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Hermann Minkowski and the Postulate of Relativity

LEO CORRY

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1. Introduction

In the history of two of Einstein's chief scientific contributions – both the special and the general theories of relativity – two of the leading Göttingen mathematicians of the beginning of this century each plays a significant role: Hermann Minkowski (1864–1909) and David Hilbert (1862-1943). Einstein published his famous paper on the electrodynamics of moving bodies in 1905. Beginning in 1907, Hermann Minkowski erected the new theory of relativity on what was to become its standard mathematical formulation and devised the language in which it was further investigated. In particular, Einstein's adoption of Minkowski's formulation – which he had initially rejected – proved essential to his own attempts to generalize his theory to cover gravitation and arbitrarily accelerated systems of reference. After a long and winding process that spanned at least three years of intense work and included the publication of several versions he later deemed incorrect, Einstein presented to the Prussian Academy of Sciences in Berlin his generally-covariant field equations of gravitation on November 25, 1915. But, as it happened, David Hilbert – the undisputed, foremost living mathematician in the world and the lifelong close friend and collaborator of the by then deceased Minkowski – had already presented to the Göttingen Academy his own version of the same equations a few days earlier, on November 20. Although Minkowski and Hilbert accomplished their most important achievements in pure mathematical fields, their respective contributions to relativity should in no sense be seen as merely occasional excursions into the field of theoretical physics. Minkowski and Hilbert were motivated by much more than a desire to apply their exceptional mathematical abilities opportunistically, jumping onto the bandwagon of ongoing physical research by solving mathematical problems that physicists were unable to. On the contrary, Minkowski's and Hilbert's contributions to relativity are best understood as an organic part of their overall scientific careers. It

is remarkable that although the close professional and personal relationship between Minkowski and Hilbert is well-known, no direct connection between their respective contributions in these fields has hitherto been established or even suggested.[1] The history of the special and the general theories of relativity has more often than not been told from the perspective of Einstein's work and achievements, and the roots and true motivations of Minkowski's and Hilbert's contributions to this field have therefore remained only partially and incorrectly analyzed.

A detailed examination of their careers makes it evident that a keen interest in physics was hardly ever distant form either Hilbert's or Minkowski's main focus of activity in pure mathematics. Minkowski's interest in physics dates back at least to his Bonn years (1885–1894), during which he was in close contact with Heinrich Hertz.[2] In 1888 he published an article on hydrodynamics in the proceedings of the Berlin Academy (Minkowski *1888*). From his correspondence with Hilbert,[3] we know that during his Zürich years Minkowski kept alive his interest in mathematical physics, and in particular in thermodynamics. In 1902 he moved to Göttingen, following Hilbert's strong pressure on Felix Klein (1849–1925) to create a professorship for his friend. It is well known that during his last years there, Minkowski's efforts were intensively dedicated to electrodynamics. But this was not the only field of physics to which his attention was attracted. Minkowski was commissioned to write an article on capillarity for the physics volume of the *Encyclopädie der mathematischen Wissenschaften*, edited by Arnold Sommerfeld (Minkowski *1906*). At several meetings of the Göttingen Mathematical Society he lectured on this, as well as on other physical issues such as Euler's equations of hydrodynamics and Nernst's work on thermodynamics.[4] He also taught advanced seminars on physical topics and more basic courses on continuum mechanics, and gave exercises in mechanics and heat radiation.[5]

Perhaps under Minkowski's influence, Hilbert also developed a strong attraction to physics from very early on. He followed the latest developments in physics closely and taught courses and seminars on almost every current physical topic. Hilbert elaborated the principles of his axiomatic method between 1894 and 1899 as part of his current interest in problems related to the foundations of geometry; but to a considerable extent, he also reflected throughout these years on the relevance of the method for improving the current state of physical theories. Influenced by his reading of Hertz's *Principles of Mechanics*, Hilbert believed that physicists often tended to solve disagreements between existing theories and newly found facts of experience by adding new hypotheses, often without thoroughly examining whether such hypotheses accorded with the logical structure of the

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[1] For example, no such connection is considered in oft-cited accounts of Minkowski's work: Galison *1979*; Pyenson *1977*; Miller *1981*, 238–244. Neither is it discussed in accounts of Hilbert's contribution to general relativity: Earman and Glymour *1978*; Mehra *1974*; Pais *1982*, 257–261; Vizgin *1994*, 54–69.

[2] See Rüdenberg and Zassenhaus (eds.) *1973*, 39–42, and Hilbert *1909*, 355.

[3] See Rüdenberg and Zassenhaus (eds.) *1973*, 110–114.

[4] As registered in the *Jahresbericht der Deutschen Mathematiker-Vereinigung* (*JDMV*). See Vol.12 (1903), 445 & 447; Vol.15 (1906), 407.

[5] See the announcement of his courses in *JDMV* Vol.13 (1904), 492; Vol.16 (1907), 171; Vol.17 (1908), 116.