String Theory and the Scientific Method

String theory has played a highly influential role in theoretical physics for nearly three decades and has substantially altered our view of the elementary building principles of the universe. However, the theory remains empirically unconfirmed, and is expected to remain so for the foreseeable future. So why do string theorists have such a strong belief in their theory?

This book explores this question, offering a novel insight into the nature of theory assessment itself. Dawid approaches the topic from a unique position, having extensive experience in both philosophy and high energy physics. He argues that string theory is just the most conspicuous example of a number of theories in high energy physics where non-empirical theory assessment has an important part to play. Aimed at physicists and philosophers of science, the book does not use mathematical formalism and explains most technical terms.

RICHARD DAWID is a Philosopher of Science at the University of Vienna, and has a PhD in theoretical physics. His main research interests are philosophical questions related to contemporary high energy physics, as well as general issues in the philosophy of science.

String Theory and the Scientific Method

RICHARD DAWID
University of Vienna

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107029712

First published 2013
Paperback edition first published 2015

Printed in the United Kingdom by Clays, St Ives plc

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

Library of Congress Cataloging in Publication data
Dawid, Richard, 1966–
String theory and the scientific method / Richard Dawid, University of Vienna.
pages cm
Includes bibliographical references and index.
ISBN 978-1-107-02971-2 (hardback)
1. String models. 2. Science – Methodology. I. Title.
QC794.6.S85D39 2013
539.7′258–dc23
2012044103

ISBN 978-1-107-02971-2 Hardback
ISBN 978-1-107-44961-9 Paperback

To Walter (1937–2008)

Contents

Preface *page* ix

Introduction 1

PART I DELIMITING THE UNCONCEIVED 5

1 String theory 9
1.1 A brief introduction to string theory 9
1.2 The conflicting assessments of the current status of string theory 19
1.3 Three contextual arguments for the viability of string theory 30

2 The conceptual framework 39
2.1 The classical paradigm of theory assessment 39
2.2 Scientific underdetermination 44

3 The assessment of scientific underdetermination in string theory 50
3.1 Connections between theory assessment and scientific underdetermination 50
3.2 The framework for claims of limitations to scientific underdetermination 59
3.3 The scope of the three arguments 62
3.4 Non-empirical theory assessment as inference to the best explanation 64
3.5 A Bayesian analysis 68

PART II A WIDER PERSPECTIVE 73

4 The dynamics of high energy physics 75
4.1 Two crucial principles in modern high energy physics 75

4.2 Theory dynamics beyond the current limits of empirical testability 82
4.3 Theory assessment in a new scientific environment 94
5 Scientific underdetermination in physics and beyond 97
5.1 The marginalization of the phenomena 97
5.2 The question of microphysical objects 103
5.3 Empirical confirmation in high energy physics 109
5.4 Non-empirical assessment of the Higgs theory 112
5.5 The confirmation of the top quark 115
5.6 A brief excursion into palaeontology 118
5.7 A new understanding of theory assessment 123

PART III PHYSICS AND TRUTH 127

6 Final theory claims 129
6.1 Two final theory claims in string physics 129
6.2 Local and global limitations to scientific underdetermination 134
6.3 Structural uniqueness and its impact on the question of finality 141
6.4 The formal structure of final theory arguments 147
6.5 The case of anthropic reasoning 149
6.6 A new conception of scientific progress 152
6.7 The end of science? 155
7 An altered perspective on scientific realism 157
7.1 The layout of the debate 157
7.2 Unconceived alternatives 164
7.3 Scientific realism and non-empirical theory evaluation 169
7.4 Consistent structure realism 174
7.5 Whither physical theory? 189

References 191
Index 198

Preface

This book has been on my mind ever since I left physics and turned to philosophy in the year 2000. A core motivation for making that step at the time was my feeling that something philosophically interesting was going on in fundamental physics but remained largely unappreciated by the world outside the departments of theoretical physics – and underappreciated even within. Twelve years of grappling with the specification of that general idea have considerably changed my perspective on the issue but left the overall idea intact. This book is the attempt to present it in a coherent form.

The book would not have been possible without the insightful comments, questions and corrections by many friends and colleagues over the years. A very important role in the genesis of the book was played by the Institute Vienna Circle Colloquium (past and present members), where I presented and discussed many of its stages. I want to thank in particular Christian Damböck, Christian Fermüller, Johannes Hafner, Manfred Kohlbach, Daniel Kuby, Christoph Limbeck Lilienau, Miles McLeod and Matthias Neuber for many enlightening discussions. My special thanks go to Richard Nickl for his unwavering insistence on the grand scheme. Of particular importance for the clarification of a number of concepts used in Part I of the book was the cooperation with Stephan Hartmann and Jan Sprenger on a Bayesian formalization of the no alternatives argument (see Section 3.5). I am also highly indebted to friends and colleagues who read preliminary versions of the manuscript or parts thereof and whose excellent comments have substantially improved the book. My thanks go to Jeff Barrett, Christian Damböck, Manfred Kohlbach, Christoph Limbeck Lilienau, Keizo Matsubara, Richard Nickl, John Norton, Fritz Stadler, Kyle Stanford and Karim Thebault. I am also grateful for the very helpful comments of the reviewers of Cambridge University Press. Finally, there are all those with whom I discussed topics and texts which eventually entered the book in some form. Without pretensions of completeness, I want to thank Paolo Aschieri,

Michael Baumgartner, Lorenzo Casini, Delphine Chapuis-Schmitz, Isabelle Drouet, Mehmet Elgin, Tobias Fox, Nikita Golovko, Daniel Grumiller, Reiner Hedrich, Herbert Hrachovec, Martin Kusch, Karl Landsteiner, Luca Moretti, Elisabeth Nemeth, Robert Nola, Ed Slovik, Michael Stöltzner, Derek Turner and Jim Woodward.

I would also like to thank Nick Gibbons and Lindsay Barnes, my editors at Cambridge University Press, for their encouraging and constructive support throughout the editing process. I am grateful as well to the Austrian Science Fund (FWF) (P22811-G17) whose funding provided the framework for writing the book.

The book contains modified versions of material that has been published in a number of scientific articles. I am grateful to the respective journals for permitting the publication of parts of those works. Specifically, material from the following scientific articles has been used in the following chapters: "Underdetermination and theory succession from the perspective of string theory," *Philosophy of Science* **73**(3), 298–322, in Chapters 1 and 3; "Scientific realism in the age of string theory," *Physics and Philosophy* **11**, 1–32, in Chapters 1, 2 and 3; "On the conflicting assessments of the current status of string theory," *Philosophy of Science* **76**(5), 984–996, in Chapter 1; "High energy physics and the marginalization of the phenomena," *Manuscrito* **33**(1), special issue *Issues in the Philosophy of Physics*, 165–206, in Chapters 4 and 5; and "String theory and theory assessment," *Foundations of Physics*, **43**(1), 81–100, in Chapter 6.

Last but not least, I want to thank my wife Lisi for her always charming support. Though we first met quite some time ago, she knows me only in the state of planning or writing this book. It seems time to open a new page.

Vienna,
July 30, 2012