Karl-Heinz Schlote *

From Möbius to Heisenberg: Mathematical and theoretical physics in Leipzig 1830–1945

(1) Introduction

The development of physics and mathematics in the 19th century was characterized by a vast extension in the subject matter and the opening of new fields. We saw the foundation of polytechnical schools as a new type of educational institution as well as a reshaping of the role of universities and academies. In Germany this process was mainly connected with the reform of the Prussian education system by Wilhelm von Humboldt (1767–1835). The newly founded university of Berlin became the classic example of the new type of university. At the Alma mater Lipsiensis this process of reorganization went on slowlier and with more difficulties than at other German universities. The structure of the university did not meet the progress in science and the standards of trade, industry, and government. Many elements of the university's structure went back to the middle ages. In the 18th century the number of students decreased about a third [1] and mathematics was lectured under very paralysing circumstances.[2] The reform of Leipzig university emerged at the beginning of the 19th century, and was finished in about 1835.[3]

In the following I will focus on four remarkable points in the history of mathematics and physics at Leipzig university:

- First, the state of mathematics and physics around 1835 and the first flash of mathematical physics in the middle of the 19th century,
- second, the alternation on the mathematical chairs in 1868 and the strengthening of mathematical physics,
- third, the establishment of a professorship for theoretical physics and
- fourth, the blossom of theoretical physics at the end of the twenties of the last century.

(2) Mathematics and physics at Leipzig university about 1835

At the beginning of the 19th century the mathematical standard was only mediocrely. The appointment to professorship depended mainly on the ancienity within the philosophical faculty, that means according to seniority. Competence in the speciality played only a minor role. For instance, Karl Friedrich Hindenburg (1741–1808), the well known founder of the combinatorical school, lectured as professor of physics from 1786 until his death in 1808. Before he was appointed to the physical chair he had applied for a chair of poetry. The chair of mathematics was held by Karl Brandan Mollweide (1774–1825) from 1815 until 1825 and then by the young Moritz Wilhelm Drobisch (1802–1896). Drobisch is remembered for his merits as rector of the university and as one of the founders of the Royal Saxon Society of Science in 1846. He took care to improve the standard of the lectures and to incorporate modern mathematics. He tried to form a standard course of periodical repeated lectures in

* Sächsische Akademie der Wissenschaften zu Leipzig, Leipzig, Germany; email: Schlote@saw-leipzig.de.

[1] Eulenburg, Franz: *Die Frequenz der deutschen Universitäten von ihrer Gründung bis zur Gegenwart*. Photomech. Nachdruck der Ausgabe von 1904. Mit einem Nachwort von Elisabeth Lea und Gerald Wiemers. Akademie Verlag Berlin 1994, p. 149.

[2] Kühn, Heidi: *Die Mathematik im deutschen Hochschulwesen des 18. Jahrhunderts* (unter besonderer Berücksichtigung der Verhältnisse an der Leipziger Universität). Dissertation A, Leipzig 1987, p. 121.

[3] For the whole reformist process cf.: Blaschke, Karlheinz: "Die Universität Leipzig im Wandel vom Ancien Régime zum bürgerlichen Staat", in: Czok, Karl (Hrsg.): *Wissenschafts- und Universitätsgeschichte in Sachsen im 18. und 19. Jahrhundert*. *Abh. Sächs. Akad. Wiss., Phil.-hist. Kl.* 71(1987), H. 3, S. 133–153.

mathematics which had to be run through by every student. Furthermore he founded a mathematical seminar in 1826 which was a new element of university instruction at this time. However, Drobisch's seminar finally failed after some years mainly because of the insufficient mathematical knowledge of the students.

He did not make a name for himself as a mathematical researcher. His interests switched very soon to philosophy. In this context he made important contributions to a mathematically founded psychology and to the emergence of mathematical logic.

Beside Drobisch mathematics was represented by August Ferdinand Möbius (1790–1868) who had succeeded Mollweide as an extraordinary professor of astronomy and observer in 1816. Möbius ought to determine the mathematical standard at the university of Leipzig for nearly half a century. He was well known for his contributions to mechanics and geometry.

Gustav Theodor Fechner (1801–1887) and Wilhelm Weber (1804–1891) lectured at the physical cabinet which was a former stage of the physical institute. Fechner, who was appointed as full professor in 1834, had given a first confirmation of Ohm's law by exact measurements (published 1831). By these and further investigations he set an example of the theoretical treatment of physical problems by mathematical means. The same was done by Weber in electrodynamics. Weber took over Fechner's duties in the instruction of physics in 1843 because Fechner had been ill since 1840. Before that Weber had studied with Carl Friedrich Gauß (1777–1855) electric and electromagnetic phenomena and developed an understanding of the inseparability of theoretical and measuring physics. His main theoretical achievement, which was published in 1846 in Leipzig, was the law named after him which was to become the base for all electrical physics. Weber installed new elements in the instruction of physics in Leipzig, a programme of physical lectures as well as a special course of practical training in physics. Bit by bit, the mathematical and physical instruction at Leipzig university reached a higher level.

All the changes in mathematics and physics constituted a general frame for studies in both disciplines which could had led to the foundation of a mathematical-physical seminar in the mid-40es. But this did not happen. There is no real evidence why such a seminar has not been established, but I will give some probable ideas.

First, there was no close scientific contact between Drobisch, Fechner, Möbius, and Weber.

Second, Weber returned to Göttingen in 1849 to renew the scientific cooperation with Gauss.

Third, the activities of the above named scientists were focused on the establishment of the Royal Saxon Society of Science which was founded in 1846.

Therefore we see only some singular steps to mathematical and theoretical physics and these steps were made more from physicists than from mathematicians. Nevertheless, there was another very important development: Fechner, Drobisch and Ernst Heinrich Weber (1795–1878) developed first elements and rules of mathematical psychology. Some decades later Leipzig became the leading centre in this new discipline.

(3) The alternation on the mathematical chairs in 1868

Mathematical research at Leipzig university moved along the traced track in both decades after the middle of the century. Drobisch withdrew more and more from mathematical lectures and focused on philosophy. Möbius continued to study problems of geometry and mechanics beside astronomy. In 1827 he had published his barycentric calculus (Der barycentrische Calcul) and ten years later a two volume „Lehrbuch der Statik“ (textbook on statics). His investigations contained many applications of mathematics to mechanics and astronomy but not to problems of the newer physics. This was what I meant with the missing scientific contact to Weber and Fechner.

In 1853 a new lecturer (Privatdozent) appeared on the scene, Wilhelm Scheibner (1826–1908). He lectured more than 50 years at Leipzig university. A good deal of the beginning prosperity of mathematics at Leipzig was due to Scheibner's varied activities and his clever policy of appointments towards the ministry of education and cultural affairs.

In 1868 the ministry in Dresden agreed to Drobisch's proposal to release him from the duties as professor of mathematics, to leave him on the chair of philosophy only and to offer the chair of Mathematics to Scheibner. Some month later Möbius died. Thus the second mathematical chair was vacant, too. The Philosophical Faculty stressed that the new geometry, Möbius' main field of research, had to be adequately represented. After several discussions the faculty sent the following proposal to the ministry: 1. Alfred Clebsch (1833–1872) (Gießen), 2. Hermann Hankel (1839–1873) (Erlangen), 3. Carl Neumann (1832–1925) (Tübingen) and Richard Baltzer (1818–1887) (Dresden).

Clebsch rejected the call to Leipzig, since he had just accepted a call to Göttingen. After that the ministry appointed the 36-year-old Neumann as full professor of mathematics at Leipzig university.[4]

Neumann was a representative of the famous mathematical-physical school at the university of Königsberg. Problems in mathematical physics became a central thread in Carl Neumann's scientific work.[5] He regarded the application of mathematics to physics, astronomy, and related disciplines as an indispensable part of mathematical research and as a fertile source of new knowledge in mathematics and physics. One central topic of Neumann's research was potential theory providing both pure mathematical problems and problems which were connected to physical applications. Neumann used potential theory to treat various problems in physics and worked hard to improve the mathematical methods used in potential theory. In 1870 he presented a first outline of his method of the arithmetic mean which he then applied for a solution of the Dirichlet problem.[6] He returned to this topic from time to time in succeeding decades. He also developed his own methodological view on mathematical physics and the relations between mathematics and physics.[7]

To Neumann, such a physical theory thus should have been derived deductively from a few basic unexplainable principles. An important objective of physical research thus consists in exposing empirical facts and formulating them as physical principles. The task of mathematical physics then consists in formulating these principles in a mathematically manageable manner, drawing logically correct conclusions from them, and presenting these conclusions in a form that can be tested by experiments.

Neumann became the spiritus rector of mathematical physics at Leipzig. However, it was not only Neumann's appointment which gave a special emphasis on this discipline. There were two further facts. Shortly before Neumann came to Leipzig Karl von der Mühll (1841–1912) habilitated and became a lecturer (Privatdozent) for mathematical physics. In addition, Adolph Mayer (1839–1908), another lecturer, also worked at the university. He too had close relations to the application of mathematical methods and the treatment of physical problems by his investigations into partial differ-ential equations as well as into the calculus of variation. This triumvirate Neumann, von der Mühll, and Mayer made mathematical physics to a main topic in research as well as in lecture at Leipzig university in the following decades. As a consequence of the impetus of mathematical physics the development of theoretical physics was delayed. The physicists at the physical institute had no special theoretical interest and there was no need to give some lectures in theoretical physics because the mathematicians did it in their way. Therefore the first upswing of theoretical physics which took place in Germany in those years was nearly completely missed out in Leipzig. Neumann's strong mathematical orientated view on mathematical and theoretical physics and its application to electrodynamics fostered a clear distinction between both disciplines. This was an important contribution to the development of mathematics and physics.

(4) The new professorship in theoretical physics

I would like to mention in passing the establishment of a physical institute which was opened in autumn 1873 under the direction of Wilhelm Hankel (1814–1899), the creation of a further professorship of mathematics in 1870, and the foundation of the mathematical institute in 1881 with Felix Klein (1849–1925) as the dominant figure.[8] All that improved the conditions for research and teaching in

[4] For a detailed description of the appointment and Neumann's view on mathematical physics cf.: Schlote, Karl-Heinz: "Zur Entwicklung der mathematischen Physik in Leipzig (I) — Der Beginn der Neumannschen Ära". *Intern. Zs. f. Gesch. u. Ethik der Naturwiss., Techn. u. Med. (NTM)* N. S. 9(2001), S. 229–245.

[5] For an analysis of Neumann's work cf.: Schlote, Karl-Heinz: "Carl Neumann's Contributions to Potential Theory and Electrodynamics". In: Wieslaw, Witold: *European Mathematics in the Last Century*. Stefan Banach International Math. Center, Wroclaw 2005, S. 123–140.

[6] The Dirichlet problem or the first boundary-value problem of potential theory is the following: Given the values of a function on the boundary of a region in space or in the plane, find a function f which satisfies $\Delta f = 0$ in this region and takes on those boundary values.

[7] Neumann, Carl: *Ueber die Principien der Galilei-Newton'schen Theorie*. Akademische Antrittsrede. Verlag B. G. Teubner, Leipzig 1870, p. 13.

physics and mathematics substantially. In those years, in the 70es and 80es of the 19th century, a professorship in theoretical physic was created at many German universities, mostly as an extraordinary professorship. At first the positions were created solely to support the ordinary professor of physics. The professor for theoretical physics had to give lecture on theoretical topics. He had to work within the institute directed by the professor for experimental physics and he had to ask when he wanted to do independent work within the laboratory. In general the professorships in theoretical physics were seen as a transitional position for young physicists, whose ultimate destination was an ordinary professorship in experimental physics in the not too distant future. On the other hand the progress of physics made a theoretical explanation of and a systematic get through the experimental results more and more necessary. Although the experimental physicists did not reject these theoretical considerations but there were only very few amongst them which had a complete command of both the experimental practice and the theory. Hermann von Helmholtz (1821–1894) was one of them.

Due to the particular situation at Leipzig's university the need for a support of the professor of physics emerged only at the beginning of the 90es. The Philosophical Faculty stated in its application for the professorship the same arguments as mentioned above: The professor of physics could not give any longer all the lectures which were necessary for a complete and modern instruction. The situation was so tricky that the examination requirements had to be reduced below the general standard which was laid down in the regulations of the state examinations. The ministry agreed to the application, however, the professor of theoretical physics could not claim his own laboratory. Already in summer 1894 Hermann Ebert (1861–1913) held the first course in theoretical physics, however he was given a full professorship at the university of Kiel in October 1894. His successor became Paul Drude (1853–1906) an outstanding theoretical physicist, who continued the organization of the course in theoretical physics and brought it to an end.

One question remains: What was the part of the mathematicians in this appointment? In the application for the professorship the faculty acknowledged that Neumann, von der Mühll and Athur von Oettingen (1836–1920) gave quite a lot of courses on theoretical physics. It was only remarked, maybe as a slight criticism, that Neumann's and von der Mühll's lectures based on a "prevailing mathematical point of view".[9] However, this was an essential point. We know that one of the main characteristics in the development of mathematics in the last third of the 19th century was its rigorization. The precise formulation of basic concepts was installed, new rigorous proofs were given. This process took also place in mathematical physics since the 80es. The explanation of physical phenomena was pushed into the background and a special emphasis was laid on the improvement and rigorization of the mathematical methods. Most of the physicists did not want to follow that way. It was difficult, complicated, and sometimes incomprehensible and above all it gave no hints to further theoretical und experimental research. We have a clear divergence of the interests of mathematicians and physicists in this time. In Leipzig the situation became much more critical by von der Mühll's return to Basle in 1889 and by Neumann's stubbornness to ignore the arrangements about the lecture courses. Of course, the latter was not written in the application of the faculty. We know it from a letter of Heinrich Bruns (1848–1919) to the Saxon State minister in 1897.[10] Certainly, Neumann held lectures on theoretical physics furthermore, but not to the former extent and not in a manner that one could speak of a regular and systematic course on theoretical physics. Thus, the stubbornness of a mathematician had an unexpected strong influence on the creation of the extraordinary professorship for theoretical physics in Leipzig and strictly spoken we have to thank him.

Leipzig's physicists caught up the backlog demand in the development of theoretical physics by the creation of a professorship of this discipline. Moreover, in 1900 they applied successfully in the State ministry for changing the extraordinary professorship to an ordinary one and Ludwig Boltzmann

[8] For further information about the establishment of the physical institute and the foundation of the mathematical one cf.: Schreier, Wolfgang: "Die Physik an der Leipziger Universität bis zum Ende des 19. Jahrhunderts". *Wiss. Zeitschrift Karl-Marx-Univ. Leipzig, Math.-Naturwiss. Reihe*, 34(1985) H. 1, S. 5–19 and König, Fritz: Die Gründung des „Mathematischen Seminars" der Universität Leipzig. In: Beckert, Herbert; Schumann, Horst (Hrsg.): *100 Jahre Mathematisches Seminar der Karl-Marx-Universität Leipzig*. DVW Berlin 1981, S. 41–71.

[9] Universitätsarchiv Leipzig, PA 429 (Personalakte Ebert), Bl. 2v.

[10] Sächsisches Hauptstaatsarchiv Dresden, Ministerium für Volksbildung 10210/17, Bl. 356.

(1844–1906) became the first full professor of theoretical physics at Leipzig. The establishment of a new building of the physical institute resulted in the creation of an Institute of theoretical Physics, however no representative of modern theoretical physics was appointed to this chair in 1903 but a classical experimentally inclined physicist. The successor of Boltzmann became Theodor Des Coudres (1862–1926). Therefore Leipzig's university was one of the universities which had the best institutional equipment for the development of theoretical physics at the beginning of the 20th century but some members of the philosophical faculty hindered that a candidate like Arnold Sommerfeld (1868–1951) was appointed. Maybe the most important person in this discussions was Otto Wiener (1862–1927) who held the position of ordinary professor of experimental physics and director of the physical institute. Wiener got most of the faculty members to agree to his opinion that it was important to gain a man who worked first of all in physics and not in mathematics for the professorship. By the way, Wiener earned the strongest protest from Neumann who preferred men like Arnold Sommerfeld, Carl Runge (1856–1927), and Emil Wiechert (1861–1928), but without succeess. Therefore the experimental point of view dominated in physics at Leipzig's university.

(5) Leipzig's upswing to a centre of theoretical physics

Leipzig became a worldwide recognized centre of theoretical physics at the end of the twenties of the last century. But this development was not a planned one. It started with the sudden death of Des Coudres in 1926. However, for a better understanding of the whole process some changes must be taken into account which took place in the years before. In the autumn of 1923 an extraordinary professorship in mathematical physics was established and occupied by George Jaffé (1880–1965). The application for this professorship was promoted by Des Coudres and Wiener as well as the three professors of mathematics, Otto Hölder (1859–1937), Gustav Herglotz (1881–1953), and Leon Lichtenstein (1878–1933). They justified their proposal by the remarkable progress of theoretical physics in the last two decennia and listed nine new fields in physics which should be lectured by the new professor in periodical terms.[11] The discussion about mathematical physics arose anew when Jaffé accepted a call for a chair at the university of Gießen two years later. A commission had to decide which field was to be continued, mathematical or applied physics, and after long discussion most of the members voted for the former one. They also pleaded for a younger representative of theoretical physics who take part in the development of the modern theories of quantum and relativity without neglecting the classical theory.[12] As candidates were named Werner Heisenberg (1901–1976), Wolfgang Pauli (1900–1958), and Gregor Wentzel (1898–1978). Each of them had already made remarkable contributions to theoretical physics and was acknowledged as a worthy representative of modern trends in this discipline. However, Heisenberg and Pauli declined a call to Leipzig and therefore Wentzel was appointed in June 1926. Hence, when Des Coudres died in October 1926 the first steps towards modern physic were already done at Leipzig's physical institute but it was only a slight opening to modern research.

In this context the choice of Des Coudres' successor was very important for the future fields of research at the physical institute. The discussion in the philosophical faculty about the possible candidates was influenced by Wiener who looked for a theoretical physicist in fact, but for one with certain experimental capacities. By the way, Heisenberg and Pauli were ignored because they had declined the call the year before. The final proposal which was sent to the ministry in Dresden put Peter Debye (1884–1966) at the first place, Erwin Schrödinger (1887–1961) at the second and clear down-graded Max Born (1882–1970) at the third one. However, before the negotiations with Debye were finished Wiener died, too. Now the faculty proposed Debye as the only candidate for the chair of experimental physics and put back the decision about the successor of Des Coudres. After further delays due to Debye's trip to America the negotiations were finished with Debye's appointment in August 1927. Regarding the chair of theoretical physics the philosophical faculty responded immediately and presented the same candidates as some years ago but in the order Heisenberg, Wentzel, and Pauli. Heisenberg who had got five offers to a professorship at that time benefitted from this favourable situation and managed to improve his position at Leipzig's physical institute. Like Debye he took up his duty in autumn 1927.

[11] Universitätsarchiv Leipzig, PA 602, (Personalakte Jaffé), Bl. 35f.

[12] Universitätsarchiv Leipzig, PA 1051 (Personalakte Wentzel), Bl. 6.

Thus, within few month the situation had completely changed. The directors at the physical and the theoretical-physical institute became now young highly acclaimed physicists. The research programme of the institute got a new profile which was directed towards the trends of modern theoretical physics, first of all to quantum mechanics and its application to atom and nuclear physics as well as the physics of solids. Heisenberg and Debye attracted a lot of students and young scientists to Leipzig and especially Heisenberg formed an efficient research group. Leipzig became a centre of theoretical research and physicists from other universities sent their students to Leipzig to spend and study one or two semesters within Heisenberg's group. Debye organized the famous "Leipziger Vortragswochen" a kind of summer school, starting in summer 1928. The number of students tripled from autumn 1927 to summer 1930 and remained at this high level. In October 1928 Wentzel accepted a chair at the polytechnic high school in Zurich and in April 1929 he was succeeded by Friedrich Hund (1896–1997). Theoretical physics now flourished in Leipzig until the middle of the thirties.[13] The institute had grown until this moment not only to a, but the leading research centre in theoretical physics in Germany. However in the following years, the institute suffered from the dictatorship of National Socialism like the physical institutes at the other German universities.

Finally, a look at mathematics must be taken. Mathematical physics had flourished since the time of Carl Neumann and had become a successful tradition in research and teaching. In the twentieth it had been represented by Lichtenstein and Herglotz. Both of them investigated problems in potential theory, aero- and hydrodynamics as well as the solution of the accompanying differential or integro-differential equations. But, Herglotz changed to a chair at the university of Göttingen in 1925 and Lichtenstein died in August 1933. His death was almost certainly caused by the hostilities and attacks by the follower of National socialism. Although the successor of Herglotz cannot be characterized as a friend of mathematical physics this discipline got an unexpected strengthening by Bartel Leendert van der Waerden (1903–1996) who became the successor of Otto Hölder in 1931. Van der Waerden was not only an excellent algebraist but also very interested in modern quantum mechanics. He got in touch with Heisenberg and Hund, participated in their seminars and contributed to the progress of theoretical and mathematical physics at Leipzigs university. This unique constellation which combined first-rate theoretical physicist and mathematicians formed the foundation of Leipzig's upswing to a centre of theoretical physics.

[13] For further information cf. Windsch, Wolfgang; Franke, Martin: 1927–1945: "Blütezeit und Niedergang der Leipzigrer Physikalischen Institute". *Wiss. Zeitschrift Karl-Marx-Univ. Leipzig, Math.-Naturwiss. Reihe*, 34(1985) H. 1, S. 30–42. Concerning Heisenberg and his school cf.: Kleint, Christian; Rechenberg, Helmut; Wiemers, Gerald (Hrsg.): *Werner Heisenberg 1901–1976. Beiträge, Berichte, Briefe. Festschrift zu seinem 100. Geburtstag. Abh. Sächs. Akad. Wiss. Leipzig, Math.-naturwiss. Kl.*, Bd. 62, 2005; Kleint, Christian; Wiemers, Gerald (Hrsg.): "Werner Heisenberg in Leipzig 1927–1945". *Abh. Sächs. Akad. Wiss. Leipzig, Math.-naturwiss. Kl.*, Bd. 58, H. 2, 1993.