quantum electrodynamics

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1 Quantum electrodynamics (*Q.E.D*)

http://planetmath.org/QEDInTheoreticalAndMathematicalPhysicsQ.E.D is the advanced, standard mathematical and quantum physics treatment of electromagnetic interactions through several approaches, the more advanced including the path-integral approach by Feynman, Dirac's Operator and http://planetmath.org/QEDInTheoreticalAndMathematicalPhysicsQED Equations, thus including either Special or General Relativity formulations of electromagnetic phenomena. More recent approaches have involved spinor (Cartan and Weyl) and twistor (Penrose) representations of Quantum Hilbert spaces of quantum states and observable quantum oprators. QED results are currently at precision levels beyond 10^{-29}, and thus it is one of the most precise, if not the most precise, physical theories that however does not encompass gravity.

1.1 Measurements and Quantum Field Theories

The question of measurement in quantum mechanics (QM) and http://planetmath.org/QFTOrQua field theory (QFT) has flourished for about 75 years. The intellectual stakes have been dramatically high, and the problem rattled the development of 20th (and 21st) century physics at the foundations. Up to 1955, Bohr's Copenhagen school dominated the terms and practice of quantum mechanics having reached (partially) eye–to–eye with Heisenberg on empirical grounds, although not the case with Einstein who was firmly opposed on grounds on incompleteness with respect to physical reality. Even to the present day, the hard philosophy of this school is respected throughout most of theoretical physics. On the other hand, post 1955, the measurement problem adopted a new lease of life when von Neumann's beautifully formulated QM in the mathematically rigorous context of Hilbert spaces. Measurement it was argued involved the influence of the Schrödinger equation for time evolution of the wave function ψ, so leading to the notion of entanglement of states and the indeterministic reduction of the wave packet. Once ψ is determined it is possible to compute the probability of measurable outcomes, at the same time modifying ψ relative to the probabilities of outcomes and observations eventually causes its collapse. The well–known paradox of Schrödinger's cat and the Einstein–Podolsky–Rosen (EPR) experiment are questions mooted once dependence on reduction of the wave packet is jettisoned, but then other interesting paradoxes have shown their faces. Consequently, QM opened the door to other interpretations such as 'the hidden variables' and the Everett–Wheeler assigned measurement within different worlds, theories not without their respective shortcomings.

Arm–in–arm with the measurement problem goes a problem of 'the right logic', for quantum mechanical/complex biological systems and quantum gravity. It is well–known that classical Boolean truth–valued logics are patently inadequate for quantum theory. Logical theories founded on projections and self–adjoint operators on Hilbert space H do run in to certain problems . One 'no–go' theorem is that of Kochen–Specker (KS) which for $\dim H \geq 3$, does not permit an evaluation (global) on a Boolean system of 'truth values'. In Butterfield and Isham (1999)–(2004) self–adjoint operators on H with purely discrete spectrum are considered. The KS theorem is then interpreted as saying that a particular presheaf does not admit a global section. Partial valuations corresponding to local sections of this presheaf are introduced, and then generalized evaluations are defined. The latter enjoy the structure of a Heyting algebra and so comprise an intuitionistic logic. Truth values are describable in terms of sieve–valued maps, and the generalized evaluations are identified as subobjects in a topos. The further relationship with interval valuations motivates associating to the presheaf a von Neumann algebra where the supports of states on the algebra determines this relationship.

We turn now to another facet of quantum measurement. Note first that QFT pure states resist description in terms of field configurations since the former are not always physically interpretable. Algebraic quantum field theory (AQFT) as expounded by Roberts (2004) points to various questions raised by considering theories of (unbounded) operator –valued distributions and nets of von Neumann algebras. Using in part a gauge theoretic approach, the idea is to regard two field theories as equivalent when their associated nets of observables are isomorphic. More specifically, AQFT considers taking (additive) nets of field algebras over subsets of Minkowski space, which among other properties, enjoy Bose–Fermi commutation relations. Although at first glances there may be analogs with sheaf theory, theses analogs are severely limited. The typical net does not give rise to a presheaf because the relevant morphisms are in reverse. Closer then is to regard a net as a precosheaf, but then the additivity does not allow proceeding to a cosheaf structure. This may reflect upon some incompatibility of AQFT with those aspects of quantum gravity (QG) where for example sheaf–theoretic/topos approaches are advocated (as in e.g. Butterfield and Isham (1999)–(2004)).