THE FETZER-FRANKLIN FUND

CENTER FOR PHILOSOPHY AND THE NATURAL SCIENCES
CALIFORNIA STATE UNIVERSITY SACRAMENTO

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Quantum Logical Causality, Category Theory, and the Metaphysics of Alfred North Whitehead

Connecting Zafiris' Category Theoretic Models of Quantum Spacetime and the Logical-Causal Formalism of Quantum Relational Realism

Workshop Venue:
Swiss Federal Institute of Technology (ETH)
Chair for Philosophy (building RAC)
Raemistrasse 36, 8001 Zurich
Switzerland
January 29 – 30, 2010

I. Aims and Motivation

Recent work in the natural sciences—most notably in the areas of theoretical physics and evolutionary biology—has demonstrated that the lines separating philosophy and science have all but vanished with respect to current explorations of 'fundamental' questions (e.g., string theory, multiverse cosmologies, complexity-emergence theories, the nature of mind, etc.). The centuries-old breakdown of 'natural philosophy' into the divorced partners 'philosophy' and 'science,' therefore, must be rigorously re-examined. To that end, much of today's most groundbreaking scholarship in the natural sciences has begun to include explicit appeals to interdisciplinary collaboration among the fields of applied natural sciences, mathematics and philosophy. This workshop will be dedicated to the question of how a philosophical-metaphysical theory can be fruitfully applied to basic conceptualizations in the natural sciences.

More narrowly, we will explore the process oriented metaphysical scheme developed by philosopher and mathematician Alfred North Whitehead (1861-1947) and Michael Epperson's application of this scheme to recent work in quantum mechanics, and the relation of these to Elias Zafiris's category theoretic model of quantum event structures. Our aim is to give participants from various fields of expertise (see list below) the opportunity to exchange their specialized knowledge in the context of a collaborative exploration of the fundamental questions raised by recent scholarship in physics and mathematics.

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. In this meeting, we will investigate the ways in which the work of Elias Zafiris on category theoretic models of spacetime quantum event structures might find a robust philosophical and physical foundation in the Relational Realist approach to quantum logical causality—a modern rehabilitation of the process event-ontology of Whitehead. Among the topics to be explored will be the relationship between a) Zafiris's category theoretic / topos model and b) the decoherent histories interpretation of quantum mechanics in the context of the Whiteheadian mereotopological model of spatiotemporal extension.

The macro-scale (spatiotemporal, cosmological) implications of these explorations of decoherence at the micro-scale will be examined by way of a Whiteheadian/Relational Realist interpretation of the decoherent histories QM formalism (cf. Epperson, 2004). The decoherent histories formalism allows for a spacetime formulation of quantum theory that is highly compatible with the mereotopological model of spatiotemporal extension proposed by Alfred North Whitehead. This is crucial because the mathematical rigidity of the Hilbert space (as a topological vector space) does not allow a relativization analogous with the one of classical relativity theory on smooth manifolds. By contrast, a mereotopological/category-theoretic reformulation of quantum logic in terms of Boolean localization systems (Zafiris's conception of 'Booelan sheaves') achieves precisely such an objective by generalizing the smooth manifold construction in generic algebraic/categorical terms.

This makes it possible to formulate a framework of local/global or part/whole relations without the intervention of a spacetime classically conceived. On the contrary, the usual spacetime manifold and its metrical relations (imposing extra conditions like the light-cone causality relations) appear as emergent at a higher level than the more fundamental level of logical and algebraic part-whole relations. Epperson's distinction between a) mereological/topological/logical relations, and b) physical/metrical/causal relations, is reflected precisely in Zafiris' distinction between these two different levels (the algebraic part-whole relations and the metrical spacetime relations, respectively), where the latter is just an emergent/metrical specialization of the former. The key issue to be explored is the problem of localization and the problem of passing from the local to the global in an extensive continuum.

III. Speakers

***Elias Zafiris**, Senior Research Fellow in Theoretical and Mathematical Physics, Institute of Mathematics, 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 as well. 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.

***Michael Epperson**, 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*.

Epperson is the founder and director of the Center for Philosophy and the Natural Sciences at California State University, Sacramento, and Principal Investigator of his current research project, “Logical Causality in Quantum Mechanics: Relational Realism and the Evolution of Ontology to Praxiology in the Philosophy of Nature.”

***Karim Bschir**, Chair of Philosophy, Swiss Federal Institute of Technology, Zurich*

Karim Bschir studied biochemistry and philosophy at the University of Zurich. In 2003 he received a M.Sci. in biochemistry with a thesis on protein chemistry (thesis title: "*In vitro* Arginine Methylation of Recombinant Ewing Sarcoma (EWS) Protein". See: *Proteins* 61 (1): 164-175, 2005.) In 2003 and 2004 he continued his studies in philosophy. During that time, he was also working as a high school teacher for philosophy and as a subject specialist in an exhibition of the Swiss National Museum in Zurich about recent developments in the Life Sciences. In November 2004, he commenced a Ph.D. project in philosophy at the University of Zurich. Since January 2007, he is continuing his Ph.D. studies at ETH Zurich. His philosophical work focuses on scientific realism and the question whether and how empirical sciences relate to reality. Karim Bschir has strong interests in general philosophy and history of science, epistemology and metaphysics, as well as in the philosophy of biology.

***Kelly John Rose**, Institute for Biocomplexity and Informatics, University of Calgary*

Kelly John Rose received his M.Sci. in Applied Mathematics from the Department of Mathematics and Statistics at the University of Calgary in 2009. He is affiliated with the Institute for Biocomplexity and Informatics as well as the Haskayne School of Business in Calgary. Currently, he resides in Toronto and is a senior partner in a software development consulting firm and works regularly with the complex systems group at the Perimeter Institute. His previous experience includes: Working as a research assistant and software developer at the Institute for Quantum Computing at the University of Waterloo, and performing cryptographic research for the Canadian government. At this time, Rose's interests focus on the relations between information theoretic measures and the input-output matrices in economical and ecological systems, and developing new mathematical tools for understanding such complex systems.

IV. Time Schedule

The workshop will span 2 days. Each talk will be followed by at least 45 min of plenary discussion. Half of the afternoon of the first day shall be reserved for an exchange among the speakers.

V. Selected Literature

Epperson, M. 2004. *Quantum mechanics and the philosophy of Alfred North Whitehead*. New York: Fordham University Press.

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Whitehead, A. N. 1978. *Process and Reality. An Essay in Cosmology*. New York: Free Press.

Zafris, E. and J. J. Halliwell, `*Decoherent Histories Approach to the Arrival Time Problem'* Phys. Rev. D57 3351 (1998), quant-ph/9706045.

Zafiris, E. ‘*Incorporation of Spacetime Symmetries in Einstein's Field Equations'*, J. Math. Phys. 38 (11), 5854, (1997), gr-qc/9710103.

_____`*On Quantum Event Structures. Part I: The Categorical Scheme'*, Foundations of Physics Letters 14(2), (2001).

_____`*On Quantum Event Structures. Part II: Interpretational Aspects'*, Foundations of Physics Letters 14(2), (2001).

_____`*Probing Quantum Structure Through Boolean Localization Systems'*, International Journal of Theoretical Physics 39, (12) (2000).

_____`*Boolean Coverings of Quantum Observable Structure: A Setting for an Abstract Differential Geometric Mechanism '*, Journal of Geometry and Physics 50, 99 (2004), math-ph/0306045.

_____`*On Quantum Event Structures. Part III: Object of Truth Values '*, Foundations of Physics Letters 17(5), (2004).

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_____`*Interpreting Observables in a Quantum World from the Categorial Standpoint '*, International Journal of Theoretical Physics 43, (1) (2004).

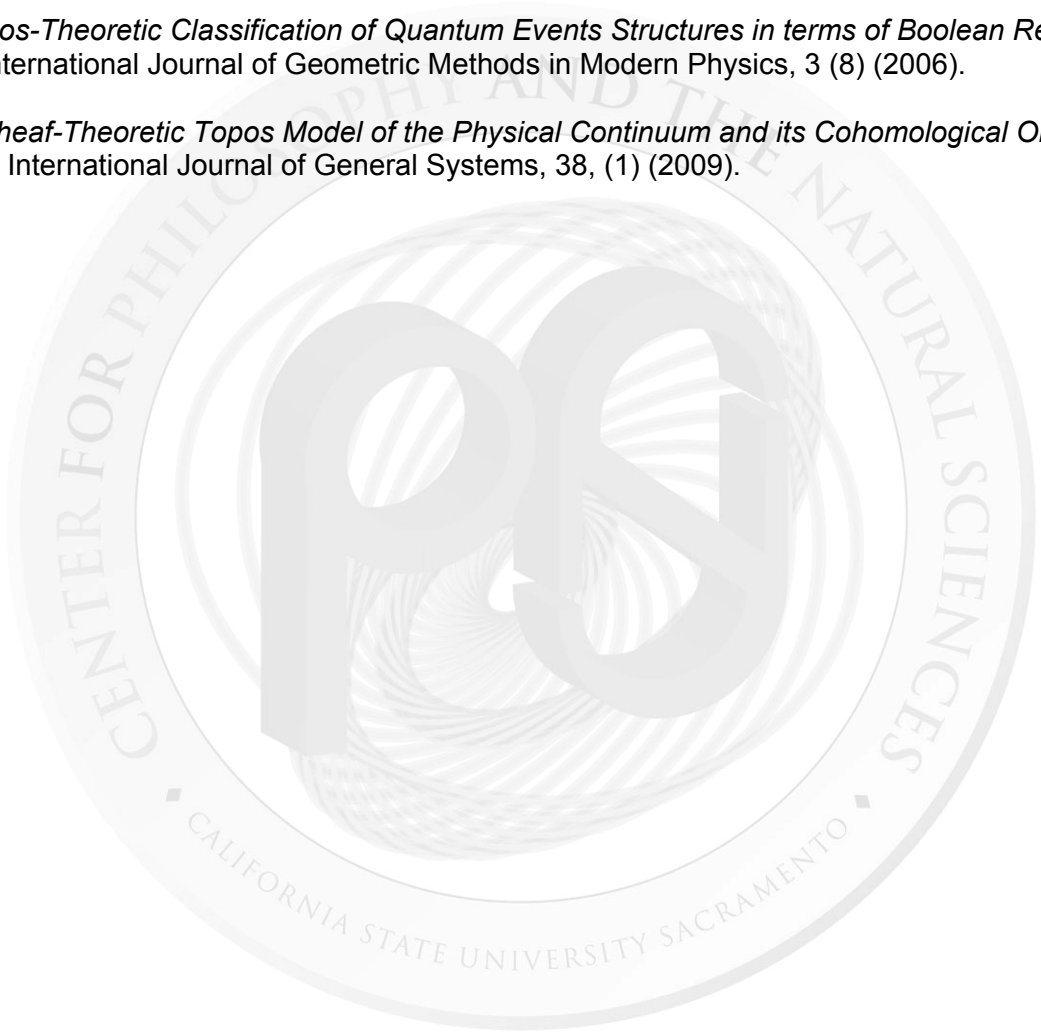
_____`*Complex Systems from the perspective of Category Theory: I. Functioning of the Adjunction Concept '*, Axiomathes 15, (1) (2005), PITT-PHIL-SCI 1236.

_____ `*Complex Systems from the perspective of Category Theory: II. Covering Systems and Sheaves '*, Axiomathes 15, (2) (2005), PITT-PHIL-SCI 1237.

_____ `*Category-Theoretic Analysis of the Notion of Complementarity for Quantum Systems'*, International Journal of General Systems, 35, (1) (2006).

_____ `*Sheaf-Theoretic Representation of Quantum Measure Algebras'*, Journal of Mathematical Physics 47, 092103 (2006).

_____ `*Generalized Topological Covering Systems on Quantum Events Structures'*, Journal of Physics A: Mathematical and General 39, (2006).

_____ `*Topos-Theoretic Classification of Quantum Events Structures in terms of Boolean Reference Frames'*, International Journal of Geometric Methods in Modern Physics, 3 (8) (2006).

_____ `*A Sheaf-Theoretic Topos Model of the Physical Continuum and its Cohomological Observable Dynamics'*, International Journal of General Systems, 38, (1) (2009).