermann wants to save Kant's category of causality, while Rovelli tries to derive the quantum formalism from three postulates in the same way Einstein had done), both proposals start by accepting the completeness and the empirical success of the theory, and proposing a philosophical way out of its problems. Given such parallels with contemporary works, I believe further analysis of Hermann's work may provide fertile suggestions to the development of today's quantum mechanics, which almost 80 years after Grete Hermann, despite its unquestionable success, still "maintains a remarkable level of obscurity".[204] This would require an appropriate study of the different contemporary relative interpretations proposed, as well as Hermann's work, and will remain here but a suggestion for further research.

Claims

Grete Hermann made important contributions to mathematics[205], philosophy and physics, and her ideas are an interesting example of what the collaboration between philosophy and science can offer. My major claim of the thesis is that Grete Hermann has not been given the recognition her, and her work, deserves. With this English language study, drawn largely from the primary German language sources, I hope to redress this somewhat. In doing so, my research fills a gap in the histories of mathematics, philosophy, and quantum mechanics, and will hopefully provoke new insight and interpretations across the fields. The primary points of interest, across historical, philosophical and foundational levels, are recapped below.

First, on the historical level comes her discovery of a lacuna in von Neumann's impossibility proof. This discovery highlights Hermann's open and attentive mind, which, coupled

[202] Rovelli Laudisa (2009), p. 2.
[203] Bitbol (2007).
[204] Rovelli (1996), p. 1.
[205] Mathematics is only briefly mentioned in this thesis, I hope further study will point this out better.

with a different philosophical background, allowed her to look at the developments of quantum mechanics from a new and valuable perspective. Her personal conviction in the face of contrary authority (first seen in her atheism, and later in her relation to Nelson), was again seen in her willingness to dispute eminent mathematicians and physicists. In this way, she turned out to be ahead of her time, pointing out a unnecessary assumption in von Neumann's proof that took another 30 years to become well known to the majority of physicists, and provoking a great change in the possible interpretations of quantum theory. It is impossible to know how an earlier acknowledgement of her discovery would have changed and likely accelerated the development of the field, yet recognition of this work and the people and circumstances surrounding it provides substantial additional insight regarding the early years of development in quantum mechanics. In addition, the renewed study of her biographical data, allowed to shed a different light on her life and her interest and connections with the history of quantum mechanics.

Second, the theoretical background in which Hermann's discovery is embedded should not be forgotten. Hermann starts tackling the mathematical proof presented by von Neumann with a strong resolution to show that a mathematical study cannot answer the question of the indeterminacy and the apparent violation of the causality principle in quantum mechanics. Hermann, fond of Kantian philosophy as further elaborated by Jacob Friedrich Fries and Leonard Nelson, could not believe that experience could prove Kant's a priori category of causality wrong, since a priori the question could only be answered on a philosophical basis. In answering this question, Hermann makes numerous contributions to both the foundations of quantum mechanics and Friesian philosophy. As detailed in chapter two, she undertakes a critical terminological analysis of the principle of causality, which separates it from the concept of predictability. This allows her to propose a relative interpretation of quantum theory, in which the theory is complete (there is, therefore, no need to seek hidden causes), and causality is maintained as a necessary characteristic of any physical theory. What needs to be accepted, she claims, is that it is no longer possible to give an absolute description of the world, but only a partial description, which depends on our context of observation. As mentioned above, this interpretation can be seen as a forerunner of today's relative interpretations, and contains relevant reflection points for the development of physical and philosophical thought.

Furthermore, from a philosophical perspective, Hermann's work also yielded remarkable results. She was an active, although critical, member of what had been called "the Friesian school", the main figures of which (Fries and Nelson), were briefly described in Chapter 3. The study of Hermann's work and life has contributed to a new historical outlook and understanding of this largely neglected and misunderstood philosophical movement.[206] Hermann's work shows how the collaboration between critical philosophy, physics and mathematics lead to positive results, such as her own achievements. Through her story we had also the chance to have a look at David Hilbert's programme. The collaboration between philosophy and mathematics which was at the basis of his programme is also the cultural background against which Hermann's ideas developed. In addition, an attentive analysis of her methodology and aims showed that Hermann's elaboration on Friesian philosophy was not simply in line with the School, but that she went further by expanding on the subject matter it had typically focused on with the inclusion of the most recent developments in physics, as well as lessening the absolutist aspects of it.

Overarching the three levels of analysis, Hermann's interpretation of the relationship between Kantian philosophy and quantum mechanics has been chronologically one of the first.[207] A comparison with the ideas von Weiszäcker and Heisenberg had on the topic helps fully comprehend the original aspects of her thought. Like Heisenberg and von Weiszäcker she proposed a relativized view of the Kantian a priori, but distinct from them, she does not want to give up the universal validity of it,

To sum up, I claim to have answered the three questions posed in the beginning of my thesis with a "yes". Yes, Grete Hermann's proposal of a relative interpretation of quantum mechanics and her analysis of causality is of much interest and it contains suggestions, such as the relative view and the distinction between predictability and causality that could interest today's physics. Yes, Friesianism has been shown to be relevant to the elaboration of Hermann's ideas, and the study of Hermann's work is also a contribution to a historical re-evaluation of this School. Yes, Hermann is of interest and worthy of study in her own right - as a German philosopher, mathematician and socialist, protagonist of the 20th century, her story provides us with a particular view of scientific development, and the many contingencies therein. Many aspects of her life that could contribute to the understanding of, and offer a different perspective on various relevant figures of philosophy and science, such as her being in a sense part of Hilbert's programme, her relationship to Heisenberg, and the dialogue with Leonard Nelson.

Many other questions, concerning for example the role Emmy Noether played in this story, or Hermann's ideas on politics, ethics and education, are left open. As stated in the beginning of this undertaking, this thesis has been an initial extensive study on Hermann's life and ideas. Her oeuvre and biographical data have been analyzed in detail and the few critical studies available augmented

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[206] Cf. Chapter 3.
[207] Cf. Soler (2001) and chapter 2.

and updated. It should serve at same time as a critical and preparatory work, analyzing some relevant and original aspects of Hermann's work and paving the way to further, detailed studies on the specific topics.

Appendix

Original quotes in German

Chapter 1

“Mein Vater hatte im Jahr 1921 nach religiös-weltanschaulichem Suchen und nach schwerer persönlicher Erfahrung mit dem bürgerlichen Leben gebrochen. Er hatte sein Geschäft und sein ganzes Vermögen auf meine Mutter überschreiben lassen und zog nun, mit langem Haar und Bart, in Lodenjoppen, Kniehosen und Galoschen als „Wanderprediger“, wie er sich selber nannte, umher oder lebte einsam meditierend für sich“. Hermann (1953), p. 180.

“Die Angst davor, dass Nelson Recht hatte, dass also die Auseinandersetzung mit ihm mich vor die Alternative stellen würde: Entweder die Hoffnung auf ein mit der eigenen Weltanschauung zusammenstimmendes religiöses Leben preiszugeben und außerdem unliebsame ethische Konsequenzen zu ziehen, oder die Methode des Philosophierens, von deren Sicherheit und Notwendigkeit ich überzeugt war, so wenig ich sie damals auch noch kannte, zu verraten.“ Hermann (1985).

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“Welch ein Glück für uns, dass sie in dieses Chaos kam! An ihr konnten wir uns neu aufrichten. Zeichnen Sie bitte: Hunger, Kälte, unterernährt bis krank, zerstörtes Elternhaus durch Bomben oder Trennung. Jeder von uns war belastet durch unterschiedliche Kriegserlebnisse an der Front, zu Hause oder auf der Flucht und befand sich in einem gebrochenen Weltbild am Suchen. [...] Wir waren so verschieden mit unseren Schicksalen, unseren Einstellungen, unserem Glauben und unserem Misstrauen.

Grete Henry nahm uns alle ernst, wie wir waren. [..] Grete Henry war der Inbegriff von Toleranz und klarer Glaubwürdigkeit. Sie bildete uns durch ihr Vorbild. Sie war selbstbestimmt, vernünftig selbstbestimmt“ Hoennecke (1995), p. 28-29.

Chapter 2

“In ihren kühnen und erfolgreichen Vormarsch hat die moderne Physik Positionen erschüttert, die noch für die klassischen Theorien als unantastbare Grundlagen jeder Naturforschung galten, ein Urteil, dem die kritische Philosophie, in ihrer Lehre von den apriorischen Grundsätzen der Erfahrung, die naturphilosophische Deutung und Begründung gegeben hatte. Man sagt, die Erfahrung habe gegen diesen Standpunkt entschieden; man feiert die physikalischen Erregungenschaften dieses Jahrhunderts als den großen Sieg der über alle vorgefassten Meinungen triumphierenden Erfahrung, als die Befreiung von Vorurteilen, die empirisch gewonnene Vermutungen in das glänzende, aber trügerische Gewand ewiger Wahrheiten kleideten. EINSTEIN aber erklärt, er habe von Tatsachen gezwungen, die Begriffe von Raum und Zeit „aus den Olymp des Apriori“ heruntergeholt, um sie zu reparieren und wider in einen brauchbaren Zustand setzen zu können. Die Vertreter der Quantenmechanik vertreten entsprechende Korrekturvorschläge für das Kausalgesetz.“ Hermann(1935), p. 7.

Was hindert uns, anzunehmen, dass ihm nicht bei einer Erweiterung der physikalischen Erkenntnis neue Formeln und Regeln angefügt werden, die zusammen mit dem jetzt vorliegenden formalen Ansatz wieder genaue Voraussagen ermöglichen? […] dann ist damit die Tür geöffnet für die Frage, ob sich nicht andere Merkmale finden lassen, von denen der Ablauf der Bewegung abhängt und aus denen er sich vorausberechnen lässt.

“Für die so mit Hilfe einer Schar physikalischer Systeme definierte Erwartungswert-Funktion Erw (R), die jeder physikalischen Größe eine Zahl zuordnet, setzt NEUMANN voraus, dass Erw (R+G) = Erw(R) + Erw(G) ist. In Worten: Der Erwartungswert einer Summe physikalischer Größen ist gleich der Summe der Erwartungswerte beider Größen. Mit dieser Voraussetzung steht und fällt der NEUMANNsche Beweis“ Hermann (1935), p. 31

The fact that quantum mechanics is conservative in exactly that aspect for which it has often been praised for overcoming, is decisive here. Despite the revolutionary changes of quantum mechanics, the fundamental concepts which mediate the passage from experience to knowledge, have been left untouched. Hermann (1935), p. 78.

“Die Naturerkenntnis zeigt uns nicht eine nach ihren eigenen inneren Eigenschaften vollständig bestimmte Wirklichkeit, sondern nur Relationsfüge, die insofern unauflösbar sind, als sich für diese Relationen keine eindeutig und in sich bestimmten Fundamente angeben lassen“ Hermann (1935), p. 75.

Chapter 4

“Wenn schon die Physik selber darauf verzichten muss, ihre Objekte in einem eindeutigen klassischen Modell darzustellen, wenn sie ihren Gegenstand vielmehr nur relativ zum jeweiligen Beobachtungszusammenhang beschreiben und erfassen kann, dann ist um so mehr der Weg frei dafür , neben der physikalisch-kausalen Naturforschung ganz andere Zugänge zur Erfassung des eigenen und des umgebenden Lebens anzuerkennen“ Hermann (1948), p. 382.

Bibliography

Archive consulted:

Archiv der sozialen Demokratie der Friedrich-Ebert-Stiftung, Bonn (AdSD), July 2011.

Books and articles by Grete Hermann:

___(1926) Die Frage der endlich vielen Schritte in der Theorie der Polynomideale, Mathematische Annalen.

___ (1935) Die naturphilosophischen Grundlagen der Quantenmechanik. Abhandlungen der Fries´schen Schule, N.F. Band 6, Heft 2, S. 69–152 (Second Edition. Berlin: Sonderdruck bei Hirtzel).

___(1937a), Über die Grundlagen physikalischer Aussagen in den älteren und den modernen Theorien. Abhandlungen der Fries´schen Schule, N.F. Band 6, Heft 3 u.4, S. 309–398.

___(1937b) and May, E., Vogel, Th, Die Bedeutung der modernen Physik für die Theorie der Erkenntnis. Leipzig: Hirtzel.

___(1945) Politik und Ethik, Internationaler Sozialistischer Kampfbund.

___ (1948)"Die Kausalität in der Physik," Studium Generale **1**, 375-383.

___(1953) Die Überwindung des Zufalls. Kritische Betrachtungen zu Leonard Nelsons Begründung der Ethik als Wissenschaft. Frankfurt: Verlag öffentliches Leben, Frankfurt. Red. (1985) Hamburg: Meiner.

___(1955), Albert Einstein, Bonn: Sozialdemokratischer Pressedienst.

___(1973) The Significance of Behaviour Study for the Critique of Reason. Ratio XV, Nr. 2, S. 206–220.

Edited by Grete Hermann

(1970-1974) with Bernays, P., Eichler W., Gysin, A., Heckmann, G., von Hippel, F. Körner, S., Kroebel and Weisser, G.: Leonard Nelson. Gesammelte Schriften in neun Bänden. Hamburg: Meiner.

Nelson, L. (1975), Vom Selbstvertrauen der Vernunft. Schriften zur kritischen Philosophie und ihrer Ethik. Hamburg: Meiner.

Other references:

Albers, D. (2001), Die Aktualitaet der politischen Beitraege von Grete Henry-Hermann, in: Susanne Miller / Helmut Müller im Auftrag der Philosophisch-Politischen Akademie (Hrsg.): In der Spannung zwischen Naturwissenschaft, Pädagogik und Politik. Zum 100. Geburtstag von Grete Henry-Hermann, Bonn: Philosophisch Politische Akademie.

Belinfante, F.J., (1973), A Survey of Hidden Variables Theories, Oxford: Pergamon.

Bell, J. S. (1966), On the Problem of Hidden Variables in Quantum Mechanics, Reviews of Modern Physics 3, 447-452.

Beller, M., (1999) Quantum Dialog: The Making of a Revolution, Chicago: The University of Chicago Press.

Bernays, P. (1928), On Nelson's Position Concerning the Philosophy of Mathematics, Die Naturwissenschaften 16, 142-145.

Bianco (1980). J.F. Fries, Rassegna storica degli studi (1803-1978), Napoli: Bibliopolis.

Bitbol, M. (2007), "Physical Relations or Functional Relations? A non- metaphysical construal of Rovelli's Relational Quantum Mechanics", Philosophy of Science Archive: http://philsci- archive.pitt.edu/archive/00003506/.

Bitbol, M.(1998), “Some steps towards a transcendental deduction of quantum mechanics,” Philosophia Naturalis **35,** 253-280.

Bonsiepen, W. (1997), Die Begründung einer Naturphilosophie bei Kant, Schelling, Fries und Hegel : mathematische versus spekulative Naturphilosophie, Frankfurt am Main : Klostermann.

Caruana, L. (1995), ‘John von Neumann's “Impossibility Proof” in a Historical Perspective’, Physis 32, pp. 109-124.

Cohen (1960), I. B., The Birth of a New Physics, London: Heinemann.

Cohen (1981), I. B., The Newtonian Revolution, Cambridge [etc.]: Cambridge University Press.

Cunningham, A. and Jardine, N. (eds) (1990) Romanticism and the sciences, Cambridge [etc.] : Cambridge University Press.

De Pierris, G. and Friedman, M. (2008), "Kant and Hume on Causality", The Stanford Encyclopedia of Philosophy, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2008/entries/kant-hume-causality/>.

De Regt, H. (2001), Spacetime Visualisation and the Intelligibility of Physical Theories, Studies In History and Philosophy of Science Part B: Studies In History and Philosophy of Modern Physics, Volume 32, Issue 2, June 2001, 243-265.

Dieudonne (1981), “John von Neumann”, Dictionary of Scientific Bibliography, C. Gillispie, Scibners (ed) , New York: Charles Scribner's Sons, 88-92.

Eckermann (1949), Johann Peter. Gespräche mit Goethe in den letzten Jahren seines Lebens, Wiesbaden: von H. H. Houben.

Faye, J. (2008), "Copenhagen Interpretation of Quantum Mechanics", The Stanford Encyclopedia of Philosophy (Fall 2008 Edition), Edward N. Zalta (ed.), URL = http://plato.stanford.edu/archives/fall2008/entries/qm-copenhagen/

Fischer, I. (2005), “Von der Philosophie der Physik zur Ethik des Widerstandes. Zum Nachlass Grete Henry-Hermann im Archiv der sozialen Demokratie” http://www.fes.de/archiv/newsletter/NL%202005/NL%2001%202005/html/fischer012005.htm (accessed January, 2012)

Friedman, M. (1992), Kant and the exact sciences , Cambridge, Massachusetts, [etc.] : Harvard University Press.

Geldsetzer, L.(1999): Jakob Friedrich Fries' Stellung in der Philosophiegeschichte in Jakob Friedrich Fries – Philosoph, Naturwissenschaftler und Mathematiker. Verhandlungen des *Symposiums „Probleme und Perspektiven von Jakob Friedrich Fries' Erkenntnislehre und* Na*turphilosophie“ vom 9.*–11. Oktober 1997 an der Friedrich-Schiller-Universität in Jena. Frankfurt am Main : Lang.

Giuntini, R. and Laudisa, F. (2001), “The Impossible Causality: The No Hidden Variables Theorem of John von Neumann,” John von Neumann and the Foundations of Quantum Physics, eds. Miklos Redei and Michael Stoltzner, , Dordrecht: Kluwer Academic Publishers.

Gower, B. (1973) "Speculation in Physics: The History and Practice of Naturphilosophie," Studies in the History and Philosophy of Science 3: 301-56.

Grant (2007), E., A History of Natural Philosophy: from the ancient world to the nineteenth century, New York : Cambridge University Press.

Gregory (2008), F., Natural Science in Western History, Boston: Houghton Mifflin.

Gregory, F. (2006), extending Kant: the origins and nature of Jakob Friedrich Fries’s Philosophy of Science in The Kantian Legacy in the Nineteenth-Century Science. Cambridge (Mass.), p. 101-121

Hawthorn (1991). Plausible Worlds: Possibility and Understanding in History and the Social Sciences, New York: Cambridge University Press.

Heisenberg, W., (1971), Physics and Beyond: Encounters and Conversations, translated by Arnold J. Pomerans, New York: Harper and Row.

Herrmann, K. Hogrebe, W. ,eds. (1999): Jakob Friedrich Fries – Philosoph, Naturwissenschaftler und Mathematiker. Verhandlungen des Symposiums „Probleme und Perspektiven von Jakob Friedrich Fries' Erkenntnislehre und Naturphilosophie“ vom 9.–11. Oktober 1997 an der Friedrich-Schiller-Universität in Jena. Frankfurt am Main: Lang.

Herrmann, K.(1999), Nelsons Kritik der Erkenntnistheorie und ihre Konsequenzen in Jakob Friedrich Fries – Philosoph, Naturwissenschaftler und Mathematiker. Frankfurt am Main: Lang.

Herzenberg, C.L. (2008), Grete Hermann: An early contributor to quantum theory, http://arxiv.org/abs/0812.3986v1 (accessed January 2012)

Hilgevoord, J. and Uffink, J., (2011), "The Uncertainty Principle", The Stanford Encyclopedia of Philosophy (Spring 2011 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/spr2011/entries/qt-uncertainty/>.

Hobsbawn (1994), The Age of Extremes: The Short Twentieth Century, 1914-1991, London: Michael Joseph.

Hoennecke (1995), Der heilige Improvisatius – Grete Henry-Hermann als Leitering der Lehrerausbildung in der Nachkriegszeit, in Susanne Miller / Helmut Müller im Auftrag der Philosophisch-Politischen Akademie (Hrsg.): In der Spannung zwischen Naturwissenschaft, Pädagogik und Politik. Zum 100. Geburtstag von Grete Henry-Hermann, Bonn: Philosophisch Politische Akademie.

Jammer, M. (1974), The Philosophy of Quantum Mechanics: The Interpretations of Quantum Mechanics in Historical Perspective, New York: John Wiley & Sons.

Kant, I. (1786), I., Metaphysical foundations of natural science, Cambridge: Hackett publishing company.

Kant, I. (1787), Critique of Pure Reason, translation Guyer, P., and Wood, A., (eds.), 1998, Critique of Pure Reason, Cambridge: Cambridge University Press.

Kraft, J (1948), Introduction, in Nelson, Socratic Method and Critical Philosophy: selected essays by Leonard Nelson, New York: Dover Publications.

Krips (2008), Henry, "Measurement in Quantum Theory", The Stanford Encyclopedia of Philosophy (Fall 2008 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2008/entries/qt-measurement/>.

Laplace, P. S. (1951), A Philosophical Essay on Probabilities, translated into English from the original French 6th ed. by Truscott, F.W. and Emory, F.L., New York: Dover Publications.

Laudisa, F. and Rovelli, C., (2008), "Relational Quantum Mechanics", The Stanford Encyclopedia of Philosophy , Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2008/entries/qm-relational/>.

Lemke-Mueller (1996), Introduction, in: Ethik des Widerstands. Der Kampf des Internationalen Sozialistischen Kampfbundes (ISK) gegen den Nationalsozialismus, Bonn 1996.

Mach, E. (1883), Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt, Leipzig: Brockhaus.

Mainzer, K. (1999): Fries' Beziehung zu Mathematik und Naturwissenschaften - Gestern und Heute in Jakob Friedrich Fries – Philosoph, Naturwissenschaftler und Mathematiker.. Frankfurt am Main : Lang.

Mermin, N.D (1993).: “Hidden variables and the two theorems of John Bell”. Review of Modern Physics **65**, 803–815.

Miller, S. (1996), „Kritische Philosophie als Herausforderung zum Widerstand gegen den Nationalsozialismus“, in: Sabine Lemke-Müller: Ethik des Widerstands. Der Kampf des Internationalen Sozialistischen Kampfbundes (ISK) gegen den Nationalsozialismus, Bonn: PPA.

NDB (V): Neue Deutsche Biographie, V, Berlin: Dunker & Humboldt, pp. 608-609.

Nelson, L. (1949) Socratic Method and Critical Philosophy: selected essays by Leonard Nelson, New York: Dover Publications.

Peckhaus, V,. (1997), "Fries in ‚Hilberts Göttingen‘: Die Neue Fries'sche Schule", in: Jakob Friedrich Fries. Philosoph, Naturwissenschaftler und Mathematiker. Verhandlungen des Symposiums "Probleme und Perspektiven von Jakob Friedrich Fries' Erkenntnislehre und Naturphilosophie" vom 9.10.–11.10.1997 an der Friedrich-Schiller-Universität Jena,. Wolfram Hogrebe/Kay Herrmann (eds), Frankfurt a.M.: Peter Lang.

Peckhaus, V, (1994), "Von Nelson zu Reichenbach. Kurt Grelling in Göttingen und Berlin", in: Hans Reichenbach und die Berliner Gruppe, Lutz Danneberg/Andreas Kamlah/ Lothar Schäfer (eds), Friedr. Wiesbaden: Vieweg & Sohn.

Peckhaus, V. (1990),Hilbertprogramm und Kritische Philosophie. Das Göttinger Modell interdisziplinärer Zusammenarbeit zwischen Mathematik und Philosophie, Inaugural-Dissertation in der Philosophischen Fakultät I (Philosophie, Geschichte und Sozialwissenschaften) der Friedrich-Alexander-Universität Erlangen-Nürnberg.

Peckhaus, V. (1999): Fries in 'Hilberts Göttingen': Die Neue Fries'sche Schule in Jakob Friedrich Fries – Philosoph, Naturwissenschaftler und Mathematiker, Frankfurt am Main : Lang.

Peckhaus, V. (2001), ‚Mein Glaubensbekenntnis‘. Leonard Nelsons Brief an David Hilbert", in: Mathematik im Wandel. Anregungen zu einem fächerübergreifenden Mathematikunterricht, Michael Toepell (eds), Berlin: Verlag Franzbecker.

Plato (1924), Meno, W. R. M. Lamb, tr., in Loeb Classical Library, London, New York, 1924, IV, 297.

Pulte, H. (1999) „..sonder Empirismus und SPecultaion sich verbinden sollen.“in Jakob Fries. Philosoph, Naturwissenschaftler und Mathematiker, Frankfurt am Main.

Pulte, H. (1999):«...sondern Empirismus und Spekulation sich verbinden sollen». Historiographische Überlegungen zur bisherigen Rezeption des wissenschaftstheoretischen und naturphilosophischen Werkes von J. F. Fries und einige Gründe für dessen Neubewertung in Jakob Friedrich Fries – Philosoph, Naturwissenschaftler und Mathematiker. Verhandlungen des *Symposiums „Probleme und Perspektiv*en von Jakob Friedrich Fries' Erkenntnislehre und *Naturphilosophie“ vom 9.*–11. Oktober 1997 an der Friedrich-Schiller-Universität in Jena. Frankfurt am Main : Lang.

Pulte, H. (2006) "Kant, Fries and the Expanding Universe of Science", in: The Kantian Legacy in the Nineteenth-Century Science. Ed. by Michael Friedman and Alfred Nordmann. Cambridge, p. 101-121.

Reid, C, (1970), Hilbert, Berlin: Springer.

Ribe, N. (1985), Goethe’s Critique of Newton: A Reconsideration, in Studies in History and Philosophy of Science, Vol. 16, N.4. 315-335.

Richards, R. (2002), The Romantic Conception of Life: Science and Philosophy in the Age of Goethe. Chicago: University of Chicago Press.

Roquette, P, Zu Emmy Noethers Geburtstag, Einige neue Noetheriana, http://www.rzuser.uni-heidelberg.de/~ci3/geburtstag.pdf (accessed January 2012).

Ross, K. L., “Grete Henry's "The Significance of Behaviour Study for the Critique of Reason," Ratio, Volume XV, No. 2, December 1973,” discussed and reproduced at: http://www.friesian.com/henry.htm (Accessed January, 2012)

Rovelli, C. (1996) "Relational Quantum Mechanics"; International Journal of Theoretical Physics **35**; 1996: 1637-167.

Sachs-Hombach (1999), Ist Fries’Erkenntnistheorie psychologistisch?, in Jakob Friedrich Fries Philosophy, Naturwissenschaftler und Mathematiker.

Seevinck, M. P, translation of "Der Zirkel in NEUMANNs Beweis", section 7 from the essay by Grete Hermann, Die Naturphilosophischen Grundlagen de Quantenmechanik. Abhandlungen der dries'schen Schule, 6, 1935.

Seevinck, M. P. (2002), "Grete Henry-Hermann: 1901-1984: Philosopher, Physicist and Mathematician before her time?"www.phys.uu.nl/igg/seevinck/gretehermann_english.ps (accessed January 2012)

Seevinck, M.P. (2004) "Conceptual and historical aspects of von Neumann's no hidden ariables proof," The Netherlands: Utrecht University http://www.phys.uu.nl/igg/seevinck/von_neumann_utrecht.ps

Siegel, C. (1913), "Fries, Fortbildung der Kantischen Naturphilosophie," in Geschichte der deutschen Naturphilosophie, Leipzig : Akademische Verlagsgesellschaft.

Soler, L. (1996), Les fondements philosophiques de la mécanique quantique .Hermann, Grete. - Paris : Libr. Philosophique Vrin.

Soler, L. (2009) " The Convergence of Transcendental Philosophy and Quantum Physics: Grete Henry-Hermann's 1935 Pioneering Proposal" in Constituting Objectivity The Western Ontario Series in Philosophy of Science.

Soler, L., Schnell, A.(2001), „Grete Henry-Hermanns Beiträge zur Philosophie der Physik", in: Susanne Miller / Helmut Müller im Auftrag der Philosophisch-Politischen Akademie (Hrsg.): In der Spannung zwischen Naturwissenschaft, Pädagogik und Politik. Zum 100. Geburtstag von Grete Henry-Hermann, Bonn: Philosophisch Politische Academie.

Specht, M., Eichler W. (1953): Leonard Nelson zum Gedächtnis. Frankfurt am Main: Verlag Öffentliches Leben.

Venz,V.(notdated),"GreteHermann"http://www.hausarbeiten.de/faecher/hausarbeit/big/17304.html (accessed July,2011)

Von Neumann, J. (1930), Matematische Grundlagen der Quantenmechanik, Berlin: Springer.

Von Weiszäcker, C. F., (1976), Zum Weltbild der Physik, Stuttgart: Hirzel Verlag.

Von Weizsäcker, C. F. (1936), *Review of Grete Hermann's naturphilosophischen* Grundlagen der Quantenmechanik, Physicalische Zeitschrift 37,527-528.

Von Weizsaecker, C. F, (1931) "Ortbestimmung eines Elektrons durch ein Mikroskop", Zeitschrift fuer Physik 70, Berlin.

Watkings (2005), Kant and the Metaphysics of Causality, Cambridge: Cambridge University Press.

Weyl, H. (1947), David Hilbert and His Mathematical Work, Bulletin of the American Mathematical Society 50, 612 – 654.

Wheeler, J. A, (1978),"The 'Past' and the 'Delayed-Choice Double-Slit Experiment'," pp 9–48, in A.R. Marlow, editor, Mathematical Foundations of Quantum Theory, Academic Press .

Whewell (1837) History of the Inductive Sciences, from the Earliest to the Present Times. 3 vols, London.

Ziechmann (1970), J., Theorie und Praxis der Erziehung bei Leonard Nelson und seinem Bund, Klinkhardt: Regenburg.