

Contents

Acknowledgments — VII

Illustrations — XV

Abbreviations — XVII

Introduction — 1

I The Bohmian System

1 Bohmian Mechanics: The Fundamentals — 9

- 1.1 The Particles — 9
- 1.2 The Wave-function — 11
- 1.3 The Wave-function and the Particles — 12
- 1.4 The Dynamics — 13
 - 1.4.1 The Schrödinger Equation — 13
 - 1.4.2 The Guiding Equation — 15
- 1.5 Non-locality — 17
- 1.6 Non-locality, Non-separability or Universality, and Entanglement — 19
- 1.7 Subsystems — 20
- 1.8 Determinism — 23
- 1.9 Probabilities — 24
- 1.10 The Rutgers-Munich-Genova Group: Quantum Equilibrium, Equivariance and Absolute Uncertainty — 25
- 1.11 Valentini's Quantum Non-equilibrium — 29
- 1.12 Summing up: The Bohmian Postulates — 30
- 1.13 The Questions We Shall Ask — 30

II The Status of the Particles

2 Bohmian Particles and Bohmian Properties — 35

- 2.1 Particles — 35
- 2.2 The Dependence of Bohmian Properties on Positions — 41
- 2.3 Contextual Properties, Particles and the Wave-function — 46
- 2.4 Mass and Charge — 48
- 2.5 The Principle of Generosity — 49

2.6	The Principle of Parsimony —	50
2.7	A Case of Underdetermination —	52
2.8	The Primitive Ontology Approach and Bohmian Mechanics —	53
2.9	The Super-Humeanism Approach by the Lausanne School —	57
2.10	Many Particles or Just One Particle? The Marvelous and the Miserable Particle View —	59

III The Status of the Wave-function

3	A Realist Interpretation for the Wave-function —	63
3.1	Wave-function Realism —	63
3.2	The Centrality of the Quantum Wave-function —	63
3.2.1	The Hamiltonian-Jacobi Equation and the Guiding Law —	64
3.2.2	The Bohmian Dynamics. From Newtonian to Bohmian Mechanics —	67
3.3	A Metaphysical Analysis of the Wave-function Realist Ontological Picture —	70
3.3.1	Field Theory —	71
3.3.2	Causality and Properties —	72
3.4	The Problems with the Resulting Ontology —	74
3.4.1	A Strange Field Theory —	74
3.4.2	Problems: The Violations of the Criteria for Physicality —	81
3.4.3	Problems with Causality —	86
3.4.4	Valentini's Responses —	88
3.5	Summary: The Realist View Is Bad for Ontological Results —	93
3.6	The Methodology of the Realist View —	94
3.6.1	The Wave-function as a <i>physical field</i> in Configuration Space: A Problem of Reification —	94
3.6.2	A First Reply from the Realist —	97
3.6.3	High-dimensional Space? —	99
3.6.4	The First Principle —	100
3.6.5	The Second Principle —	107
3.7	The Multi-field View —	112
4	A Nomological Interpretation for the Wave-function —	114
4.1	The Guiding Equation —	114
4.1.1	Simplicity and Symmetries —	114
4.1.2	Probability Current —	118
4.1.3	The De Broglie Equation —	119

4.2	The Resulting Ontology —	122
4.2.1	The Wave-function as a Law —	122
4.2.2	The Defense —	125
4.2.3	The Wave-function as a Part of the Law —	127
4.3	How to Understand Nomological Entities, and Thus the Wave-function: Different Metaphysical Scenarios —	129
4.3.1	The Realist View on Nomological Entities: Primitivism —	130
4.3.2	Problems —	133
4.3.3	Anti-realism and the Humean View: No Gap, No Explanation —	134
4.3.4	The Supervenience Problem —	137
4.3.5	The Non-locality Problem —	138
4.3.6	Simplicity and Informativeness —	139
4.3.7	The Unsatisfactory Humean View —	141
4.4	The Dispositional Interpretation —	142
4.4.1	The Dispositional Property of Motion —	147
4.4.2	The Mumford Dilemma —	147
4.5	Esfeld's Super-Humeanism —	149
4.6	General Problems of the Nomological View —	150
4.6.1	The Problem of Underdetermination —	150
4.6.2	The Physicality of the Wave-function: The Wave-function Can Kill! —	150
4.7	The Methodology —	153

IV The Structuralist View

5	Ontic Structural Realism: The State of the Art —	161
5.1	Introduction —	161
5.2	The State of the Art —	163
5.2.1	Structural Realism —	163
5.2.2	Ontic Structural Realism —	166
5.3	Ontic Structural Realism: The Methodological Program —	170
5.3.1	Ontic Structural Realism: An Anti-armchair-metaphysics Program —	171
5.3.2	Summing up: The 'Danglers' —	176
5.3.3	An Example: The Aether —	177

6 Bohmian Mechanics and Ontic Structural Realism — 178

- 6.1 The Problem of Underdetermination Given by the Wave-function — **178**
- 6.2 Is the Wave-function a Dangler? — **179**
- 6.3 The Problem of Invariance and Objectivity: What the Wave-function Represents Cannot Be in 3ND — **180**
- 6.4 What the Laws Reveal — **183**
- 6.5 Modality — **186**
- 6.6 Particles, Properties and Structure — **190**
- 6.7 The Individuality of Particles — **193**
- 6.8 The Bohmian Ontology and Moderate Ontic Structural Realism — **194**
- 6.9 Particle Positions: Extrinsic or Intrinsic Properties? — **197**
- 6.10 Position as Extrinsic and a Relational Space — **198**
- 6.10.1 A Speculative Relational Bohmian Mechanics — **198**
- 6.11 Position as Intrinsic and a Substantival Space — **201**
- 6.12 Position as Extrinsic and a Substantival Space — **203**
- 6.13 Example: Singlet and Triplet States — **205**

7 Conclusive Remarks — 207

- 7.1 The Best of Both Worlds: A Structuralist Ontology for Bohmian Mechanics — **207**
- 7.1.1 The Status of the Wave-function — **207**
- 7.1.2 Balance between Parsimony and Explanatory Power — **208**
- 7.1.3 Underdetermination — **208**
- 7.1.4 Compatibility with Different Mathematical Formulations — **209**
- 7.1.5 Experiments – Empty Trajectories — **209**
- 7.2 A Structuralist Reconciliation of the Realist and Nomological Views in Bohmian Mechanics — **210**
- 7.2.1 The Status of the Wave-function — **210**
- 7.2.2 The Determination of the Dynamics — **211**
- 7.3 A Final Defense of the Structuralist Reading of the Wave-function — **212**
- 7.4 Open Questions for Future Research — **214**
- 7.4.1 A Possible Threat: Circularity and Non-supervenience — **214**
- 7.4.2 A Possible Threat: The Wave-function as a Background Structure – A Case of Underdetermination? — **217**
- 7.4.3 A Possible Threat: The Single Particle Case — **219**
- 7.4.4 A Possible Threat: Is Bohmian Mechanics with Property-less Particles Possible? — **220**

7.5	Possible Objections —	225
7.5.1	The Unobservability and Underdetermination of the Dynamical Structure —	225
7.5.2	It Is Not a Structuralist ‘Reconciliation’, Rather It Is a Structuralist ‘Rejection’ —	226

Conclusion —	228
---------------------	------------

Bibliography —	231
-----------------------	------------

Index —	241
----------------	------------