ABSTRACTS

C2.7 Philosophy of the Physical Sciences

A diachronic perspective on the structure of quantum lattices

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In quantum mechanics, the mathematical expression of different measurements is given by the commutator between operators. If two measurements are incompatible, the commutator between the projectors associated with the measured properties is nonzero. In this case, the lattice constructed from those properties has non-Boolean features. On the contrary, if the commutator is zero, the lattice of properties is Boolean. On the other hand, the works of Kiefer and Polarski show that, the study of the evolution of quantum systems in the Heisenberg picture (where operators evolve) leads to an interesting result: under certain conditions, the evolution is such that initially the commutator between two operators is not zero, but after some time it becomes zero.

In this presentation we will study the Heisenberg evolution from the point of view of the lattices of properties. We will show that, under very specific physical conditions, the initial lattice is non-Boolean and the final lattice is Boolean. This means that, in the span between the initial time and the final time, the lattice evolves under a dynamics that allows us to study the Boolean limit of non-Boolean lattices. We will analyze this phenomenon both from a general point of view and in some specific physical examples where the evolution of the lattice can be computed.

Additionally, the lattice structure can be characterized in terms of distributive inequalities, which become equalities in the Boolean case. If we express these inequalities in terms of commutators and introduce the dynamics of commutators from Kiefer and Polarski, then we can consider how the logical structure approaches a Boolean lattice by analyzing how the distributive inequalities evolve. The analysis of the evolution of inequalities and lattices amounts to the study of the diachronic features of quantum logic structures, a matter scarcely explored to date.
Common cause closedness in orthomodular lattices

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Reichenbach proposed the principle of common cause to characterize the asymmetry of time. According to this principle, for any correlated two events which are causally independent, there must exist a common cause of them. He provided precise mathematical formulation of this statement. It has been extensively discussed, and some counterexamples of this principle were provided. But it is difficult to falsify the common cause principle by providing some counterexample because a common cause may be hidden from the perspective probability measure space. Although this principle asserts that the presence of a correlation of two events implies the existence of a common cause of them, it does not require that the common cause of the two correlated events A and B belongs to the probability measure space in which A and B have been found. Thus one cannot conclude that this principle is not valid by showing a probability measure space which lacks a common cause of correlated events because there may exist a larger space which is consistent with the original one and contains a common cause of any correlated events. Such a larger space is called common cause closed. Common cause closed probability measure spaces provide positive confirming evidence for the validity of this principle. Therefore, it is an important problem to determine when a probability measure space is common cause closed. In this talk, we investigate a general probability space with an orthomodular lattice and probability measure, and give a necessary and sufficient condition for common cause closedness in the case when an orthomodular lattice is a Boolean algebra or a non-commutative von Neumann algebra.

Popper School Methodological Disproof of Quantum Logic

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The Von Neumann/Birkhoff axiomatization was strongly criticized from the beginning. The best, but so far mostly ignored, criticism was made by Emmy Noether student Grete Hermann in 1935(Herzenberg, C. arXiv:0812.3986[physics.gen-ph], 2008). After briefly discussing criticisms by quantum physicists, the main section of the paper looks in detail at the criticism of formalized physics from the Popper School. Karl Popper falsified quantum logic from probability theory ("Birkoff and Von Neumann's Interpretation of QM", Nature 219, 1968, 682-685). Paul Feyerabend criticized quantum logic using philosophical analysis that he characterized as similar to Bohr's. Imre Lakatos showed alternatives to 20th century view that truth can only be generated from axioms. The problem with quantum logic is illustrated by tracing the initial reviewers reaction to Popper's paper available in the Karl Popper Archive. The extensive Feyerabend anti quantum logic arguments from the archive are also discussed.
Patrick Suppes, in his 1974 Popper Living Philosophers Volume contribution, seems to agree that quantum logic is wrong or at least poorly defended, but still maintains only axiomatized theories of physics are possible and suggests some as yet undiscovered axiomatization of QM will solve the problem with quantum logics (Schlipp, Vol. 14, 767-774). Surprisingly, Suppes' admission of incorrectness somehow became almost total acceptance of axiomatized quantum logic. Quantum logic became an axiom itself beyond criticism.

The paper then discusses Victor Kraft's Popper Schlipp volume contribution, in which he explains schools and shows Popper's continuation of Vienna Circle type schools (Vol. 14, 185-204). The next section of the paper connects the Popper school disproof of quantum logic to the role of mathematical rigor in physics. The attitude of physicists is complex. It probably started with Einstein's 1921 lectures on geometry. "This view of axioms purges mathematics of all extraneous elements" so mathematics "can not predict anything ...". One reason for the lack of disproof of quantum logic is related to Einstein's attitude toward mathematics. Einstein seemed even to the end of his career to believe all physicists could be unified as a theory of differential geometry of space time. This led to his criticism of the entire QM theory as being incomplete, i.e. there is a need to find hidden variables from geometry for Einstein's unification program to succeed. Einstein was mostly superseded by the more field theoretic approaches of Schrodinger and Heisenberg. The paper concludes by discussing two modern theories that depend on quantum logic: engineering quantum computers and computing as physics (sometimes called digital physics).

**Generalized Implication in Quantum Logic**

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In this paper, the implication problem in quantum logic (cf. Hardegree (1979) and Pavicic & Megill (2009) for survey) is addressed. Since Birkhoff and von Neumann's seminal work (Birkhoff & von Neumann (1936)), it has been known that quantum logic lacks the implication connective which satisfies both the modus ponens and the importation-exportation law. It has been also known that there are exactly six polynomially definable implication candidates that fulfill the criterion called "locally Boolean" in quantum logic (Kotas (1967) and Kalmbach (1974)). We show that these well-known six polynomially definable implication candidates are numbered by the Beran numbers from 01 to 96 (Beran (1985)) on the Hasse diagram of 96-element orthomodular lattice F2 characteristically (14, 30, 46, 62, 78 and 94 in each 16-element Boolean sublattice) and their non-Boolean patterns are characterized by the notion of contraposition. In quantum set theory (Takeuti (1981)), which is set theory based on quantum logic and crucially depends on the choice of implication, the ZFC transfer principle, which transfers every theorem of ZFC set theory to a valid sentence for the model, is established.
with respect to the class of implications called "generalized implication," which includes the above-mentioned six polynomially definable implication candidates as special cases (Ozawa (2007) and Ozawa (2009)). The generalized implication is locally Boolean and not polynomially definable in general. In fact, there are continuously many different generalized implications that are not polynomially definable in quantum logic. The above-mentioned criterion "locally Boolean" has a physical meaning and is justified by the standard interpretation of quantum mechanics. As for interpretational problems of values of physical quantities in quantum mechanics, we characterize the generalized implication in relation to observables and beables via the concept of commutator.