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Quantum Relational Realism: Mereotopology, Logical Implication, and Internal Relation in Quantum Mechanics as Represented via Sheaf-theoretic Boolean Covering Systems

Workshop
Swiss Federal Institute of Technology (ETH)
Chair for Philosophy (building RAC)
Raemistrasse 36, 8001 Zurich
Switzerland
&
Bernex, France

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I. Aims and Motivation

In the framework of quantum theory, events are identified as measurement outcomes referent to corresponding observables. The theory then provides the means of correlating these events. In this respect, the conceptual complexity of any ontological interpretation of quantum theory stems from two factors: [1] The existence of an event referring to a quantum system can be inferred only probabilistically, and only relative to a particular measurement context of a selected observable—a local context whereby the universe, represented by a global state vector, is decomposed into "system," "measuring apparatus," and "environment" with their respective state vectors. The actualization of probability-valuated, potential quantum events can be affirmed only after a measured result has been registered by the corresponding measuring apparatus. [2] The *totality* of events related to the behavior of a quantum system cannot be actualized within the same local measurement context due to the property of non-commutativity of quantum observables. These two factors together necessitate a thorough rethinking of our conceptual and mathematical representation of the notion of a physical continuum suited to the quantum domain of discourse. To this end, we propose a mereotopological, category theoretic interpretation of quantum mechanics that captures the relationship between a global description in terms of non-commutative algebras of quantum observables, and a description in terms of local Boolean algebras associated with particular measurement contexts. In this relational realist framework, which integrates key aspects of Whiteheadian philosophy and Grothendieck topology, the measuring apparatus and environment are thus understood not as external agents that causally affect a measured system, but rather as constitutive of an internal-relational mereotopological localizing scheme at the macroscopic level with respect to a global algebra of quantum observables.

II. Meeting Overview

This is one of a series of focused workshops exploring the phenomenon of logical causality in quantum mechanics and the relevance of this phenomenon to the philosophy of nature more broadly.

Michael Epperson
Research Professor - Department of Philosophy and
College of Natural Sciences and Mathematics
California State University Sacramento
Director and Principal Investigator
Center for Philosophy and the Natural Sciences
California State University Sacramento

Michael Epperson did his doctoral work in philosophy of science and philosophy of religion at The University of Chicago, and earned his Ph.D. there in 2003. His dissertation, Quantum Mechanics and the Philosophy of Alfred North Whitehead, was written under the direction of philosopher David Tracy and physicist Peter Hodgson, Head of the Nuclear Physics Theoretical Group at the University of Oxford. It was published the following year by Fordham University Press. His current research explores the philosophical implications of recent innovations in quantum mechanics, cosmology, and complexity theory. This exploration is ultimately a speculative metaphysical enterprise intended to contribute to the framework of a suitable bridge by which scientific, philosophical, and even theological concepts might not only be cross-joined, but mutually supported. His forthcoming book, co-edited with David Ray Griffin and Timothy E. Eastman, is entitled, Physics and Speculative Philosophy: The Rehabilitation of Metaphysics in 21st Century Science.

Elias Zafiris
Senior Research Fellow in Theoretical and Mathematical Physics
Institute of Mathematics
National University of Athens, Greece

Elias Zafris holds an M.Sc. (Distinction) in Quantum Fields and Fundamental Forces from Imperial College, University of London, and a Ph.D. in theoretical physics from Imperial College. He has published research papers on the following areas: Generalized spacetime quantum theory and the decoherent histories approach to quantum theory, symmetries and exact solutions in general relativity, covariant kinematics of relativistic strings and branes, foundations of quantum physics, quantum event and quantum observable structures, category-theoretic methods in quantum physics and complex systems theories, topological localization and modern differential geometry in quantum field theory and quantum gravity. His current research focus is on the development of a functorial sheaf-theoretic approach to quantum mechanics, quantum logic and quantum gravity using concepts and techniques of mathematical category theory and algebraic differential geometry, as well as on the study of its conceptual and interpretational implications.

Roland Omnès
Professor, Theoretical Physics
University of Paris XI
CNRS – French National Center for Scientific Research

Roland Omnès is currently Professor Emeritus of Theoretical Physics in the Faculté des sciences at Orsay, at the Université Paris-Sud XI. He has been instrumental in developing the consistent histories

and quantum decoherence approaches in quantum mechanics. His books include *The Interpretation of Quantum Mechanics* (Princeton University Press, 1994), *Understanding Quantum Mechanics* (Princeton University Press, 1999), *Quantum Philosophy: Understanding and Interpreting Contemporary Science* (English Edition - Princeton University Press, 1999), and *Converging Realities: Toward a Common Philosophy of Physics and Mathematics* (Princeton University Press, 2004).

Timothy E. Eastman
Group Manager for Space Science Support
Heliospheric Physics Laboratory - NASA Goddard Space Flight Center

Dr. Timothy E. Eastman of Plasmas International is a consultant and concurrently Perot Systems Group Manager for science support at NASA's Goddard Space Flight Center. He has more than 30 years of experience in research and consulting in space physics, space science data systems, space weather, plasma applications, public outreach and education, and philosophy. He has provided key leadership of the nation's research programs in space plasma physics while program manager at NASA Headquarters (1985-1988) and NSF (1991-1994). Dr. Eastman discovered the Low-Latitude Boundary Layer (LLBL) of the Earth's magnetosphere (1976), and discovered gyro-phase bunched ions in space plasmas by analyzing energetic ion distribution functions near Earth's bow shock (1981). He has published 100 research papers in space physics and related fields. He has conceived and edited two special issues on "Process Thought and Natural Science" published in the journal *Process Studies* (1997/1998) and co-convened the first major workshop on Physics and Whitehead at Claremont University in 1998.

Karim Bschir
Senior Research Fellow
Chair for Philosophy
Swiss Federal Institute of Technology, Zurich

Karim Bschir studied biochemistry and philosophy at the University of Zurich. In 2003 he received his MSci in biochemistry. In the following year, he continued his studies in philosophy. During that time, Karim was also working as a high school teacher in philosophy and as a guide and referee at the Swiss National Museum in an exhibition on recent developments in the Life Sciences. In November 2004, he started his PhD studies in philosophy at the University of Zurich (funded by the Forschungskredit of the University of Zurich). Since January 2007, he is a research assistant at the Chair for Philosophy at ETH Zurich. He is an affiliated researcher at the Collegium Helveticum and a research fellow at the the Center for Philosophy and the Natural Sciences (CPNS) at California State University Sacramento. From October 2009 to April 2010, Karim is visiting the Centre for Philosophy of Natural and Social Science (CPNSS) at the London School of Economics (funded by the Swiss National Science Foundation).

V. Selected Literature

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