Workshop - The Ontology of Fields

7 – 9 January, LMU Munich

Abstracts

1. A. Shadi Tahvildar-Zadeh (Rutgers University)

Title: Covariant Guiding Laws for Fields

Abstract: Least-invasive quantization refers to the passage from the classical Hamilton–Jacobi formulation of non-relativistic point-particle dynamics to the non-relativistic quantum dynamics of point particles whose motion is guided by a wave function that satisfies Schrödinger's or Pauli's equation. In this talk I show that an analogous procedure can be performed for Lorentz-covariant dynamics of classical fields on spacelike slices of spacetime. I then propose a covariant guiding law for the temporal evolution of the resulting quantized fields, and discuss some applications, including to Bohmian strings. (Joint work with Maaneli Derakhshani and Michael Kiessling.)

2. Charles T. Sebens (Caltech)

Title: The Process of Particle Localization in a Quantum Theory of Fields

Abstract: In non-relativistic quantum mechanics, if you have a particle that is in a superposition of two distant locations and look for it at one location, it appears to collapse to a single location. Bohmian mechanics says that it was already at that location before measurement. The many-worlds interpretation says that we get a superposition of branches in which the particle is either in one location or the other. I seek to better understand the relation of particles to fields by asking how relativistic quantum field theory handles such measurements, given that what you do in one region cannot alter the reduced density matrix state of a distant region (by the locality of the theory's unitary dynamics). Both Bohmian and many-worlds approaches will be discussed. In quantum field theory, you can represent the quantum state as a wave functional and square that wave functional to get a probability distribution over field configurations. To describe the aforementioned setup, the non-relativistic quantum wave function with peaks at the two locations is

replaced by a wave functional peaked around field configurations that have lumps at both locations. The particle has pieces in two different places. When you look for the particle in one place, what happens to the distant piece?

3. Ward Struyve (KU Leuven)

Title: Field Ontologies in Bohmian Mechanics

Abstract: There is an ongoing debate about whether quantum field theory (QFT) should be regarded as fundamentally a theory of particles or of fields. Several approaches have been proposed to address this question, perhaps the most direct of which is to examine whether QFT admits a particle or field ontology. This issue can be explored in a particularly clear way within Bohmian formulations of QFT, which explicitly specify the elements of the theory's ontology. In this talk, I will present an overview of field ontologies in Bohmian approaches to QFT and discuss their main features.

4. Marco Giovanelli (University of Turin)

Title: Peter Bergmann's Reappraisal of Einstein's Notion of 'Coincidence'

Abstract: In his 1916 review paper on general relativity, Einstein made the often-quoted remark that all physical measurements amount to a determination of coincidences, such as the coincidence of a pointer with a mark on a scale. Although the argument quickly gained popularity, the motivations behind Einstein's claim remained hidden in his private correspondence. This paper argues that it was not until the early 1960s that Peter G. Bergmann, in his search for the 'true observables' in general relativity, systematically employed the notion of 'coincidence' in a way more closely aligned with Einstein's intentions. Drawing on the work of Komar, Bergmann generalized Einstein's naive notion of 'coincidence' as the encounters of light rays and material particles into a more sophisticated concept: the co-realization of field values—ultimately, of the gravitational field alone. In this form, the paper contends, the claim that only coincidences are observable in general relativity captures the theory's central conceptual feature.

5. John Dougherty (LMU Munich)

Title: Against "Against Pointillisme“

Abstract: In a number of papers, Jeremy Butterfield has criticized a position he calls "pointillisme". Pointillisme is the doctrine that the fundamental quantities in a physical theory are intrinsic properties of points of or point-sized objects in spacetime. This doctrine bears on various debates in metaphysics, like those concerning Humean supervenience or the metaphysics of velocity. Butterfield argues that failures of pointillisme are ubiquitous in physics, and that this implies that extrinsicality is much more extensive than these metaphysical debates recognize. In this talk, I argue that Butterfield's opposition to pointillisme is not radical enough. As field theories illustrate, Butterfield's arguments for extensive extrinsicality in physics rely on the same kinds of pointilliste principles he opposes.

6. **Diana Taschetto** (Utrecht University)

Title: Rewriting the Quantum "Revolution"

Abstract: When the truth-seeker John Wheeler read Thomas Kuhn's challenge to the orthodox story of the origin of quantum theory in the iconoclastic *Black-Body Theory and Quantum Discontinuity* (1978), and found therein the claim that Max Planck, in 1900, did not know what he had discovered, he wrote to Kuhn to say that he, Wheeler, could not believe it. Yet he congratulated Kuhn nonetheless, for the correct answer cannot be found if no one asks the question. In this talk, I will show, first, that the two major accounts of the origin of quantum theory that have been taken for granted in the scholarship on the foundations of quantum mechanics—the orthodox story and Kuhn's alternative—are false. Both have been oblivious to the highly problematic state of the evidence in favor of the Maxwell–Boltzmann probabilistic kinetic theory of heat at the end of the nineteenth century—a state that changed dramatically after Perrin's 1908–1911 experiments confirmed Einstein's predictions for Brownian motion—and neither explains whence quantization; one has the impression that a confused Planck simply fished it from the sky. I will then present the general outlines of the new account of the origin of quantum theory I proposed in Studies in History and Philosophy of Science **109** (2025): 72–88. The quantum, I will show, was not handed down from heaven. It was demanded by the second law of thermodynamics. The philosophical upshot will be that Thomas Kuhn was manifestly wrong when, in his influential *The Structure of Scientific Revolutions*, he defended the claim that a choice of paradigm can never be unequivocally settled by theory and experiment alone—the classical-to-quantum paradigm shift demonstrably was. And in this talk, I will give the argument and the evidence that show it.

7. **Xabier Oianguren-Asua** (Eberhard Karls Universität Tübingen)

Title: Rigorous Schrödinger Quantum Mechanics of Countably Many Degrees of Freedom

Abstract: In this talk, we will provide a generalization of the quantum theories that employ square-integrable functions on "R^n" as their state vectors to the case in which n is countably infinite. The resulting structure's configuration space is the Cartesian product of countably many real lines, which can parametrize, among others, the expansion coefficients of a field with respect to an orthonormal basis. Building on this, we will present a mathematically rigorous framework for pilot-wave theories possessing a field ontology—namely for quantum field theories in "Schrödinger picture" whose primitive ontology consists of physical-space fields. For this purpose, we will employ von Neumann's infinite tensor product—which circumvents the absence of a well-behaved infinite-dimensional Lebesgue measure—and a joint spectral diagonalization theorem for infinitely many (strongly) commuting operators.

8. **Mario Hubert** (LMU Munich)

Title: From Classical to Multi Fields

Abstract: I will present the history of modern physics as a history of generalizing the classical field. Relativity theory and quantum mechanics diverged because they generalized the classical field in different ways: one leading to tensor fields, the other to multi-fields. I argue that the multi-field in non-relativistic quantum mechanics can be further generalized as a *multi-time multi-field* for a proposal of relativistic quantum mechanics. Along with generalizing fields, the way fields act on matter needs to be generalized as well.

9. **Paula Reichert** (LMU Munich)

Title: Newton, Leibniz & Laplace or An Enquiry Concerning the Ontology of Classical Gravitational Theory

Abstract: Newton's theory of gravity has two characteristic features: 1) It is a theory of action at a distance; celestial bodies attract each other independent of how far they are apart. 2) It is a theory of absolute space and absolute time; celestial bodies

move through absolute space with respect to an absolute time. If you give up on either one of these two points, you end up with a different ontology (though, noteworthy, not with a different theory). Laplace, whilst exploiting and promoting Newton's theory, gave up on action at a distance and introduced the gravitational field. Leibniz, on the other hand, fiercly disputed the existence of an absolute space and time and favoured a relationalist account instead. The latter's ideas led, via Mach and Barbour, to modern shape dynamics, a relationalist theory of classical gravity. This talk will analyse the way in which a particular, fixed form of mathematical equations equipped with different ontologies can lead to vastly different pictures of the world.

10. **Davide Romano** (University of Verona)

Title: A Novel Look at the Multi-Field, Or: Why You Should Not Think of the Multi-Field as a Field

Abstract: The multi-field is not a classical field, that is, it cannot be defined as an entity having precise values at each point of three-dimensional space. The multi-field should be regarded rather as a quantum field, that is, a completely new entity in physics, the difference between the multi-field and a classical field being as the difference between a classical field and the Newtonian force. But then, we may ask, which sort of entity does the multi-field represent? In this talk, I advance the hypothesis that the multi-field be a determinable-based entity, i.e. a continuous entity characterized by quantum indeterminacy. The multi-field assigns a determinate value to specific N-tuples of points, leaving most of the points with indeterminate values. The latter become determinate, however, when the Bohmian particles occupy the corresponding points. Taking instruments from metaphysics, all this can be quite exactly defined as a determinable-based object. Whether this also corresponds to a real physical object is open to debate.

11. **Dirk Deckert** (LMU Munich)

Title: Light and Matter

Abstract: Against the background of the role of ontology and representation in the natural sciences, I will survey some toy models, ranging from classical to quantum electrodynamics, that describe how fields mediate interactions between charges, exhibiting characteristic features such as retardation and radiation reaction. The focus will be on how one refers to certain mathematical entities as particles and others as fields, and on how these designations can be linked to ontological commitments. Particular attention will be paid to differences in the ontological status of light and matter.

12. **Antoine Tilloy** (École Nationale Supérieure des Mines de Paris)

When metaphysics matters: the example of quantum-classical dynamics

Orthodox quantum mechanics is a hollow prediction toolbox, without any clear story about what actually goes on in the world. Various completions (or reconstructions) have been proposed. We even have an embrassement of riches: wildly different ontologies are compatible with what we measure. Many physicists thus conclude that we should dismiss all this as pure metaphysics, and stick to orthodox quantum mechanics. Contrary to this view, I think even a hyper-pragmatic physicist should care about what the world is (or at least could be) made of. Having a clear ontology need not give new predictions now, but it guides theory building: different ontologies may give different predictions in natural extensions. This is not a new argument, but I think recent developments in hybrid quantum-classical theories of gravity illustrate it in a particularly compelling way. In this context, various shades of collapse models that differ only in their ontology (but not in their empirical content) give empirically distinct theories once naturally extended to a fundamentally semi-classical theory gravity. In some cases, this gives an argument to favor a particle, field, or flash ontology, without having to rely on a metaphysical a priori.

13. **Kevin Coffey** (NYU Abu Dhabi)

On Visualizing the Faraday Field