Symposium on Generalized Quantum Theory

Exploring Intersections Between 'Generalized Quantum Theory' and 'Quantum Logical Causality' / 'Relational Realism'

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Freiburg University

The Symposium on Generalized Quantum Theory, co-sponsored by the Fetzer-Franklin Fund, will explore the Generalized Quantum Theory approach under development by the following:

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Thomas Filk:	Professor of theoretical physics, Freiburg University and scientific consultant Parmenides Foundation, Munich
Harald Atmanspacher:	Physicist, Head of Theory Department, Institute for Frontier Areas of Psychology, Freiburg, Germany
Harald Walach:	Research professor in psychology, University of Northampton, UK
Stefan Schmidt:	Psychologist, Director of the Research Network Mindfulness
Thilo Hinterberger:	Professor of neuro-informatics, University of Tübingen, Freiburg University; physicist by training
Jose Raul Naranjo:	Neuroscientist; physicist, Freiburg University
Günter Mahler:	Physicist, expert for quantum systems theory, Professor at the University of Stuttgart, Germany
Peter beim Graben:	Physicist, expert on nonlinear dynamical systems, Senior research Fellow at the University of Reading, UK
Jürgen Kornmeier:	Mathematician and Biologist, expert for bi-stable perception, Institute for Frontier Areas of Psychology and Universitäts-Augenklinik, University of Freiburg, Germany
Dieter Gernert:	Mathematician, expert for systems theory and graph theory, Professor at the Technical University of Munich, Germany

Because of recent progress in both the 'Generalized Quantum Theory' and 'Quantum Logical Causality' research programs (Epperson et al, Center for Philosophy and the Natural Sciences, California State University – www.csus.edu/cpns/research.html), the convergences and divergences among the two programs will be explored. The approaches of each can be summarized as follows:

Quantum Logical Causality / Relational Realism – Epperson et al:

In recent well-regarded interpretations of quantum physics, including the consistent decoherent histories approach proposed by Robert Griffiths (1984, 2002), and those of Roland Omnès (1994) and Nobel laureate Murray Gell-Mann (1997), we have seen careful investigations into the physical (i.e., not "merely philosophical") distinction between the order of contingent causal relation and the order of necessary logical implication. A careful philosophical exploration of the function of the logical order in modern interpretations of quantum physics compels the abandonment of derivative classical, dualistic understandings of "logical necessity versus causal contingency," "subject versus object," "epistemic versus ontological," "determinism versus indeterminism," among other conventional, fundamental dualisms. The incoherence underlying this classical understanding of these principle-pairs as mutually exclusive features of reality can be relieved if they are instead understood as mutually implicative features of fundamental units of relation or logically conditioned "quantum praxes."

By such an approach, the conventionally understood quantum mechanical 'problem of measurement' and 'problem of wavefunction collapse' are likewise relieved. The latter--the quantum mechanical actualization of potentia--is re-defined as a decoherence-driven process by which each actualization (in 'orthodox' terms, each measurement outcome) is conditioned both by physical and logical relations with the actualities conventionally demarked as 'environmental' or external to that particular outcome. But by this logical-causal approach, which we have more broadly named the 'relational realist interpretation,' the actualization-in-process is understood as internally related to the environmental data per the formalism of quantum decoherence. The concept of 'actualization via wave function collapse' is accounted for solely by virtue of these presupposed logical relations—the same logical relations otherwise presupposed by the scientific method itself—and thus requires no 'external' physical-dynamical trigger: e.g., the Gaussian hits of GRW, acts of conscious observation, etc. By the relational realist interpretation, it is the physical and logical relations among quantum actualities (quantum 'final real things') that drives the process of decoherence and, via the latter, the logically conditioned actualization of potentia. In this regard, the relational realist interpretation is a quantum logical-causal praxiological interpretation; that is, these physical and logical relations are ontologically active relations, contributing not just to the epistemic coordination of quantum actualizations, but to the process of actualization itself.

For example, in the case of the photon and polarizer in an EPR-type spin ½ experiment, the classical conception of the photon as enduring object—an 'individual' whose physical qualifications/predicates are 'changed by' the filter, lies at the heart of all the infamous conceptual difficulties of the quantum theory. By contrast, the quantum logical causality/relational realist view, informed by the decoherent histories interpretation of QM (Griffiths 1984, 2002), would be that the photon before the filter is not the 'same photon' after the filter, only now with new predicative qualification. This is because the actual occasions (facts) constitutive of the photon-system prior to relations with the polarizer are not the same facts subsequent to (and consequent of) those relations. The interaction produces alternative potential quantum mechanical histories, not alternative qualifications of the same history. Therefore there is no 'generic' domain of discourse for a first order predicate logic applied to the qualification of the system; there are alternative domains, which is problematic for simple bivalent predication.

By contrast, the relational realist interpretation suggests that an appeal to propositional logic, with the presupposition of the Principle of Non-Contradiction (PNC) and the Principle of the Excluded Middle (PEM), provides a more viable description of the logical-causal ordering in quantum mechanics. In the aforementioned EPR arrangement, where

$$\Psi = 1/\sqrt{2}\ (u_1 \otimes v_1) + (u_2 \otimes v_2)$$

for System A and System B, associated with vector spaces V^a and V^b:

Both ($u_1 \otimes v_1$) and ($u_2 \otimes v_2$) are individually completely sensible as *propositions*. But as predications of a 'generic' system, they are each unrelated to the other in the sense that each is a quantification over a unique domain of discourse. Each term can be thought of as an alternative history of the two systems (the Everett equivalent would be alternative, parallel co-actual universes). When Ψ is reduced, the 'AND' conjunction of the terms in the pure state becomes an 'XOR' conjunction in the

mixed state because of the probability amplitudes qualifying ($u_1 \otimes v_1$) and ($u_2 \otimes v_2$); PNC (via the orthogonality of the vectors u_1 and u_2 in V^a, and v_1 and v_2 in V^b) combined with the probability amplitudes amounts to a presupposition that one of the terms will be actualized, in satisfaction of PEM. It is in this sense that one could argue that the fundamental logical order in a quantum mechanical description of physical causality as actualization of potentia is a propositional logical order presupposing PNC and PEM.

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Gell-Mann, M., and J. Hartle. 1997. Strong decoherence. In *Quantum classical correspondence:The 4th Drexel Symposium on Quantum Nonintegrability*, ed. D. H. Feng and B. L. Hu, 3–35. Cambridge, MA: Intemation Press.

Griffiths,R. 1984. Consistent histories and the interpretation of quantum mechanics. *Journal of Statistical Physics* 36: 219–272.

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Omnès, R. 1994. *The interpretation of quantum mechanics*. Princeton, NJ: Princeton University Press.

Generalized Quantum Theory – Römer, Filk, Walach, Atmanspacher et al.:

(Summary compiled via excerpts from 'Weak Quantum Theory: Complementarity and Entanglement in Physics and Beyond' *Foundations of Physics*, Vol. 32, No. 3, March 2002)

It is proposed that a generalized version of the formal scheme of ordinary quantum theory can be used to describe causal relations beyond the restricted locus of microphysical phenomena. Such descriptions would imply the possibility of constructing a formal framework for addressing the concepts of complementarity and entanglement not only within the context of ordinary quantum physics, but also in more general contexts. Complementarity could, for example, be extended beyond the concept of non-commuting properties of a quantum system such as momentum and position as elements of a C*-algebra. Entanglement, which is tightly related to complementarity, could similarly be extended beyond the concept of (generally) non-local correlations (not interactions) between non-commuting properties of quantum systems.

Generalized quantum theory is based on a minimal set of axioms. The basic structure of the resulting mathematical framework is that of a monoid. Ordinary quantum theory can be recovered from this framework by additional axioms, restrictions, and specifications. For example, the weak version does not necessarily entail a Hilbert space representation or a probabilistic interpretation. The non-commutativity of observables is not necessarily quantified by Planck's constant. Bell-type inequalities cannot necessarily be formulated in generalized quantum theory.

Among the many examples for complementary relations that can be found in the literature, the case of information dynamics as regards complementary types of dynamical descriptions of physical systems, is especially demonstrative of the applicability of generalized quantum theory. Expanding earlier work by Misra (1978) and Misra et al. (1979), an information theoretical description of chaotic systems (including K-systems) was found to provide a commutation relation between the Liouville operator L for such systems and a suitably defined information operator M (Atmanspacher and Scheingraber 1987).

H. Atmanspacher and H. Scheingraber (1987): A fundamental link between system theory and statistical mechanics. Found. Phys. 17, 939–963 (1987).

B. Misra (1978): Nonequilibrium entropy, Lyapounov variables, and ergodic properties of classical systems. Proc. Ntl. Acad. Sci. USA 75, 1627–1631 (1978).

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