QUANTIZED DETECTOR NETWORKS

Scientists have been debating the meaning of quantum mechanics for over a century. This book for graduate students and researchers gets to the root of the problem: the contextual nature of empirical truth, the laws of observation, and how these impact on our understanding of quantum physics. Bridging the gap between nonrelativistic quantum mechanics and quantum field theory, this novel approach to quantum mechanics extends the standard formalism to cover the observer and their apparatus. The author demystifies some of the aspects of quantum mechanics that have traditionally been regarded as extraordinary, such as wave–particle duality and quantum superposition, by emphasizing the scientific principles. Including key experiments and worked examples throughout to encourage the reader to focus on empirically sound concepts, this book avoids metaphysical speculation and alerts the reader to the use of computer algebra to explore quantum experiments of virtually limitless complexity. This title, first published in 2017, has been reissued as an Open Access publication on Cambridge Core.

George Jaroszkiewicz is a mathematical physicist recently retired from the School of Mathematical Sciences, University of Nottingham. His research interests are focused on the fundamental differences between quantum and classical mechanics.

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Quantized Detector Networks

The Theory of Observation

GEORGE JAROSZKIEWICZ

CAMBRIDGE
UNIVERSITY PRESS

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Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05-06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment,
a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of
education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781009401456

DOI: 10.1017/9781009401432

First published 2017
Reissued as OA 2023

A catalogue record for this publication is available from the British Library.

ISBN 978-1-009-40145-6 Hardback
ISBN 978-1-009-40142-5 Paperback

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Preface

In a routine optical telescope scan of a distant galaxy, astronomer Alice saw nothing unusual. Her radio astronomer colleague Bob, however, reported intense radio activity in that galaxy. Who had the true view of the galaxy?

This is the sort of question discussed in this book. If you said that Bob had the "true" view of the galaxy, you would be quite normal. *Normal*, in the sense of *average*, or *typical*, or even *reasonable*. But if you went on to read the rest of this book and understand its main message, you might then give a different answer to that question.

It is not a trick question, however. The "correct" answer is **not** "*Alice has the true view of the galaxy.*" Neither is it "*Neither of them*" nor is it "*Both of them.*"

This preface is not the place to discuss possible alternative answers to the above question; you should be able to work one out based on the principles discussed in the main text of this book. Although the question is easy to state, the answer we give in the last chapter is simple neither to explain nor to justify. It is best discussed using a lot of words and rather sophisticated mathematical models and technologies. These are introduced, developed, and applied after intensive preliminary discussions of the issues concerned.

Our answer is intimately bound up with the *laws of observation* as they pertain to quantum processes, the subject matter of this book. These laws are the rules that underpin modern, empirically based perceptions of physical reality (our term for the world of experience).[1] It has taken over two thousand years of philosophical, natural philosophical, and empirical inquiry into the physical universe for some of these rules to be discovered, particularly the ones involving quantum processes. These latter have been understood for only the last hundred years or so, and what they mean is still an active subject of debate. The old question of how many angels can dance on the head of a pin is nothing compared with the question of what the wave function means in quantum mechanics.

The problem is that most rules of quantum mechanics are counter intuitive and may even appear wrong and unphysical to the person in the street. But then, quantum mechanics has appeared baffling ever since it was stumbled on by Planck in 1900. But as with Alice and Bob above, appearances can be deceptive:

[1] I don't imply there are other forms of reality. I can say nothing about that.

it is quantum mechanics that continues to give verified predictions, while our classical intuition, experience, and expectations all continue to be confounded.

It is my intention that this book be of value to a wide spectrum of readers: refined quantum theorists, philosophers of science, experimentalists, students, and the well-educated person in the street. If nothing else, I want to provoke readers in two ways: first, to question their own ingrained belief structures about the world they live in and second, to be alerted to the fact that there are a lot of speculative concepts and theories that are discussed by some scientists as if they were scientifically meaningful, when in reality they have no empirical basis whatsoever. I call these theories *vacuous* and they are dangerous, because they equate theory with empirical evidence. They lure the unsuspecting into unfounded quasi-religious modes of thinking that may be good science fiction but have no place in science proper. A sound interpretation of quantum mechanics really does matter, because that involves our perceptions of reality. After all is said and done, that is really what distinguishes us from other creatures and affects everything that we do.

This book is timely in two ways. First, after a century of attempts to understand quantum theory from a classical, noncontextual perspective, intense activity into the neurological basis of human psychology has started to reveal a starting truth: classical reality exists only in the mind. Every day, the results of new laboratory experiments demonstrate more and more convincingly just how misleading the classical perception of the world really is. We humans are now being shown up for what we are: we live in illusory worlds of our imaginations, constructed by our brains as they attempt to match the vast flood of sensory data streaming in through our senses with patterns of preconditioned rationalization.

Second, there is intense interest and work worldwide in the development of quantum computers. In this book I discuss the application of computer algebra to quantum registers containing many quantum bits (qubits). Although my focus in this book is on the description of quantum experiments, there will be a great overlap between quantum computation and that focus, so that I expect this book to be of some interest, and I hope value, to quantum computation theorists.

A preface is the place for an author to give their thanks and acknowledgment. Here are mine. First, I have been overawed by the fact that the underlying theme of this book, which is the debate about the nature of perception, has been going on for many centuries. Some of the views that I have read greatly impressed me and I realized that there were individuals who saw through the fog of conditioning that surrounds all of us. In particular, I greatly admire the works of David Hume, whose views about the nature of perception I found remarkably in tune with this book. As an undergraduate, I was greatly influenced by the lectures of Nicholas Kemmer. Later, I encountered the brilliant works of Julian Schwinger, and even had the great pleasure of meeting him and talking with him in 1993 in Nottingham and London, during the bicentenary celebrations of the

birth of George Green. These extraordinarily generous individuals in particular and many others influenced me in one way or another in the most significant of ways.

Finally, I express my gratitude to all members of my extended family, past and present. My parents gave me the opportunities to start writing and the arrival of my granddaughter Julia gave me the motivation to continue when that writing became tedious. Without them this book would not exist. In particular, my wife, Małgorzata, has been immensely supportive and helpful in all my efforts; I thank her for that and for her great patience.

Acronyms

CA	computer algebra
CBR	computational basis representation
CM	classical mechanics
CPT	charge, parity, and time
CST	causal set theory
CTC	closed timelike curve
DS	double-slit
EPR	Einstein, Podolsky, and Rosen
eQDN	extended quantized detector networks
FLS	Feynman, Leighton, and Sands
GP	generalized proposition
GPC	general proposition classification
GR	general relativity
HV	hidden variables
LG	Leggett–Garg
LSZ	Lehmann–Symanzik–Zimmermann
MDS	monitored double-slit
MS	Misra and Sudarshan
NEO	null evolution operator
ONB	orthonormal basis
POVM	positive operator-valued measure
PVM	projection-valued measure
QDN	quantized detector network
QED	quantum electrodynamics
QFT	quantum field theory
QM	quantum mechanics
REC	relative external context
RIC	relative internal context
RQFT	relativistic quantum field theory
SBR	signal basis representation
SG	Stern–Gerlach
SR	special relativity
SUO	system under observation
ToE	Theory of Everything