Quantum mechanics as a theory of probability

Pitowsky, Itamar (2005) Quantum mechanics as a theory of probability.

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Abstract

We develop and defend the thesis that the Hilbert space formalism of quantum mechanics is a new theory of probability. The theory, like its classical counterpart, consists of an algebra of events, and the probability measures defined on it. The construction proceeds in the following steps: (a) Axioms for the algebra of events are introduced following Birkhoff and von Neumann. All axioms, except the one that expresses the uncertainty principle, are shared with the classical event space. The only models for the set of axioms are lattices of subspaces of inner product spaces over a field K. (b) Another axiom due to Soler forces K to be the field of real, or complex numbers, or the quaternions. We suggest a probabilistic reading of Soler's axiom. (c) Gleason's theorem fully characterizes the probability measures on the algebra of events, so that Born's rule is derived. (d) Gleason's theorem is equivalent to the existence of a certain finite set of rays, with a particular orthogonality graph (Wondergraph). Consequently, all aspects of quantum probability can be derived from rational probability assignments to finite "quantum gambles". (e) All experimental aspects of entanglement- the violation of Bell's inequality in particular- are explained as natural outcomes of the probabilistic structure. (f) We hypothesize that even in the absence of decoherence macroscopic entanglement can very rarely be observed, and provide a precise conjecture to that effect .We also discuss the relation of the present approach to quantum logic, realism and truth, and the measurement problem.

Subjects:	Specific Sciences: Physics: Quantum Mechanics
ID Code:	2474
Deposited By:	Pitowsky, Itamar
Deposited On:	13 October 2005
Additional Information:	Forthcoming in a Festschrift for Jeffrey Bub, ed. W. Demopoulos and the author, Springer (Kluwer): University of Western Ontario Series in Philosophy of Science.