FOUNDATIONS OF QUANTUM FIELD THEORY:
2019 ANNUAL PHILOSOPHY OF PHYSICS CONFERENCE
University of Western Ontario | London, Ontario | #FQFT2019

WEDNESDAY, JUNE 12

10:30 - 10:45 am — Check-in & welcome

10:45 am - 12:00 pm — **Collapse Theories for Relativistic QFT: Problems and Prospects**
Wayne Myrvold, University of Western Ontario

Relativistic quantum field theory confronts us with interesting conceptual issues that are alien to nonrelativistic quantum mechanics. This should not blind us to the fact that it inherits the central conceptual problem of quantum mechanics. In both domains we have a well-understood recipe for associating quantum states with preparation procedures and for calculating probabilities of experimental results, yet no consensus on what, if anything, needs to be added to this operational core to yield an account of the physical world. One avenue of approach is the dynamical collapse programme, which seeks to modify the usual, unitary dynamics of the theory to produce something like the textbook collapse postulate as a physical process.

In this talk I will present a no-go theorem that demonstrates that the most straightforward approach to constructing a theory of this sort doesn't work (based on Phys. Rev. A 96 062116, 2017). Any viable collapse theory will, therefore, have to violate one or more of the conditions assumed in the theorem. I will discuss prospects for theories that reject one or more of these conditions.

12:00 - 1:30 pm — Lunch

1:30 - 2:45 pm — **CPT, Spin-Statistics, and State Space Geometry**
Noel Swanson, University of Delaware

The CPT theorem says that any well-behaved QFT must be invariant under a combined reflection symmetry that reverses the direction of time, flips right- and left-handedness, and conjugates charge. The spin-statistics theorem connects particles' spin to statistical constraints governing collections of indistinguishable particles. Both theorems are puzzling. The physical chain of argument behind them is far from transparent, and despite being about apparently different things, they are in fact intimately related. In some proofs of the CPT theorem, the spin-statistics theorem appears as a lemma; in others the order of dependence is reversed. Moreover, the lack of analogous results for non-relativistic quantum theories and classical field theories strongly suggests that the theorems capture constraints essential for unifying relativity and quantum mechanics.

In recent work, I have argued that within the algebraic approach to QFT, CPT symmetry is best explained in terms of a certain global reflection operation on the theory's state space. In this talk I will explore the viability of extending this state space account to cover the spin-statistics connection. The ultimate goal is to crack a tricky chicken-and-egg problem: does the CPT theorem explain the spin-statistics connection, does the spin-statistics connection explain the CPT theorem, or is there an underlying common explanation?

2:45 - 3:15 pm Break

3:15 - 4:30 pm **Why can we use analytic continuation to relate relativistic QFT models to non-relativistic models?**
Doreen Fraser, University of Waterloo

One mathematical technique that is commonly used in QFT is analytic continuation of the time variable (e.g., Wick rotation). This strategy relates the relativistic QFT model of interest to a non-relativistic model of some type (e.g., in some cases, a classical or quantum statistical mechanical model). Analytic continuation has been successfully used not merely to solve existing QFT models, but as a tool to construct new QFT models. I will offer explanations for the applicability of this mathematical technique and explore what (if anything) its successful application tells us about quantum field theoretic systems.

4:30 - 5:30 pm Discussion: What are the distinctively relativistic features of QFT?

THURSDAY, JUNE 13

8:30 - 9:00 am Coffee & snacks

9:00 - 10:15 am **The theory of measuring quantum fields: myths and facts**
Eduardo Martin-Martinez, University of Waterloo

From the LHC to quantum optics experiments, performing measurements on quantum fields where we obtain information about its state is commonplace in modern physics. The theoretical formalization of these measurements typically has two extreme approaches: one, common in quantum optics, is very experiment-driven and based on a number of simplifications that are incompatible with the relativistic nature of the theory and often catastrophically fail to describe the light matter interaction in any regime where relativity actually plays a role. The other is very abstract and arguably removed from experiment, based on measurements on local algebras of observables, treating them as elements of physical reality. Both of them present challenges and problems to make themselves compatible with a relativistic description of the field theory and to describe an experimental reality. We will discuss this and give an operational perspective on what it means to extract information from quantum fields arguing that the detector system and its interaction with the field are not only important, but even ontologically crucial to the notion of measurements in quantum fields . This is strongly connected with the notion of particle in quantum field theory, and the notion of “particle detectors”.

10:15 - 10:45 am Break

10:45 am - 12:00 pm **Rethinking Perturbation Theory (in the 1950s)**
James Fraser, Durham University

Ernst Stueckelberg’s and Nikolay Bogoliubov’s work on the causal perturbation theory approach in the early 1950s is not widely known, yet it made conceptual moves that remain relevant to the foundations of QFT. I will discuss two issues illuminated by this early work in the causal perturbation theory programme. i) In using a causality condition rather than a dynamical equation to set up the perturbation series Stueckelberg and Bogoliubov pioneered the idea that perturbative QFT is distinct from, and can be developed independently of, an ‘exact’ non-perturbative characterization of QFT. ii) This approach led to a reconceptualization of the perturbative renormalization procedure, understanding it in terms of the fixing of ambiguities flowing from the causality condition rather than a subtraction of divergences. This view of renormalization formed the basis of Stueckelberg and Petermann’s (1953) introduction of the renormalization group, thus the causal perturbation theory programme served as an incubator for ideas in renormalization theory which would become much more prominent and important in later decades.

12:00 - 1:30 pm Lunch

1:30 - 2:45 pm **Quantum Field Theory, Finitely**
Michael Miller, University of Toronto

One of the central alleged obstacles to the interpretation of perturbative quantum field theory is the presence of ultraviolet divergences in empirically adequate models. While the presence of ultraviolet divergences has been taken to be an inevitable consequence of representing realistic field interactions, I argue that they are in fact an artifact of the failure to correctly handle to distributional character of field operators in standard characterizations of quantum field theory. By appealing to techniques from causal perturbation theory, I show that when the multiplication of distributions is handled correctly, ultraviolet divergences are avoided and hence renormalization in the standard sense is not necessary. Moreover, this solution to the ultraviolet problem can be incorporated into axiomatic approaches to quantum field theory. This analysis shows that what differentiates perturbative and axiomatic field theory is not their treatment of arbitrarily short distances.

2:45 - 3:15 pm Break

3:15 - 4:30 pm **Julian Schwinger and the Audacity of Scope**
Porter Williams, University of Southern California

In the late 1940s and early 1950s, Julian Schwinger developed renormalization methods for extracting Lorentz and gauge invariant results from perturbative calculations in quantum electrodynamics and, ultimately, laid the first foundations for postwar quantum field theory itself. He continued to work within the framework of quantum field theory through the mid-1960s, long after most particle theorists had shifted their hopes for modeling the strong interactions to S-matrix Theory or the methods of current algebra. However, in 1966 Schwinger abandoned quantum field theory as well, and the remainder of his work in particle theory was devoted to the development and elaboration of a new theoretical framework called Source Theory. In this talk, I describe the manner in which Schwinger's unique understanding of renormalization and the relationship between fields and particles, as well as his life-long methodological commitments, were both the cause of his persistent work on quantum field theory and of his ultimate abandonment of that framework.

4:30 - 5:30 pm Discussion: Why is renormalization needed to address ultraviolet divergences?

FRIDAY, JUNE 14

8:30 - 9:00 am Coffee & snacks

9:00 - 9:30 am **Classical gravity is safe from an ultraviolet catastrophe**
Petar Simidzija, University of Waterloo

Max Planck famously showed that the electromagnetic radiation emitted by a hot body must be quantized in order to avoid the ultraviolet catastrophe. Can we use a similar argument to argue that gravity should be quantum? By computing the power radiated from a thermal source into classical gravitational waves, we find that the result is not only non-catastrophic, but in complete agreement with our lack of observations of such phenomena. Hence, at least from a thermodynamic perspective, linearized gravity does not require quantization.

9:30 - 10:00 pm **Possible futures: How to construct quantum space-time with indefiniteness**
Nitica Sakharwade, Perimeter Institute

While QFTs have a background causal structure, we expect causal structure and quantum theory to have a deeper relationship in quantum gravity. In the last decade (2007), Lucien Hardy has suggested that the radical aspects of quantum physics (probabilistic nature) and relativity (dynamic causality) would both manifest in such a theory giving rise to indefinite causal orders between events. Since then there has been an active interest in studying causally neutral formulations of quantum theory (states and channels at the same footing); and in particular the study of indefinite causal orders, that exhibit new phenomenon. These frameworks often employ minimum space-time considerations rendering the ontology of this indefiniteness obscure. I will present a constructive toy theory for a quantum 1+1 D space-time that exhibits locally definite but globally indefinite causal structures, which reproduces phenomenon like the quantum switch, and attempts to illuminate the ontology of indefinite causal orders.

10:00 - 10:30 am Break

10:30 - 11:45 am **Quantum fields as sensors for Fundamental physics**
Ivette Fuentes, University of Nottingham--speaking virtually

Quantum sensors that are used to measure gravitational fields and detect dark energy typically use single particle interferometric techniques that are limited by the time of flight in the interferometer arm. In this talk I will present a new detection method that uses quantum resonances and the sensitivity of collective excitations (phonons) to gravitational fields. When phonons in a Bose-Einstein condensate are initially prepared in a squeezed state, spacetime distortions can create additional excitations through parametric amplification. This effect can be used to detect gravitational waves at high frequencies. We have also developed a phonon based scheme to estimate spacetime parameters, miniaturize devices to measure gravitational fields and gradients and set further constraints on dark energy models.

11:45 am - 1:30 pm Lunch

1:30 - 2:45 pm	**Baseless Speculation**

Laura Ruetsche, University of Michigan

At the risk of infuriating the audience, I'm hoping to talk about what exactly an "emergent" or "nonnfundamental" ontology for particle physics could possibly be. My aim is to articulate (or exorcise) a persistent dissatisfaction, in some sense directed at David Wallace, with appeals made to emergent/nonfundamental entities in various parts of the foundations of physics literature. It's not obvious how to make sense of such entities, or how to argue about whether to endorse them, in the absence of agreement either about what's fundamental or about what it is to be spatiotemporally located. A striking counterpoint here is the contemporary metaphysics literature about fundamentality and emergence, much of which seems unfolds in the scope of the assumption that we know what the fundamental entities are, and they're a lot like the particles of Lucretius.

2:45 - 3:15 pm Break

3:15 - 4:30 pm **Classical limits of particle concepts in quantum field theory**

Benjamin H. Feintzeig, University of Washington

A number of arguments purport to show that there is no fundamental particle concept in relativistic quantum theories. This presents a puzzle because relativistic quantum field theory underlies all of modern particle physics. So in what sense can particle-like behavior emerge from fundamental theories that do not allow for particles? I propose to approach this question by looking at the behavior that emerges from relativistic quantum field theories in the classical limit. This requires some technical work to extend the modern framework for analyzing the classical limit to unbounded quantities, like particle number and field operators. The result promises to (1) shed light on a sense in which particles are approximately local and (2) help trace the origin of inequivalent particle concepts in quantum field theories.

4:30 - 5:30 pm Discussion: What is the ontology of QFT?

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