Quantum Physics and the Nature of Reality: An Introduction to the Book*

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This book grew out of the Satellite Symposium "Quantum Physics and the Nature of Reality" organised by the International Quantum Structures Association (IQSA) during the conference "Einstein Meets Magritte: an Interdisciplinary Reflection on Science, Nature, Human Action, and Society" which was organised in Brussels at the Vrije Universiteit Brussel from May, 29 to June 3, 1995. The purpose of the Symposium (and of the present book) was to acquaint the possibly widest audience consisting of people interested in foundations of quantum physics but not necessarily physically or even mathematically experienced with the variety of subjects considered within the IQSA, aims, problems, and methods used to solve them.

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International Quantum Structures Association was established in 1991 and it groups researchers interested in studying various aspects of logico-algebraic structures encountered in the very foundations of quantum physics. *Quantum structures* (formerly called *quantum logics*) are situated on the Map of Science in the place where quantum physics (esp. the foundations of quantum mechanics), mathematics (esp. mathematical logic, abstract algebra, theory of ordered structures, measure theory, probability theory, and fuzzy set theory), logic (esp. many-valued, modal, intuitionistic, and paraconsistent), and philosophy (esp. philosophy of science) meet. Therefore, activities of the members of the IQSA are really interdisciplinary, which was one of the reasons for including the IQSA Satellite Symposium within the scope of the Interdisciplinary Conference "Einstein meets Magritte".

Although the present book consists of papers written independently by various authors which unavoidably leads to some repetitions, we tried to organise it in such a way that it could serve as a possibly self- contained introduction to the theory of quantum structures oriented towards an inexperienced reader. Therefore, the book begins with the review paper by **D. Foulis** (University of Massachusetts, Amherst, USA) *A Half-Century of Quantum Logics - What Have We Learned* which in its first part contains a brief exposition of the historical development of quantum structures from their prehistory traced back to Leibniz and Boole till the most recent papers concerning effect algebras, with the exclusion, however, of the "parallel stream" within the theory of quantum structures connected with many-valued logics and fuzzy sets[1]. In the main part of his paper Foulis illustrates practically all fundamental notions encountered within the theory of quantum structures, and relations between them on the very elementary example of a firefly in the box with windows using only the simplest mathematical tools, i.e., sets and functions.

Almost an equally elementary example is used in the next paper *Quantum Mechanical Measurements* by **S. Gudder** (University of Denver, USA) to illustrate the notion of an effect algebra. Studying effect algebras became nowadays popular within the IQSA since these structures are more general, therefore, also more "flexible" than traditional "quantum logics", i.e., orthomodular partially ordered sets or lattices. Their introduction allowed a lot of

[1]The brief history of this "stream" is contained in the paper by Pykacz

"fresh air" to come into the theory of quantum structures[2], which, after the period of a rapid development in the sixties and the seventies, in the eighties was seen by many as a "decaying" theory without much future.

The paper *From Logic to Physics: The Logico-Algebraic Foundations of Quantum Theory* by **G. Cattaneo** and **F. Laudisa** (Università di Milano and Università di Firenze, Italy) also contains a brief description of the historical development of quantum logic ideas. In particular, the reader will find here more detailed outline of the seminal Birkhoff and von Neumann's paper *The Logic of Quantum Mechanics* generally regarded as a cornerstone of this branch of Science. Cattaneo and Laudisa paper is finished with the notion of an effect (already encountered in the paper by S. Gudder) introduced, however, with the aid of Zadeh's idea of a fuzzy set, i.e. a set that admits gradual rather than abrupt transition from membership to non- membership.

Fuzzy set theory is as closely related to Łukasiewicz infinite-valued logic as traditional set theory is related to the classical, two-valued logic. These relations are exposed in the paper *Non-Classical Logics, Non-Classical Sets, and Non-Classical Physics* by **J. Pykacz** (Uniwersytet Gdański, Gdańsk, Poland) in which it is also shown how these two "non-classical" branches of mathematics can be utilised in the "non-classical" branch of physics, i.e., in quantum mechanics. Also this paper contains a brief survey of the historical development of all "non-classical" theories that it deals with.

The paper by **C. Garola** (Università di Lecce, Italy) *Against "Paradoxes": A New Quantum Philosophy for Quantum Mechanics*, shows that changing of the basic philosophical premises (in this case abandoning the *verificationist theory of truth* in favour of the *classical (Tarskian) theory of truth* and introducing a new conception of physical laws) implies changes in the interpretation of quantum theory and provides new solutions to some old "paradoxes" encountered in the very foundations of quantum physics.

The paper by **D. Aerts** (University of Brussels, Belgium) *Quantum mechanics: Structures, Axioms and Paradoxes*, gives an overview of some of the results in quantum structures research that have been obtained in the Brussels group. Working within a realistic approach to quantum mechanics - following the inspiration that was outlined in the Geneva approach - the Brussels group tries to elaborate a generalised quantum mechanics, were

[2] and also was one of the reasons of changing the name of this branch of Science from "theory of quantum logics" to the more general "theory of quantum structures"

some of the basic axioms of standard quantum mechanics are abandoned (e.g. the superposition principle). The reason of this generalisation is the impossibility of standard quantum mechanics to describe the situation of two separated quantum entities, a shortcoming that is directly linked to the Einstein Podolsky Rosen paradox. Aerts shows the different steps of this generalised axiomatic quantum mechanics and the related problems that are trying to be solved by means of a simple macroscopic model entailing a quantum mechanical structure. Together with this alternative quantum mechanics an explanation for the probabilities of quantum mechanics, finding their origin in a lack of knowledge about the interaction between the measuring apparatus and the system, is exposed by means of the simple example.

The paper *Orthogonality Relations and the ϵ-Model* by **T. Durt** (Vrije Universiteit Brussel, Belgium) is also written in the spirit of the Brussels approach and devoted to various orthogonality relations that are quantum-logical generalisations of the classical negation. These relations are studied within the ϵ-model of quantum spin-measurements developed recently in Brussels, where a continuous transition from quantum to classical mechanics can be modelled. Also this description needs the more general framework developed in Brussels and presented in the paper of Aerts, where some of the standard quantum mechanical axioms are not fulfilled.

The final paper of the book *Quantum Logical Semantics, Historical Truths, and Interpretations in Arts* by **M. L. Dalla Chiara** and **R. Giuntini** (Università di Firenze, Italy) shows that notions and constructions typical to the theory of quantum structures, and non- classical logics implied by them can find application even in such remote fields as History and Art. This shows that the methods elaborated within the theory of quantum structures do not apply exclusively to microworld and quantum physics and justifies once more the idea of including the IQSA Symposium within the very broad scope of the Interdisciplinary Conference “Einstein Meets Magritte”.

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