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★**How Einstein found his field equations—sources and interpretation.**

Classic Texts in the Sciences.

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It became clear, some years afterwards, in an a posteriori lecture, that the answer to the question asked in the title is: by discovering the generalised covariance. That was Einstein's greatest discovery and I regret that it does not appear at the level of the title, a consequence, I imagine, of avoiding the usual shortcuts. Fortunately, it is in due place inside the book. But, on the contrary, it is also clear that Einstein did not invent that covariance in order to write his field equations. The interaction between those discoveries is much more complex and an underlying aim of this book is to provide documents allowing one to understand that interaction.

This wonderful book is not a book to read! It is a book to be used. It is a tool that could help a great number of people to understand general relativity more deeply and to apply it. But the authors' aim is not to teach general relativity to anyone. It requires a good background not only in physics but also in mathematics, as well as a deep taste for the fundamental and profound physics that allowed humanity to better understand the Universe, from the infinitely small to the infinitely large. Certainly more elaborate versions exist today, allowing a lot of shortcuts, but as I have learned through experience, original works always constitute the best guide, even if they are not always the shortest. This book should figure in the library of anyone working on relativity, remembering that it also contains an important bibliography, not exclusively historical but also containing important texts linked to that development.

The preface intelligently orients the reader without imposing any scheme on the lecture. The authors observe that no particular order of reading is preferred. The reader may pursue his own goals. A best way of reading is difficult to imagine. The richness of what Einstein has shown to the world is so bright, why should one impose a choice on the reader?

General relativity, however, was by no means the work of a lone genius (Janssen and Renn, 2015). First of all, one of the central claims the authors argue for in this volume is that Einstein, in developing his theory for the gravitational field, was guided predominantly not by considerations of mathematical elegance, as he would maintain in his later years, but by an elaborate analogy with the Maxwell-Lorentz theory for the electromagnetic field reformulated in the four-dimensional formalism of special relativity by Hermann Minkowski, Arnold Sommerfeld, Max von Laue and others. It is through that reformulation that Einstein introduced the general covariance. One could thus completely separate the invention of general covariance from general relativity. Or, to put it another way, it was not a problem appearing in general relativity that led Einstein to introduce general covariance. It was the intuition of its generality that drew him to general covariance.

"Moreover, although he did not always acknowledge this in print, Einstein, as he was developing his theory, received substantial help and feedback from a number of individuals, some well known, others long forgotten, such as Paul Bernays, Michele Besso, Paul Ehrenfest, Adriaan D. Fokker, Erwin Freundlich, Marcel Grossmann, Paul Hertz, Friedrich Kottler, Tullio Levi-Civita, Hendrik A. Lorentz, Gunnar Nordström and Moritz Schlick."

In the second part of the introduction, the authors underline the fundamental notions that are indispensable to understanding this book. The book is thus not a book of trivialisation; far from that. But a student towards the end of his study of the math-

ematics of physics, as well as a doctoral student, can follow most of it. More seasoned researchers can gain a lot if they are interested in history and if they are aware of what history may teach them.

Next the authors enter the heart of the matter, facing the deepest point, the invariance of equations under some coordinate transformations, or better of their covariance. The stage is set; we reached the deepest point of general relativity, where one speaks of the generalised covariance that applies to any equation and that we already mentioned. Any equation that is not covariant is just wrong and should be rejected. This is in fact a tool of incredible power that far exceeds the power of the one used before, namely experimentation, because it allows one to know truths about objects that one cannot test, such as the measure of the universe.

The central difficulty of this book lies in the fact that Einstein combined many elements coming from very different topics. This point justifies the numerous and various analyses linked to rather different theories that are generally more straightforward, given on the same partial object. They should not be rejected, and the authors don't reject them, because they make up part of the whole that Einstein structured, a whole that comprises such different parts of our knowledge.

The work accomplished in this book is not only remarkable but also useful. As has already been emphasised, its unusual presentation leaves a lot of freedom to the reader to reflect on that situation. Everyone, according to his vocational training, will reassemble this complex mechanism in his own way. But, as in all projects of that style, not all constructions lead to the researched object.

The authors thus decide not to guide the reader, but to make accessible to him, within the book itself, all the different propositions that have already been made. To do so, they reconstruct Einstein's way of thinking step by step using principally the draft (Entwurf) and the few letters of his rare collaborators. This will be discussed in detail below.

All this justifies the organisation of the book into two parts, the first due to the authors and explaining the emergence of the central point, namely Einstein's field equations, and the second, giving precisely Einstein's documents, drafts and letters, or extracts of them and quoting them all, justifying their allegations and giving precise references to numerous interpretations.

Part I Essay

Chapter 1: Overview of the contents of this volume.

This book describes the radical change in theoretical physics that gave it its actual power, whose limits are actually far from known to us. The authors do this in a particularly intelligent way, underlining only the original development of Einstein's thought, through five different drafts (Entwurf), all written in 1915. It is in those drafts that Einstein built the concept of generalised covariance and imposed it. There lies the turning point, not only of physics but of science in its generality.

No critique is given against any element of the entire literature that those drafts inspired, if only a criticism of incompleteness. But the authors underline with force the discovery by Einstein of the key to that understanding, namely generalised covariance.

The book's structure follows the development of that idea through the different sketches of the theory by Einstein.

Chapter 2: From the *Entwurf* field equations to Einstein field equations: a first pass

Chapter 3: The Zurich Notebook: How Einstein found the *Entwurf* field equations

Chapter 4: Consolidating the *Entwurf* theory

Chapter 5: The *Entwurf* field equations as the scaffold for the Einstein field equations

Chapter 6: Mercury's perihelion: From $18''$ in the *Entwurf* theory to $43''$ in general relativity

Chapter 7: Beyond the search for field equations

Part II Sources

Chapter 1: The Zurich Notebook (1912–13)

The reader finds the few sources organised chronologically. He finds first a photographic reproduction of the source, followed by its transcription. Each entry is completed by a short commentary and direction to the list of references given at the end of the book. Then follows a description of the manuscript and a commentary on its content.

Chapter 2: The Einstein-Besso Manuscript (1913)

This chapter is on the perihelion motion of Mercury (1913). In this particular case, the reader finds in annotation the author of the particular lines, Einstein or Besso; the same indications are given in the transcription.

Chapter 3: "Formale Grundlage ... " (November 1914)

Chapter 4: Einstein to Freundlich, September 30, 1915

Chapter 5: Einstein to Lorentz, October 12, 1915

Chapter 6: The November 1915 papers

Chapter 7: Einstein to Sommerfeld, November 28, 1915

Chapter 8: Einstein to Ehrenfest, January, 1916

Chapter 9: "Die Grundlage ... " (May 1916)

Chapter 10: "Hamiltonsches Prinzip ... " (November 1916)

References: The book ends with references to a large number (15 pages) of articles and books, most of them well known and appreciated, concerned with or contributing to the development of the argument.

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