Foundations of Physics, Vol. 30, No. 9, 2000

Editors' Preface: Interdisciplinary Studies of Quantum Structures

Two special issues of *Foundations of Physics* are devoted to Maria Luisa (Marisa) Dalla Chiara, in celebration of her 60th birthday. The authors of the contributions are pupils, colleagues, and friends of Marisa from different fields and institutions.

A simple look at the affiliations of the contributors and at the titles of their papers reveals one of Marisa's main merits: interdisciplinarity. Bridging the gap between physics (*in primis* quantum mechanics) on the one hand and philosophy, logic and mathematics on the other, has been the leading idea of Marisa's scientific work for thirty years.

Today, it is evident that the investigations into the conceptual and logical foundations of quantum mechanics are not only important in their own right, but also interact significantly with "militant" physics research. Quantum computation is no exception.

Marisa can be considered one of the leading figures in the quantum-logical renaissance, which began in the sixties with the "Geneva school" and then blossomed in the seventies and eighties.

Her seminal work on quantum logic (epitomized in the paper "Quantum logic," D. Gabbay, Guenthner, *Handbook of Philosophical Logic*, Kluwer Academic, Dordrecht, 1986) and on the conceptual puzzles of quantum mechanics show clearly how physics, logic and mathematics are intertwined.

In an academic world where labels and formal distinctions based on a rigid separation between humanistic and scientific studies seem sometimes to prevail over real scientific content, Marisa's work has been, and continues to be, a notable exception. It will be a source of inspiration for generations of students and researchers.

The present, first issue contains physics papers that are contributions on the foundations of quantum mechanics.

In a paper titled "Local measurements of nonlocal observables and the relativistic reduction process," GianCarlo Ghirardi reconsiders the constraints that are imposed by relativistic requirements to any model of dynamical reduction. He presents a new formulation of the proposal put

0015-9018/00/0900-1331$18.00/0

forward by Aharonov and Albert to perform measurements of nonlocal observables by means of local interactions and detections. He shows that recently proposed relativistic models of dynamical reduction represent a perfectly appropriate conceptual framework which meets all necessary requirements for a relativistic account of wave packet reduction. In an article titled "The violation of Bell inequalities in the macroworld," Diederik Aerts, Sven Aerts, Jan Broekaert and Liane Gabora investigate how Bell and Clauser Horne inequalities are violated in the macroworld. They show that if nonidentical events are consistently differentiated, Bell inequalities are no longer violated, even for Bohm's example of two entangled spin 1/2 quantum particles. They also show how Bell inequalities can be violated in cognition, specifically in the relationship between abstract concepts and specific instances of these concepts. They demonstrate, using a model, that increasing nonlocality increases the degree of violation, while increasing quantum uncertainty decreases the degree of violation. In a paper titled "Remarks on two-slit probabilities," Enrico Beltrametti and Slavomar Bugajski study how two-slit probabilities behave under extensions of quantum theory preserving some classical structure. They consider a generalization of the standard classical probability theory, called operational probability theory, that turns out to host the so called quantum probabilities. In an article titled "Delocalized properties of the modal interpretation of a continuous model of decoherence," Guido Baccialuppi investigates the character of the definite properties defined by the Basic Rule in Vermaas and Dieks' version of the modal interpretation of quantum mechanics. He shows in an exact soluble case that that definite properties that are possessed with overwhelming probability in this modal interpretation are delocalized over the entire spread of the state. Guilio Peruzzi and Alberto Rimini have contributed an article titled "Compoundations invariance and Bohmian mechanics." They study the property called compoundation invariance which allows us to treat compound objects as particles under suitable conditions in the framework of Bohmian mechanics. They show that standard Bohmian mechanics satisfies the requirement of compoundation invariance, with some reservation in the case of compound objects with spin, but find that this requirement is violated when additional terms are added to the standard velocity. In a paper by Diederik Aerts, Ellie D'Hondt and Liane Gabora, titled "Why the logical disjunction in quantum logic is not classical," the quantum logical disjunction is studied from a physical perspective. It is shown that it is the presence of EPR-like correlations that makes it deviate from the classical logical disjunction. They investigate how this insight could apply to the study of concepts in the mind in cognitive science. In the article "A model with quantum logic, but non-quantum probability: the product test issue," by Jan Broekaert

and Bart D'Hooghe, an example is presented of a physical entity that has a quantum logic structure isomorphic to the one of the spin of a spin 1/2 quantum entity, but where the probability model is not quantum. The problem of the quantum logical conjunction is investigated by means of this example. In the paper "Lukasiewicz operations in fuzzy set and many-valued representations of quantum logic," Jaroslaw Pykacz studies a fuzzy set and a many-valued Lukasiewicz logic representation of the Birkhoff–von Neumann quantum logic. He investigates the Lukasiewicz logical operations within the representation. Federico Laudisa's contribution "On time asymmetry and history in an Everett quantum world" investigates the question of whether and how it should be possible to uniquely reconstruct one's own history in an Everett no-collapse interpretation of quantum theory. He considers a particular approach to the Everett interpretation, proposed by John Bell, according to which one of the chief claims of the Everett quantum theory is precisely that it allows us to do without the notion of history. The article by Claudio Garola, "Objectivity versus nonobjectivity in quantum mechanics" shows that the choice for nonobjectivity is epistemic rather than ontologic, such that an objective interpretation of quantum mechanics is not impossible *a priori.* Garola elaborates such an objective interpretation based on a classical language in which the language of the standard interpretation is embedded as a subset of statements that are directly testable according to quantum mechanics.

The forthcoming, second issue concentrates on the philosophical and mathematical contributions. The philosophical papers are on the philosophy of physics while the mathematical contributions contain elaborations on mathematical structures the are important for quantum mechanics.

Patrick Suppes analyzes in his paper "Invariance, symmetry and meaning" the role of the concept of invariance in physics and geometry. He examines the question of why the fundamental equations of physical theories are not invariant, but only covariant, and focuses on the example of entropy as a complete invariant in ergodic theory. Elena Castellani and Peter Mittelstaedt analyze Leibniz's principle of the identity of indiscernables in classical and in quantum physics in their contribution titled "Leibniz's principle, physics, and the language of physics." Their approach to the problem justifies the principle in the domain of classical physics, but not in the domain of quantum physics. The contribution by Mauro Dorato, "Substantivalism, relationism, and structural spacetime realism," proposes an original ontology for relativity theory, called spacetime realism, as a third option to commonly held substantivalism and relationism. Giovanni Boniolo and Fernando de Felice investigate what a measurement is in general relativity theory. In their contribution "On the philosophical foundations of measurements in general relativity" they suggest that foundational

problems related to measurement can be avoided by relying on gauge invariance and the principle of equivalence. Michel Ghins' article, titled "Empirical *versus* theoretical existence and truth," reflects on the criteria for acceptance of the existence and truth at the empirical level, and their possible extension to the scientific theoretical level. The paper by Bas van Fraassen, "Michel Ghins on the empirical versus the theoretical," is a comment on the article of Ghins that analyzes how the empiricist tradition admits of a great variety of views and of diverse links with other traditions, and also points out the difference between his own empirist view and Ghins'.

In a contribution "What is fuzzy probability theory," Stanley Gudder introduces the basics of a fuzzy probability theory, and explains how it is built step by step. He also considers some applications of fuzzy probability theory to quantum mechanics and computer science. Beloslaw Riecan investigates the construction of the sum of observables and the conditional probability in his paper "On the joint distribution of observables." He proceeds in this analysis by introducing a general algebraic system with two binary operations, a state is a morphism from this system to the unit interval, while an observable is a morphism from the family of Borel sets to this system. In a paper titled "MV and Heyting Effect Alebras," David Foulis investigates different relations between effect algebras, MV-algebras, HMV-algebras and Heyting algebras. These are all structures that are important for the axiomatic foundations of quantum mechanics. Chris Isham and Jeremy Butterfield contribute a paper with the title "Some possible roles for topos theory in quantum theory and quantum gravity," which discusses how topos theory (a branch of category theory) can be applied to interpretative problems in quantum theory and quantum gravity. George Chevalier, Anatolij Dvurecenskij and Karl Svozil' contribution, "Piron's and Bell's geometric lemmas and Gleason's theorem," presents results concerning measures on finite as well as infinite-dimensional Hilbert spaces, including measures with infinite values. They derive parabola-based proofs of the weak Piron's geometrical and Bell's lemmas, that do not use Gleason's theorem. In a paper titled "A theorem of Ludwig revisited," Gianni Cassinelli, Ernesto De Vito, Pekka Lahti and Alberto Levrero reconsider a theorem by Ludwig which allows one to identify a class of effect automorphisms as the symmetry transformations in quantum mechanics. Gianpiero Cattaneo, Roberto Giuntini and Sylvia Pulmannova, in their article "Pre-BZ and degenerate BZ posets: applications to fuzzy sets and unsharp quantum theories" introduce two different generalizations of Brouwer–Zadeh posets (BZ posets) and study the standard Brouwer negation in these generalizations. In the next paper by Gianpiero Cattaneo, Jan Hamhalter and Pavel Pták, named "On the De Morgan property of

the standard Brouwer–Zadeh poset," the De Morgan property for the two natural orthocomplementations on the standard Brouwer–Zadeh poset is investigated. It is shown that this property is satisfied for the case of finite dimensional Hilbert space, and is not satisfied for the infinite dimensional case. In J. Neggers, Anatolij Dvurecenskij and Hee Sik Kim's article, titled "On *d*-fuzzy functions in *d*-algebras," is introduced the concept of *d*-fuzzy function. It generalizes the concept of fuzzy subalgebra to a much larger class of functions in a natural way. They then discuss a method of fuzzification of a wide class of algebraic systems onto $[0, 1]$.

We thank all the contributors to the special issue in honor of Marisa Dalla Chiara. By means of their contributions that range from philosophy, over physics to mathematics, they demonstrate the interdisciplinary nature of Marisa's scientific activities.

Diederik Aerts, Gianpiero Cattaneo,
Anatolij Dvurecenski, and Roberto Giuntini