ARTICLE IN PRESS YHMAT:3052

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Historia Mathematica ••• (••••) •••–•••

HISTORIA MATHEMATICA

www.elsevier.com/locate/yhmat

Book Review

Émile Borel. ***À l'aube de la théorie des quanta : notes inédites d'Émile Borel sur un cours de Paul Langevin au Collège de France (1912-1913)***

Édité par Martha Cecilia Bustamante De La Ossa. Turnhout (Brepols Publishers). 2019.
ISBN 978-2-503-58638-0. x, 335 p. (De diversis artibus, 105; Nouv. série, 68). 1 vol. relié de 20 × 26 cm.
65,00 €

This sumptuous book published by the Belgian publisher Brepols contains the critical edition of a notebook that belonged to the mathematician Émile Borel, in which he took notes on lectures given by his friend the physicist Paul Langevin in 1912 in Paris. At the end of the 1980s, when the Institut Henri Poincaré in Paris was undergoing a complete renovation, a few boxes of archival materials were recovered from the inextricable mess of the basement and saved from destruction. Among the salvaged archival materials were papers belonging to Émile Borel, who founded the institute in 1928 and remained its director until his death in 1956. This material represents almost all of the primary sources which can be related to the intense activity of this major 20th-century mathematician, who had one of the most extensive international networks of professional contacts at the time. As meager as it is, this documentary harvest nonetheless contains a number of treasures. Its crown jewel is most likely the correspondence between Borel and Henri Lebesgue, which makes it possible to follow Lebesgue's invention of his new theory of integration based on the concept of the measure of sets formulated by Borel starting in 1894. The letters, transcribed and commented on by Pierre Dugac in the *Cahiers du Séminaire d'Histoire des Mathématiques* in the 1990s, gave rise to Vuibert's publication of a selection of these letters, supervised by Bernard Bru, in 2004 under the title *Les lendemains de l'intégrale*.

Browsing Borel's archives, Martha-Cecilia Bustamante, a historian of physics at the University of Paris, discovered a small notebook containing notes taken by Borel during the academic year 1912-1913, when he attended several sessions of Paul Langevin's course at the Collège de France on the problem of radiation and on the quantum hypothesis. Langevin, an exact contemporary of Borel and his long-time friend and fellow student at the École Normale Supérieure, was known at that time as one of the most innovative scientists of his generation, and one of the most cultured too. Langevin had been continuously interested in the upheavals in the field of physics, beginning in the 1860s with the spectacular emergence of statistical mechanics led by Maxwell and Boltzmann. In fact, the intention behind his appointment to the Collège de France in 1909 was specifically to promote the dissemination of new physics concepts in France, shaking up the traditional and deterministic approach inherited from Newton and Laplace. Very early in his career, Langevin had already studied the paradoxes resulting from the confrontation of the atomic theory of matter – now firmly established as a basis of modern physics – with the standard concepts of classical mechanics and thermodynamics. One of the first paradoxes arose from experiments on a black body in equilibrium. Such a body absorbs all of the radiation received and reemits a radiation whose classical thermodynamical description predicted a spectrum that was dependent only on temperature (the Rayleigh-Jeans law). However, for short wavelengths, the emitted radiation strongly deviated from that predicted by

https://doi.org/10.1016/j.hm.2020.09.001

the Rayleigh-Jeans law. (In 1911, the physicist Paul Ehrenfest would call this phenomenon the *ultraviolet catastrophe*.) In 1900, the German physicist Max Planck proposed a hypothesis that fit the experimental results well but startled his contemporaries: it said that energy exchanges between matter and radiation do not take place in a continuous manner, as traditionally thought, but in indivisible packets, energy quanta, that were proportional to the frequency of the radiation. At first, Planck's hypothesis was considered to be a mathematical trick. Its subsequent use by Einstein in 1905 to successfully explain that the photoelectric effect of light is related to its corpuscular nature gave it considerable weight. The discussion of the quantum hypothesis and its consequences was one of the most heated debates in physics in the 1910s. This is evidenced by the now famous meeting organized by the Belgian industrialist Solvay in 1911 in Brussels, which brought together the most eminent scientists from the world of contemporary physics. Langevin was one of the major hosts of the meeting, together with Poincaré and Einstein. He was also responsible for drafting the meeting report, and it is not surprising that he considered this an ideal topic for a course at the Collège de France in 1912.

The course seems to have been a great success in terms of the number of attendees. This success was probably due to the public attention that the Solvay congress held the previous year had generated. Furthermore, Poincaré's unexpected death in July 1912 meant that Langevin was now considered the top French expert on these hot topics. Matter had a fundamentally discontinuous structure, and the description of its properties called for new conceptual tools, among which statistical explanations held a prominent position. At the beginning of the 1890s, Poincaré had done everything he could to postpone the introduction of probability into concepts from physics, so much so that the presence of randomness seemed incongruous to him within the scientific context in which, according to Laplace, randomness was only another name for ignorance. But the unavoidable successes of statistical mechanics eventually overcame Poincaré's reluctance, more or less. Above all, these successes stimulated his young disciple Émile Borel to take a spectacular turn towards probability theory in 1905. From that year on, Borel became the mathematician who most actively campaigned for the significant incorporation of probability into the mathematical culture in France. This development occurred very late compared to other countries such as Belgium, Germany, and Great Britain: the creation of the Henri Poincaré Institute at the end of the 1920s was in a way the crowning achievement of Borel's efforts to make up for lost time. It is therefore understandable that Borel was one of the listeners at Langevin's course in 1912. And he was a very careful listener, both because of his highly cultured scientific mind, as well as his avid interest in the concepts that his friend was presenting. Borel, moreover, devoted one of his first probabilistic works to a geometric probabilistic approach to the Maxwell-Boltzmann kinetic theory of gas. He had been convinced for a long time that the microscopic properties of matter were a powerful source of inspiration for mathematicians.

What makes Borel's notebook particularly valuable is the fact that Langevin published very little and also never published his lectures. As a result, before this notebook became available, the only knowledge we had of the physicist's course at the Collège de France was the program summary published by the institution for the benefit of potential attendees. This was a limited source of information, and it is thus fortunate that an unexpected document has come to light that provides a much better understanding of the content of the course.

The critical publication of Borel's notes by Bustamante is divided into three parts. The first part explains in detail the context within which Langevin gave his series of lessons on quantum theory at the Collège de France. The second part contains the transcription of Borel's notebook, and the third part contains some documentation regarding the state of theoretical physics in France. Below we will discuss some details regarding the content of each of the three parts.

In the first part, Bustamante describes in detail how statistical physics would eventually gain a foothold in the French physics community, starting with a seminar arranged by Marcel Brillouin at the Collège de France in Paris at the beginning of the century. This was almost the only place in France where Kirchhoff's, Boltzmann's, and Wien's discoveries on the thermodynamics of radiation were presented. Bustamante details the results of the fruitful year of 1905: Lorentz's conference in Paris that increased Langevin's knowledge of Planck's approach, and the publication of Einstein's work on the structure of light. To better explore how these questions evolved, Bustamante closely follows the work of Langevin's young doctoral student Edmond Bauer, who in 1908 undertook a thesis on the thermodynamics of radiation that he defended in 1912, the same year that the lectures were delivered at the Collège de France. Bustamante also provides a detailed picture of the preparation for and events of the Solvay congress of 1911 which, as mentioned above, played a decisive role in propelling Langevin onto the international scientific scene as an undisputed specialist of statistical mechanics. A short chapter looks at the audience of Langevin's lectures and focuses in particular on the presence of Émile Borel. Although he was a mathematician and not a physicist, at that time Borel was specifically interested in exploring how a reliable probabilistic model could serve as a sound theoretical foundation for statistical mechanics, and he therefore had good reason to attend his friend Langevin's lectures. Finally, the third chapter of this first part of the book poses the methodological question of what we can learn from reading these lecture notes. Bustamante rightly points out that taking notes involves a complex relation between the various individuals involved (the lecturer, the writer but also other members of the community who participate in a common scientific culture). Far from being a passive exercise, note-taking requires the writer to take the initiative, in particular by selecting what to write down (or not) based on his or her interest, understanding, and attention. As a result, the notes taken during this course are a hybrid work whose analysis reveals valuable information not only about the writer, but also about the scientific communication at the beginning of the 20th century in France.

The second part of the book contains the complete transcription of the few dozen pages making up the notebook, without omitting countless abbreviations, erasures, corrections, figures, etc. Borel obviously wrote these lecture notes for his own exclusive use, without ever imagining that they might be published. The page-by-page transcription is published next to the photographic reproduction of the original, thus allowing readers to form their own opinion of the original text in case of doubt; the transcriptions are generally clear, although there are also many uncertainties, especially as the note-taker made extensive use of all of the space available on the page. Transcribing these notes undoubtedly required a significant amount of patience and skill on Bustamante's part. Moreover, rather than transcribing the notes in a single block, she found it useful for the reader to subdivide the transcription into five parts that correspond more or less faithfully to how the course was originally organized by Langevin, with the chronological order, of course, being maintained.

The short third part of the book presents a selection of documents that complete the picture of the situation in thermodynamics in France at the beginning of the 20th century. First, it addresses the contents of the courses given by Marcel Brillouin and Langevin between 1900 and 1914 as summarized in the official directories of the Collège de France. We thus have a very clear synopsis of the changes in how theoretical physics was taught in Paris and of the decisive impetus provided by Langevin's arrival. Bustamante has also reproduced the second chapter of Edmond Bauer's thesis, which offers an overview of the understanding and presentation of statistical mechanics as taught in Paris at Langevin's instigation.

The book thus contains a substantial amount of original material that brings us straight into the roaring years of physics at the beginning of the 20th century. Bustamante's precise and very erudite commentary deserves full praise for its clarity and relevance. Mathematicians may regret that she did not emphasize Borel's role in the story more strongly, especially by explaining in more detail the interest in probability that motivated him to scrutinize the changes in atomistic physics. But Bustamante's already voluminous work can hardly be expected to cover everything. Besides, an abundant and helpful bibliography allows the interested reader to further reflect on these and other fascinating topics.

The high material quality of the book is uncommon for scientific publishing these days. The choice of paper, the quality of the graphics, and the high resolution of the photos, among other features, result in what can be called a "beautiful book," and may lead one to fear that the publisher will go bankrupt... Let us hope that this fear is ill-founded, and that Brepols will continue producing such high-quality works, as good science must also be a matter of beauty.

Laurent Mazliak
Sorbonne-Université, LPSM, Paris, France

Laurent Mazliak is Assistant Professor at the Laboratoire de Probabilités, Statistiques et Modélisation at Sorbonne Université, Paris. His research concerns the history of mathematics, in particular that of probability theory, around the beginning of the 20th century. He has written and edited several works on the effect of the Great War on the mathematical community.