MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

Tagungsbericht 05/2000

The History of Mathematics of the 20th Century

30.01. – 05.02.2000

48 participants attended the meeting on the History of Mathematics of the 20th Century, organized by Moritz Epple (Mainz), Jeremy J. Gray (Milton Keynes), and Jesper Lützen (København). Among the participants were scholars with various interests in and approaches to the history of mathematics, and historians as well as mathematicians. In general discussions and informal talks, this made for vigorous discussions.

The Tagung was a success in many ways. There were a number of strong papers on the history of physics and its relations with mathematics. Papers presented included a new analysis of Hilbert's work in this area, which considerably changed our picture of Hilbert, as well as one on Einstein and one on Weyl that demonstrated how these two major investigators sought, in different ways, to unify physics by an original use of differential geometry. The paper on von Neumann and quantum mechanics was one of the first historical studies of this topic, and raised a number of interesting questions about von Neumann's shifting point of view. Another central topic was the history of topology and its relations to neighbouring mathematical fields in the first half of the 20th century.

An area that has become much more sophisticated and informative in recent years is the study of mathematical communities, and this provided a valuable alternative approach to many of the issues discussed. There was a fruitful overlap between papers of this kind and the more technical ones, for example in the account of how and why Einstein became isolated among the physicists and more congenial to mathematicians after the mid-1920s. Other papers in this vein included a detailed analysis of how Hilbert's vision of mathematics, and the students he brought to Göttingen, fit well into Klein's vision of the place of mathematics in science and technology. Mention should also be made of an account of number theory in France before 1945, one on how Bourbaki drew up its plans, and one on the impact of Bourbaki. Each in their different ways showed how the study of what sort of mathematics was done benefits from, and illuminates, the study of who did it and why. There were also two papers on developments in applied mathematics, one on meteorology and one on how non-linear programming emerged after the Second World War. Further sessions of the meeting addressed topics such as algebraic geometry, set theory, and the foundations of mathematics, as well as mathematics in Italian fascism and German national socialism.

It is worth stressing that the mere existence of such work was unthinkable ten years ago, and the emergence of a language at once technical enough to embrace such topics as modern topology and yet attentive to historical circumstances is an indication that a serious investigation of the mathematics of the 20th century has finally begun. In many ways the conference demonstrated that the history of recent mathematics is becoming a lively area with increasingly high standards. On the other hand, the simple fact that most of the papers dealt with the period up to about 1950 shows that serious historical research on the mathematics of the 20th century is still in its beginnings.

Schools of mathematics around 1900

David E. Rowe

Mathematics in Göttingen and beyond, 1895-1945: the spectrum of pure and applied approaches

Contextually, mathematics in Göttingen around 1895, when Hilbert joined Klein, involves long-standing rivalries (Prussian purism/Parisian maths, Berlin/Göttingen). Klein identified Hilbert early on as the pure mathematician with whom he hoped to overcome Berlin's traditional dominance of mathematics in Prussia. Neither he, nor anyone else, imagined that Hilbert would turn away from algebra and number theory after 1900 and begin advancing a massive program in analysis and mathematical physics. In a series of complex negotiations with representatives of the Prussian Ministry and Rhineland industrialists, Klein succeeded in founding a new alliance for funding applied research in Göttingen. In 1898 the Göttingen Association for the Promotion of Applied Physics was founded with two presiding officiers: Henry Böttinger (Bayer) and Klein. During the next 8 years it raised over 200.000 Marks for funding new technological institutes with "matching funds" from Friedrich Althoff, the head of Prussian university affairs. By 1904, Ludwig Prandtl and Carl Runge took over as heads of the institutes for applied mechanics and applied mathematics, respectively. This opened new avenues for applied mathematical research by Karl Schwarzschild (astronomy), Emil Wiechert (geophysics), Gustav Herglotz (celestial mechanics), and others. Hilbert and Minkowski took up a parallel interest in physics (1905 electron theory seminar, etc.). These developments manifest a variety of approaches to physical problems, a spectrum of styles that suggest the limitations of Lewis Pyenson's position regarding the Göttingen approach to physical reality.

Umberto Bottazzini

The Italian mathematical scene, 1900-1914 or why and how the decline of Italian mathematics began

It has been observed many times that the period of time spanning from the end of the 19th century to the first decade of the 20th century represented a high mark in the development of Italian mathematics. Algebraic geometry provides a well-known example. But, in addition, one could mention mathematical analysis, logic, tensor calculus and so forth. At the same time, hints of an oncoming crisis are evident in each of these fields. It turned out that the Italian mathematicians who did pioneering work until the end of the 19th century took almost no part in the further developments of the theories they continued to create. In the talk these points were discussed taking into account, in particular, mathematical analysis (functional analysis, Lebesgue measure theory), logic, and the foundations of geometry (Peano and his school as well as Enriques and the school wich developed around him).

Around Hilbert/von Mises

Craig Fraser

Hilbert's *Grundlagen der Geometrie* and some aspects of the relation to Euclid's *Elements*

Hilbert's *Grundlagen* (1899) are widely regarded as one of the canonical works of modern mathematics. The origin and historical character of the book have been explored in the writings of Michael Toepell and Leo Corry. The purpose of my paper is to provide a comparative study of the *Grundlagen* and *Elements II* in order to elucidate points of similarity and differences in approach, concept and outlook between the two works. The paper also explores the meaning of deduction in the modern mathematical tradition.

Leo Corry

Hilbert and Physics

Traditionally, Hilbert's involvement with physical topics has been seen as sporadical incursions into questions where his mathematical abilities could produce immediate results. Hilbert's name is often mentioned in relation with the 6th problem of his 1900 list ("the axiomatization of physical theories"), the solution of the Boltzmann equation, and the formulation of the field equations of gravitation in general relativity.

However, Hilbert's dealings with physics manifest a deep-going, organic element of his scientific work. This becomes clear when examining the lecture notes of courses given in Göttingen between 1898 and 1926, and which cover a surprisingly wide scope of physical topics ranging from mechanics to kinetic theory to quantum mechanics.

Hibert's scientific work, and much of his mathematics, cannot be understood without paying due attention to his interests in physics, to his specific contributions to physical questions, and to the influence he exercised on the many brilliant physicists that attended his Göttingen lectures.

Reinhard Siegmund-Schulze

Richard von Mises (1883-1953): Axiomatics of Probability, Ergodic Theory, Determinism, and the Forman Thesis

The talk presented one segment of a broader biographical research project on von Mises, which has been started in 1999. Apart from his program in applied mathematics, von Mises started a second line of research after WW I, on the foundations of probability, based on the limit of relative frequency and a certain axiom of randomness, and its relations to theoretical physics, especially ergodic theory. In a 1920 article and in his probability book of 1931, von Mises expressly excluded the ergodic hypothesis and related assumptions, since its deterministic nature was incompatible with the probability statements of ergodic theorems. He used instead his notion of a "Kollektiv", both for the description of space (phase-) states and of time-states. This procedure was intimately connected to von Mises' understanding of a generalization of causality. The latter has been, in the opinion of R. Siegmund-Schulze, misrepresented in a thought-provoking article by Paul Forman (1971), dealing with the contribution of the Weimar culture to the gradual abandoning of classical causality in physics.

Mathematics, Fascism, and National Socialism

<u>Aldo Brigaglia</u>

The decline of Italian Mathematics during the years between the two world wars

Before the first world war, and especially roughly before 1910, Italian mathematics had a repution of being among the most thriving in the world. One can mention the Italian school of algebraic geometry (Castelnuovo, Enriques, Severi,...), of mathematical logic (Peano), of real and functional analysis (Dini, Ascali, Volterra), of differential geometry (Ricci, Bianchi, Levi-Civita) and so on.

After the war, a decline began, resulting in growing closure against external developments (new algebra and topology, new logic and so on). With different velocities this decline involved every branch of mathematics. One may try to find (if there are) links between this decline and external political developments, i.e. the cultural politics of fascism, resulting in 1938 in the racial laws.

<u>Volker Remmert</u>

Business as usual? The Deutsche Mathematiker - Vereinigung and Nazi politics: Examples from mathematical publishing

In the Nazi period the DMV under its president Wilhelm Süss (1895-1958) – founder of Oberwolfach – became closely entangled with some of the issues which stood at the very core of Nazi ideology as for instance its anti-semitism and anti-internationalism. Süss' dealings with Springer Verlag and its main representative F. K. Schmidt exemplify this:

1. Pressure on Mathematische Zeitschrift in 1938 in order that I. Schur resigns from his office as editor.

2. Reorganization of the system of mathematical journals – an idea J. Stark had propagated in 1933 and which was reanimated by L. Bieberbach and Süss in 1939/40.

3. Mathematical publishing in WW II when Süss succeeded in obtaining a factual monopoly to commission books as official censor for Goebbel's Ministry of Propaganda and Speer's Armament Ministry.

These and other examples illustrate the everyday collaboration of Süss and the DMV with Nazi offices and officials.

Herbert Mehrtens

National Socialism and Mathematics as Cultural Techniques

Mathematical cultural techniques (counting, ordering, mapping...) are a neglected historical phenomenon. Social control and organization played an enormous role for National Socialism and ought to be studied in relation to the tools used. The mathematical in such fields plays an ideological role and a functional role simultaneously. This view of the tools of control and self-control of modern societies relates to the basic question of "ambivalence and modernity" (Zygmunt Baumann).

Mathematical Physics

Scott Walter

Breaking in the 4-vectors: The emergence of 4-dimensional electromagnetism and gravitation

The rapid adoption by theoretical physicists of Arnold Sommerfeld's 4-dimensional vector formalism has obscured the history of two alternative approaches proposed by Henri Poincaré (1906) and by Hermann Minkowski (1908).

A comparison of these three methods is accomplished by studying their application to a single problem: The derivation of a law of gravitation compatible with the principle of relativity.

Jim Ritter

Mathematicians, Physicists and Albert Einstein

From 1919 until the end of his life, Einstein's principal work was the search for a unified field theory. Though, at the beginning, Einstein felt himself part of an avant garde among physicists, after 1928 he portrayed himself as isolated within that community. The scientific – and popular – success of his 1928-1930 Fernparallelismus theory, and the contact this gave him with mathematicians like Weitzenböck and especially Elie Cartan provided a new strategy for him. Increasingly turning away from a theoretical physics community won over to quantum theory, he addressed himself more and more, especially after his arrival at Princeton, to mathematicians. Publishing almost exclusively in pure mathematical journals and using increasingly formal arguments he sought to gain with the new public, a sympathetic response to his programme for physics.

Miklós Rédei

John von Neumann's struggle with quantum logic and quantum probability

Based partly on unpublished documents in the von Neumann Archive in the Library of Congress and in the Harvard University Archive the talk reconstructed and discussed von Neumann's ideas on quantum logic and interpretation of quantum probability.

It was argued that

1) von Neumann's concept of quantum logic (= modular projection lattice of a type II_1 von Neumann algebra) differs subtly but markedly from what has become and is the standard view (= non-modular Hilbert lattice)

2) von Neumann's notion of quantum logic was motivated by his desire to interpret quantum logic as event structure of a non-commutative (quantum) probability theory

3) on Neumann remained frustrated by seeing that there exists no properly non- commutative probabilty theory if probability is interpreted as relative frequency in the sense of R. von Mises.

Set Theory/Topology/Algebraic Geometry

W. Purkert

Felix Hausdorff's Beiträge zur Mengenlehre

Hausdorff war zunächst theoretischer Astronom und angewandter Mathematiker. Seine Hinwendung zur Mengenlehre war durch seine philosophischen Interessen veranlaßt (philosophisch-literarische Schriften unter dem Pseudonym Paul Mongré). Das Kontinuumproblem regte ihn zu einem eingehenden Studium geordneter Mengen an. Einige herausragende Resultate dieser Untersuchungen wurden vorgestellt: Konfinalität, exorbitante Zahlen, Klassifizierung dichter Mengen durch ihre Element- und Lückencharaktere, Graduierung nach dem Endverlauf, allgemeiner Produkt- und Potenzbegriff für Ordnungstypen, saturierte Mengen und verallgemeinerte Kontinuumshypothese. Desweiteren wurde Hausdorffs Rekursionsformel für die Kardinalzahlexponentiation und im Zusammenhang damit seine Rolle bei der Klärung des durch J. Königs Vortrag auf dem Heidelberger Kongress entstandenen Problems behandelt.

K. Volkert

The contributions of Seifert and Threlfall to topology

Some informations about their lives and publications were given. Afterwards we discussed the situation of topology around 1930, in particular the stagnation of the classical combinatorial approach. The construction of 3-manifolds used by Seifert and Threlfall using groups of isometries of the 3-sphere was presented. Two problems occured: an algebraic problem (determination of subgroups) and a topological problem (determination of the fundamental region). Seifert's and Threlfall's merit lies in the combination of the methods from geometry, group theory and topology.

At the end of the talk we had a look at the so-called lens-spaces; their lens-shaped form being deduced by Seifert and Threlfall for the first time in 1931.

Silke Slembek

Oscar Zariski's work in algebraic geometry

From the beginning of the 20th century there has been a shift in algebraic geometry: from "classical" algebraic geometry to "modern" algebraic geometry. It affected methods, motivations and aims of the field. What were the motivations, objectives, strategies of mathematicains, how did they shape the body of knowledge of algebraic geometry and its images? In order to understand the global development, the contributions of Oscar Zariski to this shift were investigated. Zariski bridged this process. He was trained in Italy under Castelnuovo, Enriques, Severi and went to the US later where he learned modern algebra and the "arithmetic theory" of ideals and valuations. Tools and devices from those theories allowed him to give new foundations to algebraic geometry and to establish the resolution of singularities on algebraic surfaces convincingly. At the same time he contributed to shaping the image of italian algebraic geometry as beeing notoriously unrigorous but rich in geometric imagination.

Number Theory/Measure Theory/Foundations

Catherine Goldstein

French number theorists: an oblique look at mathematics during the pre-Bourbakist era

At the beginning of the century, the main trend of mathematics in France concerned analysis, while various interconnected changes took place in the training of mathematicians as well as in the membership of the French Mathematical Society. Mathematicians were not especially in favor of the development of number theory, but there were nonetheless various signs which indicated efforts to learn and develop number theory (Humbert, Châtelet,...). Their works had nonetheless to cope in one way or another with the requirements of main stream mathematicians, in particular while stressing geometrical representations as a means of demonstration or effectiveness. These mathematicians however did not seem to have established themselves as models for the new generation who arrived from the mid-twenties on, in particular the future members of the Bourbaki enterprise. The talk discussed some of the connections between these mathematicans and the reasons (mathematical, human,...) of their estrangement, as well as the impact of this generation on the writing of history.

S. S. Demidov

"The case of academician Luzin" as historico-scientific problem

"The case" took place in 1936. It was the best known "political case" in the history of Soviet mathematics. All that we know about it until quite recently was the information from the Soviet newspapers of the years 30. Against Luzin a campaign was organized. His activity was qualified as a sabotage. This campaign could have a bad result for him but it was stopped (apparently by Stalin himself). The documents from the Archive of Russian Academy of Sciences and from the Archive of the President of Russia permit to reconstruct the real picture of the development of this case. This development was the result of activities of many groups, each of them having their own interest. All these groups operated in a field of powers which was given by Stalin's policy concerning the construction of the new Soviet science.

G. Heinzmann

Some coloured remarks on the foundations of mathematics in the 20th century

According to the 20th century main-stream view, foundations of mathematics were identified with logic and set theory. Main results such as the undecidability of 1st order logic, the consistency question (Gödel 1931), the independence of the axiom of choice are negative but of philosophical interest. Technical results such as completeness, relative consistency or the Löwenheim-Skolem theorem are not in all regards philosophically interesting. In particular, set theory considered in view of technical results needs its proper foundations.

So, given the fact that the set theoretical universe is deductively incomplete, inevitably non-standard, and given that we have no unproblematically clear idea of what the intended models of set theory are, why should we reduce arithmetic and analysis to set theory?

Two solutions are discussed:

(1) Mathematics without foundations.

(2) The adoption of Hintikka's independence-friendly first order logic which permits the definition of the truth predicate in that language itself.

Applied Mathematics in the USA

Amy Dahan

The debate about models: Meteorology as a case study

The paper focusses on scientific practices and problems of modeling in the case of meteorology. This domain is considered, due to its crucial influence on the conception of mathematical models, and the key-role of computer, and its links with numerical instability and dynamical systems. In particular, the debate between "physical models" and "laboratory models", in relation with the alternative between predicting and understanding raises deep questions about what could be an epistemology of models.

Tinne Hoff Kjeldsen

The rise of mathematical programming in the USA and the impact of World War II

Mathematical programming emerged in the USA as a consequence of the Second World War. Several elements were involved in this process. There were connections between different branches of mathematics and between different kinds of driving forces in the development. The first step towards mathematical programming was G.B. Dantzig's work on the Air Force Programming Planning problem which was a concrete practical logistic problem.

Through the involvement of John von Neumann with linear programming, the mathematical model for the Air Force Problem got connected with game theory and one can see a shift towards theory building. The ONR initiated a university research project on this connection between game theory and linear programming. Albert Tucker from Princeton mathematical department became the principal investigator of this project. They developped the mathematical theory for linear programming. This meant a shift in scientific status for linear programming. It became an interesting research area in mathematics. From here on the field extended to nonlinear programming where the driving force was an interest in pursuing a purely mathematical issue of generalisation and understanding. Also the further development of the duality theory for nonlinear programming went on from both a pure theoretical context and from an applied practical context. The talk also discussed the role of operations research in the establishment of mathematical programming.

Topological Issues

Erhard Scholz

Some remarks on H. Weyl's spinor gauge structures and their relation to early Yang-Mills theory

Yang/Mills' 1954 paper elaborated a gauge idea taken over from Pauli's *Handbuch der Physik* article from 1933. Only with the maturation of the theory in the late 1960s Yang realized that Weyl had outlined a research program for a comprehensive unification of electromagnetism and gravitation, linked by a (modified) Dirac electron field. The talk discussed differences of the philosophical outlooks of Weyl's unified theory of the early 1920s and the 1929 one, although central mathematical concepts could be taken over (the gauge idea, connections). The conceptual and mathematical research strategies Weyl proposed in 1929 (*Elektron und Gravitation*) for a "soft unification" was sketched. Pauli's articles (1933, 1941) served as a kind of "message in the bottle" between the different disciplines and between the generations to the next generation of physicists in the early 1950s.

John McCleary

Manifolds and bundles; examples and definitions, tortoises and hares

Frank Adams introduced the distinction between (mathematical) tortoises and hares – hares seek the most general, skip details, introduce the uncomfortable; tortoises move out from the solid-works for clean statements of known theorems. Poincaré gave many constructions for manifolds in his *Analysis Situs* and left problems and examples. Hilbert, König, Weyl, H. Kneser and finally O. Veblen and J.H.C. Whitehead gave axioms for n-dimensional manifolds. In efforts to study the Poincaré conjecture, Seifert introduced fibred spaces (1932). Threlfall gave an example (1932). Seifert also had a base space, a surface, thus having (implicitly) fibre, and base space. Stiefel studied a generalization of the Poincaré index theorem and the idea of proof given in Alexandroff-Hopf. Around the same time, Whitney introduced sphere-spaces – locally products but globally interesting. He also showed at this time (1935/36) that abstract manifolds may be thought of as embedded in Euclidean spaces. With this image, he studied both tangent and normal bundles and found invariants, dual to Stiefel's, that measure the existance of fields of m linearly independent vectors. Around this time a major conference was held in Moscow, with exchange of ideas and cross fertilization. Of particular note is the introduction of homology groups by Hurewicz and the relations among them for homogeneous spaces, $H \subset G$, a closed subgroup of a Lie group, and $G \to G/H$. This example was developed already by Elie Cartan and its homotopy properties were taken up by Ehresmann and Feldbau. Their definition of fibre space generalized Whitney's considerably. Competing definitions by Hurewicz-Steenrod and Eckmann all led to the covering homotopy property – the key to Serres definition of fibration in his celebrated thesis. The evolution of definitions brought about by the desire to compute new invariants and the successful examples is a kind of normal research in algebraic topology for this time.

Athanassios Strantzalos

On the historical significance of D. Hilbert's Foundations of geometry in 1902 by transformation groups

Hilbert's Foundations of Geometry by transformation groups has more or less been ignored by historians of mathematics; however it seems to be of interest in the history of mathematics as a 'nodal point' of the evolution of mathematics, in a sense that was exhibited in the talk and resembles to notions of dynamics.

We indicated that the ideas and methods presented in this work may be considered as:
(1) absorbing ideas and results entering in a research path initiated roughly by von Staudt's and Möbius' ideas about invariance, and containing as main ingredients Helmholtz's idea of "Bewegungen" as structural elements of space, Klein's Erlanger Programm and Lie's foundations of the notion of space by analytic transformation groups
(2) a starting point of a new research path within the research field called nowadays "Topological Dynamics": the path leading to the modern theory of proper transformation groups, which, for instance, includes the actions of groups of symmetries in connected, locally compact metric spaces (e.g. actions on Riemannian manifolds), and is suitable for the study of the interaction between geometrical structures and topological structures related to the fundamental group.

Both paths above may be considered as "connected", in the sense that works entering in each of them are, more or less, related through direct references.

Bourbaki

<u>Liliane Beaulieu</u>

Narratives from Bourbaki's skits

Jean Dieudonné ritually conducted Bourbaki's internal discussions on the overall plan for the *Eléments de mathématique* during the group's meetings. The reports describe his collegues mobbing the poor actor who brandished the prospect of hard toil.

These "overall plan acts" have nevertheless played a programmatic role. The outlines themselves served as blueprints of the shaping of the "Fundamental Structures of Analysis", which constitutes the first part of the *Eléments.* Considered as a sequence they also reveal some of the major shifts in the group's agenda.

Looking at what they hide, as well as what thy disclose, I evaluate these tables of contents as sources for the history of Bourbaki's enterprise.

<u>Christian Houzel</u>

How to appraise Bourbaki's role in the history of mathematics

Bourbaki's activity took place principally between 1935 and 1965. This period is marked by quite special characteristics: in several branches of mathematics, we see an effort to build powerful theoretical tools: algebraisation of topology and homological algebra; sheaf theory; abstract algebraic geometry and commutative algebra; functional analysis, with the theory of distributions; axiomatization of probability and the development of the stochastic processes; model theory in logic.

These efforts resulted in a withdrawal of mathematics from physics in a tendency of abstraction.

On the contrary, the war effort pushed a lot of mathematicians towards applied topics, if not in France, which was an occupied country. Most of the French mathematicians were far away from applications. This was the case of the founders of Bourbaki: A. Weil, H. Cartan, J. Delsarte, J. Dieudonné, C. Chevalley. They wanted to write a new, and quite modern treatise of analysis. For instance they wished Stoke's formula to conform to E. Cartan's ideas, without knowing how to manage it.

The "abstract package" of algebra and general topology they planned to write at the beginning grew and became almost the whole book. One main idea behind Bourbaki's conception is the unity of mathematics. The method adopted was axiomatic, with a reference to Hilbert. Bourbaki introduced the notion of structure in order to make clear what an isomorphism between mathematical objects is.

In the heritage from Bourbaki, we find a new style to write mathematics and some useful concepts. There are only a few misconceptions as in the theory of integration. But Bourbaki was in constant self-criticism and some new editions show testimony to it.

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