PIAF Workshop 2008

TITLES AND ABSTRACTS

Robin Blume-Kohout: What one quantum system can know about another

ABSTRACT: The role of measurement in quantum theory remains both perplexing and controversial, especially for no-collapse interpretations (e.g., many-worlds, or the ``existential'' view). One of the outstanding challenges in these frameworks is to explain preferred bases -- i.e., why measurements and observations always break unitary invariance. In this talk, I'll present a framework, motivated by information theory, to address this question -- then use it to derive a simple answer to the question ``Why do measurements yield classical information, about a single basis?'' A measurement is any interaction causing knowledge acquisition (development of correlations between observer and observed). Quantum theory supports two kinds of measurements (predictive and retrodictive), in which the observer learns either about the future or the past of the observed system. Generalizing a recent result, which classified the kinds of information that a quantum process can preserve, allows us to analyze both kinds of measurement, yielding a unified answer to the question ``What can one quantum system know about another?'' As an application, I'll prove that that one system (e.g. an apparatus or observer) can have non-classical knowledge about another system's future OR its past -- but not both.

Eric Cavalcanti: Steering, predictability and other concepts of experimental metaphysics

ABSTRACT: Since the seminal work of Bell, inspired by the paradox of Einstein, Podolsky and Rosen, many assumptions and concepts until then considered "metaphysical" were shown to have experimental consequences. In this talk I will review a few of these concepts and show some new results.

First, I argue that a formalisation of local causality and completeness, in the spirit of Bell, leads to either the notion of quantum separability or to a local hidden state (LHS) model, depending on whether one or both of Alice's and Bob's subsystems are given a quantum description. I therefore argue that the LHS model, the violation of which is called Steering [Phys. Rev. Lett. 98, 140402, (2007)], is the most general formalisation of the EPR paradox, and show that previously known criteria, as well as new ones, can be directly derived from that assumption. Implications to arguments commonly used to defend the epistemic view of quantum states will be discussed.

On another of Einstein's contentions with Bohr, I will propose that in the 1927 Solvay conference, Bohr's reply to Einstein could have been stronger. At that conference, Einstein tried to attack not simply the completeness, but the empirical correctness of quantum theory, by attempting to evade Heisenberg's Uncertainty Principle (HUP), which implies that quantum phenomena are irreducibly unpredictable. Bohr's reply established the consistency of the HUP -- but not necessarily its correctness -- by showing that a consistent application of it does not allow contradictions. I will propose a result that goes beyond that: by carefully defining predictability as distinct from determinism, and considering the (observed) Bell violations, we can show that if relativistic invariance is assumed, Nature must be irreducibly unpredictable.

Carl Caves: Should we think of quantum probabilities as Bayesian probabilities?

ABSTRACT: Should we? Seems unlikely, since quantum probabilities are part of the fabric of quantum mechanics, the framework for all physical law. Yet all classical probabilities are Bayesian, never dictated by facts, and so it is with all quantum probabilities, suggesting that they, too, should be thought of as Bayesian. I will compare and contrast classical and quantum probabilities and conclude with a stab at the ontology behind quantum mechanics, which lies not in the framework of quantum states, which we use to make inferences and predictions, but rather in the physical laws themselves.

John Corbett: Quantum measurement and quantum reality from a topos theoretical perspective.

ABSTRACT: Most approaches to understanding quantum mechanics use mathematical concepts founded on set theory. Topos theory gives an alternative foundation for mathematics. I argue that re-interpreting quantum formalism in terms of topos theory will help to solve some of the central conceptual problems in quantum theory. In this talk I firstly review the quantum measurement problem to obtain a concept of reality and then reformulate the problem using quantum real numbers which are the topos theoretical numerical values of the physical qualities of the quantum systems. If I have time a particular example of a position measurement will be given.

The first part of the talk is based on work with Dipankar Home, the latter parts were developed in work with Thomas Durt and with Frank Valckenborgh.

Chris Fuchs: Relational Quantum Mechanics, Jamesian Pragmatism, Pricean Pragmatism, and What I'd Like To Get Out of This Collaboration

ABSTRACT: TBA

Steve Jones: Steering witnesses as criteria for the (non-)existence of local hidden state (LHS) models

ABSTRACT: The concept of quantum steering was introduced by Schrodinger in 1935 as a generalisation of the EPR paradox for pure states. In a recent work [Phys. Rev. Lett. 98, 140402, (2007)] we provided a rigorous definition of steering which applies also to mixed quantum states, and shows that steering is a property of some quantum states and is distinct from both the concepts of entanglement and violating a Bell inequality. Bell inequalities are a useful tool as they allow one to answer the general question of whether experimental outcomes could possibly be explained by a local hidden variable theory. Entanglement is based on answering the question of if a quantum state could be described by a separable representation (i.e. by assigning a valid quantum state to each subsystem). The concept of steering raises a hybrid question. Is it possible for the outcomes of an experiment to be explained by a local hidden variable model for one subsystem correlated with a valid quantum state for the other subsystem? We phrase this question as; is it possible to explain experimental outcomes using a local hidden state (LHS) model? We introduce the concept of "steering witnesses" in analogy with entanglement witnesses as a tool to address this question.

Owen Maroney: Maxwell through the looking glass: from Szilard to Landauer and back again

Dean Rickles: Philosophy of Science for Physicists and Foundationsists

ABSTRACT: Following a request by Howard Wiseman that "one of you philosophers" give an overview talk on any of the following topics: scientific realism, the idea of a 'theory of everything', scientific understanding, and the relationship between explanation and causation, I give a brisk review of all of these topics. I then compare this with the kind of work done in foundations of physics.

Rob Spekkens: TBA

Ward Struyve: De Broglie-Bohm theory and quantum field theory

ABSTRACT: I will present an overview of possible extensions of the de Broglie-Bohm pilot-wave theory (Bohmian mechanics) to quantum field theory. In the de Broglie-Bohm theory quantum systems are not only described by their wavefunction (or quantum state), as in standard quantum theory, but also by some additional variables, called "hidden variables" or "beables". Within the context of non-relativistic quantum mechanics it is very natural to introduce particle positions as beables. Within the context of quantum field theory, a number of approaches seem possible. I will discuss approaches with particle positions as beables and an approach with fields as beables. In addition I will present a surprisingly minimalist approach, which amounts to introducing beables only for the electromagnetic field degrees of freedom.

Joan Vaccaro: Flow of Time in a Quantum Mechanical World

ABSTRACT: The matter-antimatter arrow of time associated with the weak force in neutral Kaon decay has been an enigma for 40 years. While other arrows (cosmological, electromagnetic, thermodynamic and psychological) have been linked together the matter-antimatter arrow stands alone. It is often regarded as having negligible effect on time in our daily lives. The main reason for this view appears to be the relatively small violation of the Charge-Parity conjugation (CP) invariance involved. However a small difference in a quantum state fidelity for a single particle can lead to a large difference that grows exponentially with number for a collection of particles. In principle the smallness of the violation is not an obstacle in terms of macroscopic effects, provided sufficient numbers of particles are involved.

In this talk we will examine the effect of the violation of CP invariance (or equivalently time reversal invariance) on the dynamics of a large system such as the universe. The analysis will be in the context of Pegg's quantum time formalism where time is defined within the system and not imposed as an external parameter. The state of the universe is the ground state of the Hamiltonian in accord with the Wheeler-deWitt equation, and is expressed as a superposition of "time"-ordered states. Care is taken to avoid inserting a bias in time direction when dealing with a CP non-invariant Hamiltonian. Everett's Many Worlds interpretation is used to follow the trajectories of the state of the system. An arbitrary initial state involving neutral kaons is seen to perform a random walk with a drift towards one direction, the "future". Within this formalism, the seemingly insignificant kaons appear to be responsible for our apparent motion through time.

Steve Weinstein: Backward causation models for quantum phenomena

ABSTRACT: Bell's theorem appears to rule out local, relativistic hidden-variable theories, but the theorem assumes that there are no "pre-correlations" between detector settings and initial data. It has been suggested by Cramer, Price, and others that this assumption is reasonable only if there is no "backward" causation, meaning causation along or within the past lightcone of the detectors. In this talk I consider Price's idea and show that the form of backward causation proposed is one which, if it is to be effective, must be nonrelativistic in the sense of being incompatible with Lorentz-invariant equations of motion.

Hans Westman: Is the wave-function epistemic?"

ABSTRACT: Recently there has been a growing interest in epistemic interpretations of quantum mechanics where it is conjectured that the wave-function should be regarded as mere ignorance over the true state. This is in contrast to the deBroglie-Bohm theory where the wave-function cannot be understood as a purely epistemic object. This can be taken as a draw-back of deBroglie-Bohm theory leading to conceptual problems such as "empty waves". We will discuss recent efforts to make more precise the idea of epistemic theories. We also point out problems with some concrete proposals for epistemic theories. Then we turn to the problem of quantization of timeless theories such as Jacobi's timeless mechanics (not to be confused with Hamilton-Jacobi theory). A straightforward canonical quantization generates a quantum theory in which a probabilistic interpretation of the wave-function is highly problematic. We develop a deBroglie-Bohm theory for the timeless quantum Jacobi theory and explore the semi-classical approximation where the wave-function seems to acquire a probabilistic interpretation. Thus, it is possible that the probabilistic interpretation of the wave-function only emerge approximately in the semi-classical domain and is not fundamental. We speculate that regions in configuration space where the semi-classical approximation breaks down might act as generators of quantum non-equilibrium states in deBroglie-Bohm theory.

Ken Wharton: The Klein-Gordon Equation Revisited

ABSTRACT: Quantum mechanics was originally developed in the non-relativistic regime, and most foundational research continues to treat relativity as an unimportant complication. But efforts to extrapolate interpretations of the non-relativistic Schroedinger equation to the relativistic Klein-Gordon equation have failed. I will outline a foundational research program that instead starts with a new interpretation of the Klein-Gordon equation. The key is that relativistic wave equations have double the parameter space of first-order (in time) differential equations, inviting the imposition of a second boundary condition corresponding to a final measurement of the system (arXiv:0706.4075). Such an interpretation not only reduces to a novel (and time-symmetric) picture of quantum mechanics in the non-relativistic limit, but also hints at an alternate path to quantum gravity (where the boundary condition on any system is imposed on a closed hypersurface in space-time, similar to proposals by both L. Hardy and R. Oeckl).

Howard Wiseman: Grounding Bohmian Mechanics in Weak Values and Bayesianism

ABSTRACT: Bohmian mechanics (BM) is a popular interpretation of quantum mechanics in which particles have real positions. The velocity of a point x in configuration space is defined as the standard probability current j(x) divided by the probability density P(x). However, this "standard" j is in fact only one of infinitely many that transform correctly and satisfy dP/dt + div j = 0. In this article I show thata particular j is singled out if one requires that j be determined experimentally as a weak value, using a technique that would make sense to a physicist with no knowledge of quantum mechanics. This "naively observable" j seems the most natural way to define j operationally. Moreover, I show that this operationally defined j equals the standard j, so, assuming dx/dt = j/P one obtains the dynamics of BM. It follows that the possible Bohmian paths are naively observable from a large enough ensemble.

Furthermore, this justification for the Bohmian law of motion singles out x as the hidden variable, because (for example) the analogously defined momentum current is in general incompatible with the evolution of the momentum distribution. Finally I discuss how, in this setting, the usual quantum probabilities can be motivated from a Bayesian standpoint, via the principle of indifference.