

EINSTEIN'S UNIFICATION

Why did Einstein vainly study unified field theory for more than 30 years? In this book, the author argues that Einstein believed he could find a unified theory of all of nature's forces by repeating the methods he is thought to have used when he formulated general relativity.

The book discusses Einstein's route to the general theory of relativity, focusing on the philosophical lessons that he learnt. It then addresses his quest for a unified theory for electromagnetism and gravity, discussing in detail his efforts with Kaluza–Klein theory and, surprisingly, the theory of spinors. From these perspectives, Einstein's critical stance towards quantum theory comes to stand in a new light. This book will be of interest to physicists, historians and philosophers of science.

JEROEN VAN DONGEN is Assistant Professor at the Institute for History and Foundations of Science at Utrecht University, the Netherlands, and has served as Editor of the *Collected Papers of Albert Einstein* at the California Institute of Technology.

Cambridge University Press
978-0-521-88346-7 - Einstein's Unification
Jeroen van Dongen
Frontmatter
[More information](#)

EINSTEIN'S UNIFICATION

JEROEN VAN DONGEN
*Utrecht University
and
Einstein Papers Project,
California Institute of Technology*



Cambridge University Press
978-0-521-88346-7 - Einstein's Unification
Jeroen van Dongen
Frontmatter
[More information](#)

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,
São Paulo, Delhi, Dubai, Tokyo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521883467

© J. van Dongen 2010

This publication is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without
the written permission of Cambridge University Press.

First published 2010

Printed in the United Kingdom at the University Press, Cambridge

A catalog record for this publication is available from the British Library

ISBN 978-0-521-88346-7 Hardback

Cambridge University Press has no responsibility for the persistence or
accuracy of URLs for external or third-party internet websites referred to
in this publication, and does not guarantee that any content on such
websites is, or will remain, accurate or appropriate.

Contents

<i>Acknowledgments</i>	<i>page vii</i>
Introduction	1
1 Formulating the gravitational field equations	6
1.1 The dual method and the Zurich notebook	9
1.2 Conceptual struggles with the Entwurf theory	19
1.3 November 1915: mathematics produces the covariant Einstein equations	26
1.4 Conclusion: general relativity and Einstein's methodological lesson	32
2 On the method of theoretical physics	36
2.1 The change in epistemological outlook	36
2.2 Principle and constructive theories	49
2.3 Einstein's methodological schema	51
3 Unification and field theory	58
3.1 Unification: motivation and implementation	58
3.2 Unified field theory	64
4 Experiment and experience	75
4.1 Einstein and experimentation	76
4.2 Experience in Einstein's philosophy	89
5 The method as directive: semivectors	96
5.1 The unnaturalness of the spinor	97
5.2 Semivectors and the unification of charged particles	106
5.3 Reception of the semivector	122
5.4 Conclusion: nature and mathematical naturalness	127
6 Unification in five dimensions	130
6.1 Particle solutions in field theory	130
6.2 Kaluza, Klein and Einstein	132

Cambridge University Press
978-0-521-88346-7 - Einstein's Unification
Jeroen van Dongen
Frontmatter
[More information](#)

vi	<i>Contents</i>	
6.3	Einstein–Bergmann–Bargmann theory	139
6.4	Conclusion: classical field theory and quantization	154
7	The method and the quantum	157
7.1	The old quantum theory	158
7.2	The formulation of matrix and wave mechanics	166
7.3	Einstein and quantum mechanics	174
7.4	Conclusion: the quantum and the practice of field theory	182
	Conclusion	184
	<i>References</i>	191
	<i>Index</i>	208

Acknowledgments

This book began as a thesis project, with the loosely prescribed perimeter of Albert Einstein's unified field theory work as a subject. The advisors that dedicated themselves to my project could not have been chosen better: historian of modern physics Anne J. Kox and string theorist Herman Verlinde. Anne taught me many things, Einstein and otherwise, and has been extremely supportive of, and important to my work. I am proud and very grateful that he has continued his advice and friendship well after my days as a graduate student ended; between us a bond has formed that easily surpasses that of professor and student. Similarly, this book would not have come into being without Herman's manifold contributions. I have fond recollections of the many engaging discussions and blackboard instructions, and Herman, too, has given much more than can be captured by the title of thesis advisor alone; I have greatly valued his intellectual stewardship, friendship and extensive hospitality in New Jersey.

The project started at Anne Kox's history of physics group at the Institute for Theoretical Physics of the University of Amsterdam. The Institute's faculty, postdoctorate and student members provided the best intellectual environment any young scholar can wish for: applying a high standard while maintaining a warm atmosphere. I am honored to be a graduate of the University of Amsterdam. I also greatly enjoyed the hospitality that was awarded me as a visitor for nearly two years at Princeton University's Physics Department, by both its faculty and most welcoming fellow graduate students.

Starting from a loosely prescribed subject, my work took a major turn when I learnt of the work conducted on the history of general relativity by Michel Janssen, John Norton, Jürgen Renn, Tilman Sauer and John Stachel. Only when I became acquainted with their studies did I begin to see the outline of my thesis project, and ultimately this book. I have further heavily drawn upon the work of such eminent Einstein scholars as Gerald Holton, Abraham Pais, Vladimir Vizgin, and many more.

How does this book differ from my earlier thesis? Postdoctoral scholarships and editorial responsibilities have made me much more seasoned in Einstein scholarship, and history of science in general, and this has expanded the book in proportion. Following my graduation in 2002 I had the privilege of becoming a member of Jürgen Renn's group at the Max Planck Institute for the History of Science in Berlin, until 2004, when I joined the Einstein Papers Project, directed by Diana Kormos Buchwald at the California Institute of Technology. Both experiences have given me a deepened understanding of Einstein's relation to his science and a sharpened sense for historical scholarship. This book benefitted greatly from these experiences. Interactions in Berlin with many of the Institute's permanent and transient members – Jürgen Renn, Michel Janssen, Dieter Hoffmann, Giuseppe Castagnetti and Matthias Schemmel must be mentioned in particular – gave me a fuller sense of Einstein's road to relativity, as well as of many other aspects of his science. At the Einstein Papers Project, my maturing as a historian of science continued, and in Pasadena I have enjoyed strong support and most valuable exchanges of ideas with Diana Buchwald, Tilman Sauer, József Illy, Ze'ev Rosenkranz and Dan Kennefick; I am also grateful for the help I received from Carol Chaplin, Rudy Hirschmann, Rosy Meiron, Osik Moses and Jennifer Nollar. In particular my views on Einstein's relation to quantum mechanics were formed while studying his correspondence for our edited volumes; the reconstruction of Einstein's life in day-to-day detail provides enthralling insight into his science. It is a privilege to serve as a member of the Einstein Papers team, and I wish to thank Diana for her persistent help in bringing this book to a successful close.

Lately I have found a true home at the Institute for History and Foundations of Science at Utrecht University, where I have had the opportunity to join the excellent group headed by Dennis Dieks. Dennis has been most helpful in steering this book project into final form by serving as a critical reader and dedicated sounding board; he has given me thoughtful and much valued advice on all of its subjects. I have further greatly appreciated his careful coaching of my teaching; I am indebted to Dennis for any future success I may enjoy as a lecturer. In Utrecht I have further found a dedicated colleague in Jos Uffink, who also has given me support and direction in completing this project. At the Institute, I have aspired to act as someone resembling an intellectual *trait d'union* between the foundationalists and historians, and I thank my historian colleagues, Bert Theunissen, Lodewijk Palm and honorary member Frans van Lunteren for their encouragement. I also owe gratitude to Utrecht's many smart graduate and undergraduate students who by their probing questions and dedicated work make doing research and teaching in Utrecht a most joyful experience. Finally, Utrecht has recently created a unique infrastructure for history and philosophy of science with the Descartes Center; in

it, both humanities and science faculties have been unified, and I look forward to fulfilling my role as one of its members.

In preparation for this study I have consulted Einstein's personal correspondence, as contained in duplicates of the Einstein Archive, an invaluable research tool, the original of which is to be found at the Hebrew University of Jerusalem, as per Einstein's last will. I depended on the copy of Princeton University's Firestone library and, more recently, on another, updated copy in the basement of the Einstein Papers Project in Pasadena. This resource has been most helpful; in fact, without its many revealing documents it would have been well-nigh impossible to formulate my ideas. I thank Roni Grosz of the Albert Einstein Archives and Daphne Ireland at Princeton University Press for permission to use the Archive's material in this book. Please note that

- references in the footnotes to the Einstein Archive will be indicated with the abbreviation EA.

An earlier version of Chapter 5 on semivectors has appeared in the *Archive for History of Exact Sciences*, and I thank its publisher, Springer, for permission to use the material in this book.

This book has benefitted from many proofreaders. For their engaging criticism, I would like to express my sincere gratitude to Eddy Ardonne, Sander Bais, Michel Janssen, Jürg Käppeli, Dan Kennefick, Klaas Landsman, Ad Maas, John Norton, Tilman Sauer, Michiel Seevinck, Jürgen Renn, Ze'ev Rosenkranz and Jos Uffink. I am grateful to Rob van Gent for help with figures, and Albert van Helden for advice. I have benefitted greatly from interacting with many historians and philosophers of science of my generation during my *Wanderjahre* as postdoc; I would like to thank in particular Sven Dupré, Christoph Lehner, Alberto Martinez, Suman Seth, Chris Smeenk, Milena Wazeck and Daan Wegener for sharing their insight and company with me. I thank John Norton for much appreciated discussions, advice and help. Discussions with Martin J. Klein inspired me to write Chapter 4 on experiment. Martin and his wife Joan Blewett invited me for a lovely week at their home in North Carolina in 2005, and on that occasion we committed ourselves to ambitious collaborative plans, yet busy schedules regrettably inhibited progress. I was greatly saddened, and it was a great loss to the scholarly community, when Martin passed away in March of 2009.

I thank the Netherlands Organization for Scientific Research (NWO) for supporting me with a generous Veni grant, and for support during my graduate study. I am further most grateful to the Pieter Zeeman Foundation and the Center for High Energy Astrophysics of the University of Amsterdam for their financial aid. I am honored that the Society for the Advancement of Science, Medicine, and Surgery,

Cambridge University Press
978-0-521-88346-7 - Einstein's Unification
Jeroen van Dongen
Frontmatter
[More information](#)

Amsterdam, chose to award my thesis its Andreas Bonn medal for 1999–2003. At Cambridge University Press, I wish to thank Simon Capelin, whose enthusiasm at our first contact was very motivating, Laura Clark, Lindsay Barnes and Graham Hart, and Sehar Tahir of CUP's tex support.

I wish to thank my friends for their patience and help, scattered as they are from the heart of Brabant to the Pacific coast of the American continent. My father deserved to see this book appear; sadly, he passed away too early. This book could never have been written without the unfailing support of my loving and dedicated mother, Mia Savenije. I thank you, Rocio, for your love.

Utrecht, July 2009