FOUNDATIONS2021

The 20th UK and European Conference on Foundations of Physics

Programme with abstracts

Thursday, 28

09:00-10:00 — room Jaurès, **Plenary session**

- **Eliahu Cohen. Telling a smile from a veil: Weak values, Cheshire cats, and counterfactual communication.**

10:00-10:30 — room Curie **break**

10:30-13:00 — room Jaurès, ***Space and Time* session**

- **James Weatherall. Where Does General Relativity Break Down?**

It is widely accepted by physicists and philosophers of physics alike that there are certain contexts in which general relativity will ``break down''. In such cases, one expects to need some as-yet undiscovered successor theory. This paper will discuss certain pathologies of general relativity, including singularities and Cauchy horizons, that might be taken to signal that the theory is breaking down, and consider how one might expect a successor theory to do better. The upshot will be an unconventional interpretation of the ``Strong Cosmic Censorship Conjecture'' and the significance of recent work thereon.

- **Adán Sus. Relativity without miracles**

It has been claimed that the fact that all the non-gravitational fields are locally Poincaré invariant and that these invariances coincide with the symmetries of the spacetime metric is miraculous in general relativity (GR). I show that, in the context of GR, it is possible to account for these so-called miracles of relativity. This involves integrating the constraints imposed by gravitational field equations (Einstein field equations in GR) on matter fields in a novel interpretation of the equivalence principle, which dictates the determination of local inertial frames through gravitational interaction. This explanation of the miracles can also deal with the problematic cases for attempts at explaining the coincidences in the context of the standard geometrical perspective on relativity theory.

- ➢ **Jingyi Wu and James Owen Weatherall. Between a Stone and a Hausdorff Space**

A generalization of Stone's representation theorem shows that, given two manifolds, the algebras of smooth functions on them are isomorphic iff the manifolds are diffeomorphic. Recently, Rosenstock et al. (2015) suggests that this duality deflates a brand of "substantivalism" associated with starting one's analysis of spacetime structures with a spacetime manifold (e.g. Earman 1989). In this talk, we show that this interpretation of the spacetime manifold depends on background assumptions about manifold topology. If we allow for not-necessarily-Hausdorff manifolds, the algebra-geometry duality breaks down, and there exist non-diffeomorphic manifolds with isomorphic function algebras. We proceed to draw several morals.

- ➢ **Kian Salimkhani. The Dynamical Approach to Spin-2 Gravity**

This paper is concerned with the status of the equivalence principle in general relativity (GR), and (b) the question whether the GR metric is derivative on symmetry properties of matter field dynamics. The paper attempts to complement these debates by studying the spin-2 approach to (quantum) gravity. In particular, the paper argues for three lessons: (1) already the classical spin-2 theory provides new insights for the equivalence principle; (2) the `second miracle' (see Read et al. (2018)) disappears in the classical and quantum version of the spin-2 approach; (3) the spin-2 approach allows for an ontological reduction of the GR metric field to symmetry properties of matter field dynamics.

- ➢ **Helen Meskhidze. Energy Conditions in Theories of Modified Gravity**

Energy conditions are typically imposed in General Relativity to capture the intuition that energy should be positive. Einstein's field equation allows us to capture this intuition in two distinct but equivalent ways: as a physical constraint and as a geometric constraint. I investigate whether such a division between the physical and geometric formulations of the energy conditions holds in modified theories of gravity. I argue that in f(R)/f(G) gravity, neither the formulation nor the interpretation of the energy conditions can be given in solely physical or geometric terms. More broadly, I claim that the motivations for imposing the energy conditions on modified theories of gravity must be sensitive to changes in the theories' fundamental terms.

10:30-13:00 — room Marbo, ***Quantum physics*** **session**

- ➢ **Patrick Fraser, Nuriya Nurgalieva and Lídia del Rio. A No-Go Theorem for Quantum Knowledge**

The Frauchiger-Renner paradox demonstrates that four of seemingly reasonable postulates for reasoning about the world are inconsistent, and thus at least one must be rejected. In philosophical logic, a similar narrative arises via Fitch's paradox; if one formalizes knowledge in a minimal modal setting, and makes three minimal assumptions about knowledge, a paradox seems to arise. Intuitionists are able to cope with this problem. However, we here demonstrate that, when the assumptions of the Frauchiger-Renner paradox are expressed as statements about knowledge in the same modal setting as Fitch's paradox, any violation results in contradiction. Thus, we see that the Frauchiger-Renner paradox imposes fundamental constraints on the nature of knowledge in a quantum mechanical world.

- ➢ **Emilia Margoni. Can Bohmian ontology be a minimalist ontology?**

One of the topical issues in the philosophy of physics is the type of ontology that can be derived from today's well-established physical theories. A promising research line concerns a minimalist ontology, that is, a set of hypotheses about the natural world that aspires to cover all possible physical theories, from classical mechanics to quantum field theory. This article puts this conceptual strategy to the test by scrutinizing one of its sources, that is, Bohmian mechanics, to conclude that, if one sticks to David Bohm's own interpretation, the minimalist ontology programme is too restrictive.

- ➢ **Antoine Tilloy and Howard Wiseman. Non-Markovian wave-function collapse models are Bohmian theories in disguise**

Spontaneous collapse models models and Bohmian mechanics are two different solutions to the measurement problem plaguing orthodox quantum mechanics. They have a priori nothing in common. At a formal level, collapse models add a non-linear noise term to the Schrödinger equation, and extract definite measurement outcomes either from the wave function (e.g. mass density ontology) or the noise itself (flash ontology). Bohmian mechanics keeps the Schrödinger equation intact but uses the wave function to guide particles, which comprise the primitive ontology. Collapse models modify the predictions, whilst Bohmian mechanics keeps the empirical content intact. However, it turns out that (non-Markovian) collapse models and their primitive ontology can be exactly recast as Bohmian theories.

- ➢ **Pablo Acuña. Hidden Variables: from von Neumann's theorem to (deflationary) contextuality**

It is a widely held view that von Neumann's "impossibility proof" is an uninteresting result that does not accomplish its alleged goal of establishing the absolute impossibility of hidden variables. It is also a widely held view that the Kochen-Specker theorem imposes a contextuality constraint on the beables in hidden variables theories. I will challenge both these "official" views. Elaborating on Bub's reassessment, I show that von Neumann's theorem establishes that hidden variables theories cannot be Hilbert space theories, and that the same result can be obtained from Gleason's celebrated theorem. I also show that if we consider the constraint that both von Neumann's and Gleason's theorem impose on viable hidden variables theories, we see that the constraint that the Kochen-Specker theorem imposes on such theories is much weaker that what is normally thought: it does not affect the ontology of beables in any sense.

- ➢ **Fabrizio Napolitano. Tests of Foundations of Quantum Mecanics at the Gran Sasso underground laboratories**

We are performing a series of searches at the Gran Sasso underground laboratory looking for New Physics at the foundations of Quantum Mechanics. Two important and defining characteristics of Quantum Mechanics are under scrutiny using radiation detectors: Collapse models and Pauli Exclusion Principle (PEP). The dynamics and the origin of the quantum collapse is in fact still an open question and the quantum-to-classical transition is treated purely phenomenologically. Gravity-related and more generic Continuous Spontaneous Localization (CSL) models have been introduced in attempt to explain the decades-old problem of the measurement in quantum mechanics, predicting the emission of faint, additional radiation. High-purity germanium detectors have been employed to exclude the parameter space fo the gravity-related collapse model and put stringent limits on the CLS. The recent results published in Nature Physics "Underground test of gravity-related wave function collapse” and the future perspective will be discussed. Finally, the VIP-2 experiment is currently in data taking, looking for possible violations of PEP in atomic transitions. The impact of this measurement in relation to Quantum Gravity models will also be discussed

13:00-14:30 — room Curie **lunch**

14:30-16:30 — room Jaurès, ***Quantum physics and Bell’s theorem*** **session**

➢ **Richard Healey. Beyond Bell?**

In an archive post last summer Shan Gao argued that quantum theory is incompatible with relativity. He calls this a new proof beyond Bell’s theorem, arguing in another post that it closes the superdeterminism loophole in Bell’s theorem. Such strong claims must be backed up by irrefutable arguments. My aim here is to refute Gao’s "proof" and to show how quantum theory is compatible with relativity theory and so why Gao’s "proof" does not take us beyond Bell’s theorem.

➢ **Marton Gömöri and Carl Hoefer. Classicality and Bell's Theorem**

A common view among physicists is that Bell's theorem assumes “classicality” or “classical realism”, a condition which goes against the fundamental tenets of QM. According to this view, the violation of Bell’s inequalities poses no challenge to locality, but simply reinforces the fact that QM is not classical. We examine two recent variants of this thesis (Werner 2014; Griffiths 2020), and their associated versions of QM: operational QM, and the consistent histories approach. We show that the notions of classicality they employ are equivalent with probabilistic conditions formulated by Pitowsky and Fine in the 1980s. However, classicality thus construed is not a presupposition of Bell’s theorem but rather a consequence of the standard causal-statistical assumptions. In evading the derivation of Bell’s inequalities, each of the theories in question violates one of these standard assumptions: in operational QM the Common Cause Principle doesn’t hold; the histories formulation of QM is conspiratorial.

➢ **Ravi Kunjwal and Victoria Wright. Contextuality in composite systems: entanglement vs. the Kochen-Specker theorem**

I will present some recent work on the necessity of entanglement in proofs of the Kochen-Specker theorem on multiqubit systems. We show two key results: firstly, that any proof of the KS theorem that uses KS sets necessarily requires entangled measurements, and secondly, that a *statistical* proof of the KS theorem with unentangled measurements on a multiqubit state exists if and only if this state can witness a Bell inequality violation. I will also discuss some implications of these results for the role of contextuality as a resource for multiqubit quantum computation with state injection. Based on arXiv:2109.13594

- **Guido Bacciagaluppi and Ronnie Hermens. Reverse Bell's Theorem and Relativity of Pre- and Postselection**

In this paper we prove a Bell's theorem in the setting of postselection ('reverse Bell's theorem'). Specifically, we show under which conditions the Bell inequalities can or cannot be violated with classical postselection, and how this differs from the quantum violations. We then propose a variant of existing experiments that discriminates between quantum violations and classical simulations. The proposed experiment can be adapted to test simultaneously the standard and reverse Bell's theorems. In this case, the distinction between these pre- and postselection effects becomes frame-dependent.

14:30-16:30 — room U209, ***Cosmology and gravitation*** **session**

- **Vera Matarese. Direct or Conceptual Replicability as the Gold Standard for Science? The case of the Hubble Constant**

This talk uses the case of the Hubble constant to contribute to the debate on replicability in science. First of all, I argue that this case shows, contra Machery's account (Machery 2019), that direct and conceptual replication serve different functions in assessing the credibility of models, by verifying and validating them respectively. Second, I suggest that it sheds light on the connection between conceptual replication and robustness, which however should not be quickly identified with the notion of robustness discussed in the literature on model confirmation (Weisberg 2006).

- **Kevin Coffey. Symmetry and Interpretation in Newtonian Gravitation: The Importance of Interaction(s)**

Newtonian gravitation theory is often claimed to exhibit an important symmetry with respect to its inertial structure, a symmetry that allows one to draw the distinction between inertial structure and gravitational field in indefinitely many ways. Philosophers of physics have used this fact to conclude that both features ought to be interpreted as gauge quantities—as conventional choices without underlying physical significance—and thus that there really are no gravitational fields posited by the theory. This paper provides a counterpoint to this view: I defend the postulation of a genuine distinction between inertial structure and gravitational field. Along the way I argue that, despite current consensus, Newtonian cosmology really is inconsistent. These claims are then marshaled in support of a broader lesson regarding the relationship between symmetry considerations and theory interpretation.

- **Matthew Parker. Lotteries, Dice, and Multiverse Cosmology**

Norton argues that his Infinite Lottery Logic is the correct logic for self-location in the infinite multiverse of eternal inflation. There, the chance of observing a local property is determined by the choice of a world under a label-independent distribution of non-additive, non-numerical chances. This implies that nearly any property is "as likely as not", making confirmation of eternal inflation theories problematic. I argue that a better model is an array of dice, in which the chance of observing an outcome is determined by the stochastic properties of local processes.

- **Niels Martens. Comparing the explanatory power of ΛCDM & modified gravity**

We compare and contrast the explanatory power of dark matter (ΛCDM) and modified gravity. The research programmes implicitly adhere to different models of explanation. We claim that 1) both notions of explanation are relevant for both research programmes, 2) neither research programme, when evaluated against its own standard of explanation, is as explanatory as usually proclaimed, and 3) modified gravity does not do badly when evaluated against ΛCDM's standard of explanation. Modern physics and philosophy of science can each benefit from the other by bringing together these hitherto barely connected debates of dark matter & explanation.

16:30-17:00 — room Curie **break**

17:00-18:00 — room Jaurès, **Plenary session**

- **Eleanor Knox. Spacetime Functionalism in Newtonian Theories**

Friday, 29

09:00-11:00 — room Jaurès, ***Time and quantum physics* session**

- **Giovanni Valente and Bryan Roberts.Two interpretations of Feynman on antimatter and time's arrow**

In this talk we discuss a standard claim known as the Feynman perspective, according to which matter evolving in the forward-time direction can be equivalently viewed as antimatter evolving in the backward-time direction. We submit that the issue whether this claim holds true or not depends on how exactly one relates matter and antimatter by means of a charge conjugation, as well as on how one interprets the concept of moving backwards in time. Specifically, we identify two possible interpretations, that is (1) the Time-Reversal Interpretation and (2) the Backwards-Spectrum Interpretation, which we evaluate and compare.

- **Lev Vaidman. The impact of quantum mechanics on philosophy**

The uncertainty principle and Bell-type correlations led to a dramatic change in the philosophy of science. Today we are ready to accept indeterminism and some kind of action at a distance. I will argue that this move is not necessary and maybe mistaken. Accepting existence of multiple parallel worlds allows restoring determinism and avoiding action at a distance. The issue of probability in the many-worlds framework, however, requires introducing a novel element in science.

- **Ward Struyve. Time-reversal invariance and ontology**

According to the standard lore, theories like classical electrodynamics and quantum mechanics are time-reversal invariant. David Albert has challenged this view and has argued that these theories are not time-reversal invariant. The source of the disagreement is that Albert considers a different notion of time-reversal invariance. For Albert, the time-reversal of a history of instantaneous states is just the history run backwards in time, while the standard notion allows for an additional transformation of each instantaneous state. I will argue that the ontologies of the aforementioned theories are actually underdetermined and that by a suitable choice, these theories are time-reversal invariant in Albert's sense.

➢ **Elise Crull. Temporal Entanglement and the Quantum-to-Classical Transition**

The Leggett-Garg inequality (LGI) is typically considered a temporal analogue to Bell's inequalities, in that it measures nonclassical correlations in a single system at different times. Yet while tests of Bell's inequalities have inspired a rich interpretational debate concerning entanglement across space, numerous empirical violations of LGI have not generated a comparably rich discussion regarding entanglement through time. In this talk I consider two features of temporal entanglement of special philosophical significance: its polygamy (as against the monogamy of spatially entangled systems), and the emergence of causal ordering in the classical limit from spacetime correlations which lack definite ordering.

10:00-11:00 — room Marbo, ***Quantum physics and causality 1* session**

➢ **Julian Wechs. Existence of processes violating causal inequalities on time-delocalised subsystems**

It has been shown that it is theoretically possible for there to exist quantum and classical processes in which the operations performed by separate parties do not occur in a well-defined causal order. In order to provide a rigorous argument for the notion that certain such processes have a realisation in standard quantum theory, the concept of time-delocalised quantum subsystem has been introduced. In this paper, we show that realisations on time-delocalised subsystems exist for all unitary extensions of tripartite processes. Remarkably, this class contains processes that violate causal inequalities, i.e., that can generate correlations that witness the incompatibility with definite causal order in a device-independent manner.

➢ **Hippolyte Dourdent and Cyril Branciard. Violation of causal and logical inequalities in a causal game**

We present an example of a new kind of causal game which, in addition to defining a causal inequality, also provides a logical inequality. The violation of this bound indicates that the resource into play can lead to logical inconsistencies. Processes generating correlations describing definite causal order, consistent indefinite causal order, and inconsistent indefinite causal order between two parties are identified and characterized. In particular, we found an inconsistent classical process able to win the game with certainty. This result confirms that non-causality does not imply logical inconsistency and that it is a classical feature.

11:00-11:30 — room Curie **break**

11:30-13:00 — room Jaurès, ***Quantum field theory* session**

➢ **Michael Stoeltzner. Constraints on new physics: The modal challenge of effective field theories**

Searches for physics beyond the standard model (SM) of elementary particle physics have hitherto been unsuccessful. This has led to a shift from model testing to bottom-up approaches, among them simplified models and SM model effective field theory that intends to find deviations from the SM and, if such deviations are measured, turn them into constraints on physics beyond the SM. The goal of this paper is to discuss the philosophical status of these constraints against the backdrop of recent debates about perspectival realism in the context of simplified models and realist readings of effective field theories.

➢ **Sebastien Rivat. Ken Wilson's early concept of effective theory**

The notion of "effective theory" is often either too liberally employed or too closely tied to a particular context in the literature. My goal here is to show that the history of effective theories brings crucial conceptual insights. I will retrace the main steps that led Wilson to his first prototype in 1965 and argue that: (i) he already had a peculiar way of "integrating out" high-energy degrees of freedom at this stage; (ii) the structure of his prototype was already largely determined by this transformation. I will conclude with a brief contrast with Weinberg's early concept in 1967.

➢ **Michael Miller. Infrared Cancellation and Measurement**

Quantum field theories containing massless particles such as photons and gluons are divergent not just in the ultraviolet, but also in the infrared. Infrared divergences are typically regarded as less conceptually problematic than ultraviolet divergences because there is a reseaonably straightforward cancellation mechanism that renders measurable physical observables such as transition amplitudes and cross-sections infrared finite. In this paper, I scrutinize the restriction to measurable physical observables that is required to make the cancellation mechanism applicable.

11:30-13:00 — room Marbo, ***Quantum physics and causality 2*** **session**

➢ **Timothée Hoffreumon and Ognyan Oreshkov. The multi-round process matrix: emergence of new causally indefinite dynamics through activation**

Physical theories often assume a well-defined causal order between the events in an experiment. This assumption was shown to be too stringent in the context of higher-order quantum processes, e.g. sequences of operations that are coherently controlled. Relaxing this assumption leads to indefinite causal structures that are described using the process matrix formalism. We show, using an extension of the formalism, that when separate parties are allowed to exchange sequences of messages, new forms of causal indefiniteness can arise, which are not captured by process matrices.

➢ **Laurie Letertre. Causal nonseparability and its implications for spatiotemporal relations**

This work focuses on the process matrix formalism that generalizes quantum mechanics by relaxing the assumption of a well-defined causal structure. That broader theoretical context predicts the existence of noncausal quantum correlations, which violate the causal equivalent of Bell inequalities. A new notion of causal nonseparability is introduced, somehow suggesting the extension of entanglement to the geometry of spacetime. The goal of this paper is to discuss the connection between the notions of quantum and causal nonseparability, and, in a realist framework, have a preliminary reflection regarding their potential implications for the world's ontology.

➢ **David Schmid, John Selby and Robert Spekkens. Unscrambling the omelette of causation and inference: The framework of causal-inferential theories**

Correlations call out for causal explanation. Achieving such an explanation for quantum correlations, however, is problematic. Most notably, Bell-like no-go theorems rule out explanations which respect the natural causal structure, and proofs of the impossibility of noncontextual models rule out explanations that respect Leibniz's principle of the identity of indiscernibles. We introduce a mathematical framework for defining generalized notions of causation and inference, which opens the door to providing a causal account of quantum correlations that preserves the spirit of locality and noncontextuality. This in turn constitutes a promising path towards a more compelling realist interpretation of quantum theory.

13:00-14:00 — room Curie **lunch**

14:00-16:30 — room Jaurès, ***Symmetries* session**

➢ **David Wallace. Observability, redundancy and modality for dynamical symmetry transformations**

I provide a fairly systematic analysis of when quantities that are variant under a dynamical symmetry transformation should be regarded as unobservable, or redundant, or unreal; of when models related by a dynamical symmetry transformation represent the same state of affairs; and of when mathematical structure that is variant under a dynamical symmetry transformation should be regarded as surplus. In most of these cases the answer is ‘it depends’: depends, that is, on the details of the symmetry in question. A central feature of the analysis is that in order to draw any of these conclusions for a dynamical symmetry it needs to be understood in terms of its possible extensions to other physical systems, in particular to measurement devices.

➢ **Guy Hetzroni. Symmetries and Interactions: From Heuristics to Ontology**

The presented research examines the methods through which symmetry principles are used in three different cases: the gauge principle in field theories, general covariance in GR, and the gauge argument in gauge theories of gravity. It is argued that these cases can all be understood as a manifestation of one heuristic principle, the *methodological equivalence principle,* according to which the particular way in which a theory violates an invariance requirement provides the coupling prescription associated with a new interaction. At the interpretational level, I argue that this methodology replaces absolute local dynamical quantities with relational ones, introducing exactly the structure necessary for achieving invariance while at the same time explaining the initial non-invariance. I discuss the implications on spacetime ontology, contrasting the introduction of non-Riemannian geometrical structures in gauge theories of gravity with the introduction of curvature in general relativity.

➢ **Valeriya Chasova. Relationships between actions, equations of motion, symmetries and conservation laws: dispelling some misunderstandings**

If Kosso [2000] is right, theoretical elements entailing conservation laws should have an indirect empirical status (IES) and hence some physical significance. But what are these elements? I firstly explain that these are not only global symmetries of actions and matter equations of motion, but also local symmetries of actions and gauge equations of motion. I then address such more controversial issues as the status of the Bianchi's identities and whether symmetries of equations of motion have IES, as well as Wigner's and Lange's views on symmetries and conservation laws.

- **Cristian López. Against symmetry realism. A prospect for symmetry deflationism**

Many symmetries are taken to be fundamental in physics. Yet, its fundamentality can be construed in, at least, two ways. *Symmetry realism* holds that symmetries are features of physical reality and should hence be employed as guides to what's fundamental. *Symmetry deflationism* rather holds that symmetries are fundamental but not real --they are primarily epistemic tools and heuristic constraints in theory construction. In this presentation, I call for philosophical caution when symmetry realism is employed for metaphysical research. First, I will stress that to a good extent many symmetries in physics are stipulated, which might discourage a realist attitude towards them; second, I will argue that symmetry realism implies idealization realism, which, in turn, implies some commitment to nomological modality. I conclude that symmetry deflationism, instead of symmetry realism, should be adopted. I will provide a brief prospect for symmetry deflationism as the more adequate way to construe the role of symmetries in current physics.

- **Henrique Gomes. Holism as the significance of gauge**

The thought experiment known as Galileo's ship exemplifies a relational empirical significance of subsystem boosts. Can gauge transformations in Yang-Mills theory---taken as mere descriptive redundancy---exhibit a similar empirical significance? I argue that the answer is `yes' and results from the inherent non-locality of gauge theory; it is compatible with gauge as descriptive redundancy. Focusing on physical, gauge-invariant information, we can show that, given two subsystems' states, the universal state obtained by the composition is not always uniquely determined: the residual variety is encoded in the action of a symmetry group on a subsystem. For Galileo's ship, the variety is encoded in boosts and translations, in gauge theory it has the structure of the finite-dimensional Lie group of the theory.

14:00-16:30 — room Marbo, ***Quantum gravity and particles physics session***

- **Martin King. The rise of model independence**

The lack of new physics discoveries at the LHC has had a dramatic effect on the efforts of the particle physics community. Among other things, it has led to an increase model-independent approaches, such as precision measurements, AI searches, and bottom-up approaches that use the Standard Model Effective Field Theory. The terms `bottom-up' and `top-down' are relatively recent ones, but correspond well to an old and lasting debate between inductivist and hypothetical approaches to science. This shift towards model-independence and the bottom-up approach may not be transient and may settle the debate on methodology for better or for worse.

- **Milla Lifke. All things strings: From theory to a method of thinking**

In this paper we will examine how string theoretical research has reshaped disciplinary boundaries of theoretical physics. Recent debates among philosophers and physicists tend to concentrate on what string theory has failed to accomplish. Here, however, we will focus on the role of string physics in enhancing collaboration between theoretical and mathematical physics and mathematics, and the use of stringy methods in other areas of physics. We will explore how string physics – far from being a proper theory – has become a method of thinking in some areas of physics and mathematics, and how our philosophical views on it should change

- **Francesca Vidotto. On the tensor product structure of general covariant systems**

Defining a generic quantum system requires, together with a Hilbert space and a Hamiltonian, the introduction of a tensor product structure. Assuming a background time variable, Cotler, Penington and Ranard showed that the Hamiltonian selects an almost-unique tensor product structure. This result has been advocated by Carrol and collaborators as supporting the Everettian interpretation of quantum mechanics and providing a pivotal tool for quantum gravity. I argue against this: the CPR result does not hold in the generic background-independent case where the Hamiltonian is replaced by a Hamiltonian constrain. This reinforces the understanding that entropy and entanglement, that in the quantum theory depend on the tensor product structure, are quantities that are observable dependent.

- **Philipp Berghofer. Towards gauge invariant accounts of the Brout-Englert-Higgs Mechanism: Ontological implications of the "dressing approach"**

As a reaction to well-known conceptual problems plaguing the standard account of the Higgs mechanism, several physicists have aimed at manifestly gauge invariant accounts. One such account is the "dressing approach." In the case of Abelian gauge theory, this approach implies that elementary fields are dressed by clouds of photons. This seems to have crucial ontological implications. Electrons would no longer be conceived as excitations of the elementary (non-gauge-invariant) electron field but of the built-up gauge invariant field consisting of the elementary electron field "dressed up" by a photon cloud. The objective of this contribution is to clarify these implications.

- **Rasmus Jaksland. The Many Problems of Spacetime Emergence**

At places, the philosophical literature can give the impression that there is one overarching philosophical problem associated with the emergence of spacetime in quantum gravity research. However, without a qualification of 'spacetime' and a specification of the quantum gravity approach being considered, it is just too ambiguous what this problem amounts to. The consequence is that the alleged overarching problem is ill posed if one insists on its full generality. As this paper argues, there are many philosophical problems relating to spacetime emergence in the different approaches to quantum gravity, and these must each be considered in their own specificity

14:00-16:30 — room Langevin, ***Quantum mechanics* session**

- ➢ **Leon Loveridge. Relative Quantum Time**

The need for a time-shift invariant formulation of quantum theory arises from fundamental symmetry principles as well as heuristic cosmological considerations. Such a description then leaves open the question of how to reconcile global invariance with the perception of change, locally. By introducing relative time observables and using the formalism of quantum reference frames, we are able to make rigorous the Page–Wootters conditional probability formalism to show how local Heisenberg evolution is compatible with global invariance.

- ➢ **Anne-Catherine de la Hamette, Thomas Galley. Quantum reference frames for general symmetry groups**

Treating reference frames as physical systems, subject to the laws of quantum mechanics, they become quantum reference frames. Located at the interplay of quantum and gravitational physics, their treatment marks an essential step towards the construction of a relational quantum theory. In this work, we introduce a relational formalism which identifies coordinate systems with elements of a symmetry group G. We define a general operator for reversibly changing between quantum reference frames associated to a group G. This generalises the known operator for translations and boosts [1] to arbitrary finite and locally compact groups, including non-Abelian groups. — Journal reference: Quantum 4, 367 (2020), arXiv reference: arXiv: 2004.14292 [quant-ph]

- ➢ **Hamed Mohammady. Measurement disturbance and conservation laws in quantum mechanics**

The disturbance caused by measurements in quantum mechanics depends on the interaction between system and apparatus. If this interaction obeys a conservation law, the observables that may be non-disturbed will be restricted. We obtain general bounds that indicate the necessary conditions for non-disturbance in the presence of a conservation law and show that an observable not commuting with the conserved quantity admits a repeatable measurement – a special instance of a non-disturbing measurement – only if it is unsharp, and the apparatus is prepared in a state with a large uncertainty in the conserved quantity. This generalises the well-known Wigner-Araki-Yanase theorem.

- ➢ **Erik Curiel. Interaction and Evolution in Quantum Mechanics**

I think there is currently no satisfactory resolution of the Measurement Problem in quantum mechanics. There seems to be something about the idea of "interaction", along with its relation to and difference from the idea of "evolution", that we do not understand. In classical mechanics, evolutions and interactions are conceptually, physically and mathematically distinct things. In quantum mechanics, to the contrary, the same mathematical structures represent both possible evolutions and interactions: there is no clean distinction between "evolution" and "interaction" there. I discuss some possible philosophical lessons of this fact.

- ➢ **Hervé Zwirn. The role of the observer in quantum mechanics**

Many attempts to solve the measurement problem have been made since the inception of quantum mechanics. They gave rise to many different interpretations that are, in my opinion, all unsatisfactory. Either they are fuzzy on some points and they do not give a formulation strict enough to clarify the subject, or they are inconsistent and assume contradictory hypotheses. In this paper, I show that trying to get an objective solution (i.e. a solution that can be expressed without any mention of the observer) is doomed to failure for logical reasons. I will defend a new position, the “Convivial Solipsism”, taking a full account of the role that the observer plays in the measurement process.

16:30-17:00 — room Curie **break**

17:00-18:00 — room Jaurès, **Plenary session**

- **Christian Wuthrich. Dynamical laws at the big bang**

The concepts of law, retro-/prediction, and explanation are centrally spatiotemporal, describing dynamics and underwriting scientific inference. So in a theory in which time (or space) are not fundamental, they will need to be re-examined. In this talk I will probe this line of thought, by considering the possible breakdown of spacetime in quantum gravity models of the big bang. On the basis of a case study of loop quantum cosmology, I will argue that one can meaningfully study such a universe in a ’semi-classical’ framework, asking for instance: how parameters describing the singular region are determined by earlier or later epochs, or offer clues to more fundamental, perhaps non-spatiotemporal, degrees of freedom?

Saturday, 30

09:00-11:00 — room Jaurès, ***Symmetries* session**

➢ **Samuel Fletcher. On Surplus Structure Arguments**

Surplus structure arguments famously identify elements of a theory regarded as excess or superfluous. Despite their prominence, the form, justification, and range of applicability of such arguments is disputed. I provide a new account, following Dasgupta ([2016]) for the form, which makes plain the role of observables and observational equivalence. However, I diverge from him on the argument's justification: instead of demanding that the symmetries of a theory be defined without recourse to any interpretation of those theories, as he does, I suggest that the process of identifying what is observable and its consequences for symmetries work in dialog through a reflective equilibrium that is responsive to new experiments, arguments, and examples.

➢ **Clara Bradley. The Significance of Isomorphic Models**

If two or more models of a theory are isomorphic to one another, should they be treated as equivalent even if they have features which distinguish them? This question animates a recent debate about the hole argument and gives it broader significance for the interpretation of gauge theories. I will argue that having distinct isomorphic models can be important representationally, but this does not mean that the features distinguishing them should be taken to have physical significance.

➢ **Joshua Babic and Lorenzo Cocco. Special Relativity and Theoretical Equivalence**

Quine [1975] has proposed an attractive criterion for when two first-order systems count as formulations of the same theory: they must be translatable into a logical equivalent of the other. Philosophical considerations suggest that such equivalent theories differ in notation, but not in substance. No distinction about ontology can be made between them. Few of the physical theories traditionally held to be equivalent have been examined under this strict notion of equivalence. In this work, we prove that some `dynamical' formulations of relativity, framed in terms of observers and coordinate systems, are equivalent to older, `geometric' formulations of the theory.

➢ **Robert Booth. Contextuality and Wigner negativity are equivalent for continuous-variable measurements**

Quantum computers promise considerable speedups over their classical counterparts. However, the identification of the innately quantum features that enable these speedups is difficult. In the continuous-variable setting—a promising paradigm for the realisation of scalable, fault-tolerant quantum computing---contextuality and Wigner negativity have been perceived as two such non-classical features. We show that they are in fact equivalent for the standard models of continuous-variable quantum computing. While our results provide a unifying picture of continuous-variable resources for quantum speedup, they also pave the way towards practical demonstrations of continuous-variable contextuality, and shed light on the significance of negative probabilities in phase-space descriptions of quantum mechanics

09:00-11:00 — room Marbo, ***Quantum mechanics*** **session**

➢ **Natasha Oughton. Singling out quantum correlations: The role of the Shannon information in the Information Causality principle**

The Information Causality principle has been proposed, in conjunction with no-signalling, to re-axiomatize quantum mechanics. From this principle we can re-derive the quantum limit on correlations by constraining the maximum amount of information gained after sending a number of classical bits. However, I show that despite appearing intuitive, this derivation rests on the choice of Shannon information as the appropriate measure of information sent. I argue that this choice is merely conventional, and further that an alternative uncertainty measure no longer arrives at the quantum bound. I conclude that Information Causality lacks sufficient justification to play a foundational role.

➢ **Victoria Wright and Stefan Weigert. General probabilistic theories with (and without) Gleason-type theorems**

Gleason's theorem shows that in quantum theory the representation of states as density operators follows from the representation of observables as projection-valued measures, i.e. there are no further possible states of a quantum system to those postulated in the theory. But is the existence of such a result unique to quantum theory? We consider this question in the setting of general probabilistic theories (GPTs) and find a necessary and sufficient condition for a GPT to admit a Gleason-type theorem. This result identifies a new class of GPTs and provides an alternative method for deriving the GPT framework.

➢ **Tomasz Placek and Thomas Mueller. On experimenters' free choice and deterministic hidden variable models**

Using Belnap's (1992) Branching Space-Time theory, we analyze deterministic hidden variable models for Bell-type experiments. Such models aim to remove the indeterminism present in measurement's outcomes, while upholding the idea of experimenters' free selection of the measurement settings. We investigate this combination in terms of appropriate extensions of an initial BST structure that contains both non-local modal correlations and experimenters' freedom. We apply this framework to analyze the GHZ experiment in formal detail.

➢ **Martino Trassinelli. An unique probability function for quantum and classical phenomena where distributivity is violated**

In Quantum Mechanics, probabilities are obtained by the squared modulus of complex amplitudes, which is substantially different from the classical probability expression and gives rise to the possibility of interference phenomena. We show here that a unique definition of the probability function for quantum and classical phenomena can be formulated. This universal definition has however a price: the distributive property of the function argument is no more valid. Different arguments correspond to different conditions of discernibility on which the presence or absence of interference effects depends. We demonstrate the non-validity of distributivity in the context of measurements represented by projectors and its generalization with positive-operator valued measures.

09:00-11:00 — room Ribot, ***General philosophy of science*** **session**

➢ **Radin Dardashti. Understanding Scientific Problems**

Scientists solve scientific problems all the time. It is a crucial aspect of the practice of any scientist. Nevertheless, the question as to what constitutes a scientific problem, its structure, its elements and its dynamics have not received much attention within the philosophy of science literature. It is the aim of this paper to argue for the importance of a conceptual and rigorous analysis of scientific problems and apply them to a current case study from modern particle physics, namely the Higgs naturalness problem.

➢ **Patricia Palacios and Rawad El Skaf. Getting off the armchair: The crucial role of thought experiments in black hole thermodynamics**

We analyse thought experiments (TEs) in black holes (BH) physics and contend that their use does not fit well with central positions in the philosophical literature on TEs. Our main claim is that their principal epistemic function is to reveal an inconsistency between the statements of at least two different theories, e.g. quantum theory and general relativity. This shows, contra Brown, that TEs cannot give us a priori knowledge by revealing new laws governing BHs. This also shows, contra Norton's elimination thesis, that TEs are indispensable: These TEs reveal inconsistencies by applying our theoretical statements to an external scenario involving ``particulars''.

➢ **Quentin Rodriguez. Distinct unifications, different fundamentalities? Universality in condensed matter physics**

Unification of physics is usually related to reductionism, especially micro-reductionism: if an entity can be related to others by means of a composition relation, a kind of unification may be achieved through theories regarding increasingly smaller length scales. In other words, "fundamental physics" must be regarded as micro-physics. However, the development of condensed matter physics since the mid-20th Century challenged this vision following the elaboration of a concept of universality of critical phenomena. The explanation of this universality displays properties belonging to phenomenological unification instead, and yet is compatible with descriptions in terms of constituents. This presentation aims to show that universal behavior constitutes a transverse unification, combining two linearly independent explanatory hierarchies—the micro-reductive and the phenomenological one.

- **Marco Forgione. Emergent Trajectories and Path Integrals**

In the present work I will argue that classical trajectories, in the sense of classical mechanics, emerge from ensemble of possible trajectories in quantum mechanics --more specifically, from the path integral interpretation (PI) of quantum mechanics. To support the thesis it will be shown (i) the non classical character of quantum paths, (ii) how the total ensemble determines (at the classical limit) a single classical trajectory; (iii) one can at best reduce the ensemble to subsets of possible trajectories, but ultimately at the quantum level the very concept of "single traversed path" loses its physical meaning.

11:00-11:30 — room Curie **break**

11:30-13:00 — room Jaurès, ***Mathematics and Physics* session**

- **Peter Woit. Unifying Foundations for Physics and Mathematics**

Since the 1970s, research in fundamental physics and mathematics has uncovered close relations between the deepest unifying ideas in the two subjects. In mathematics, the geometric Langlands program has brought together number theory, representation theory and geometry, in a synthesis described by Edward Frenkel as a "Grand Unified Theory of mathematics." In physics, the Standard Model and general relativity provide a rigid geometric structure that has resisted all attempts at modification or enlargement. This indicates that foundations of physics may best be understood in terms of unifying foundational ideas in mathematics.

- **Flavio del Santo. Fundamental indeterminism in classical mechanics and special relativity**

Physics is formulated in terms of timeless, axiomatic mathematics. A formulation based of intuitionist mathematics, built on time-evolving processes, would offer a perspective that is closer to our experience of physical reality. We elaborate on the close connection between indeterministic physics, following the intuition of many physicists, and a poorly known mathematical language which makes it easy to “talk” indeterministic physics.

- **Marco Giovanelli. Relativity Theory as a Theory of Principles. Origin and Development of Einstein’s Distinction between Principle and Constructive Theories**

Toward the end of 1919, in a two-column contribution for the *Times* of London, Einstein declared relativity theory to be a 'principle theory,' like thermodynamics, rather than a 'constructive theory,' like the kinetic theory of gases. The paper attempts to trace back the prehistory of this distinction through a systematic overview of Einstein’s repeated use of the relativity theory/thermodynamics analysis after 1905. Einstein progressively transformed a negative defensive argument to address the concerns of his opponents into a positive heuristics guiding the discovery processes. The paper concludes that special relativity is indeed better characterized as a principle theory. Unlike constructive theories, principle theories do not say anything about the laws governing specific physical system, rather they put constraints on them.

11:30-13:00 — room Marbo, ***Statistical mechanics and thermodynamics* session**

➢ **James Wills. Dynamical Indistinguishability**

I offer a precise definition of classical particle indistinguishability in Gibbsian statistical mechanics in terms of the permutation symmetry of the Hamiltonian. I do this by analysing Gibbs' 1902 treatment of particle indistinguishability, arguably the first rigorous treatment of the concept in physics. I argue that Gibbs' comments are ambiguous and I identify two more precise versions. I argue for one of the versions and use it to reconstruct the precise definition of indistinguishability. I then show that this definition meshes with, and illuminates, Gibbs' other arguments

➢ **Athamos Stradis. The Origins of Observation**

In statistical mechanics, a system E at a given moment is described by a 'microstate', an exact microscopic configuration of its particles. However, we only observe certain indistinguishable sets of E's microstates ('familiar macrostates'). Why do we observe these sets, and not others ('alternative macrostates')? Some have offered an evolutionary explanation: since observ- ing robust regularities is advantageous, and since the familiar macrostates exhibit such regularities (e.g. the Second Law), it's no surprise that these are the macrostates we observe. I shall argue that this account is undercut by a simpler explanation from first principles in statistical mechanics.

➢ **Emanuel Bertrand. An attempt to promote out-of-equilibrium thermodynamics as a new foundation for physics. Ilya Prigogine and Isabelle Stengers' Order out of chaos (1979).**

Abstract: In 1979, Ilya Prigogine and Isabelle Stengers published a French bestseller, La Nouvelle Alliance. Métamorphose de la science (Gallimard), mainly about philosophy and history of physics. This book, translated in English in 1984 as Order out of Chaos. Man's New Dialogue with Nature (Bantam Books), is both dense and complex, and includes rigorous technical developments. I will show that this book may be understood as an attempt to replace Newtonian science by a supposedly more complete Prigoginian science and thereby to promote Prigogine's thermodynamics as a new foundation for physics.

11:30-13:00 — room Ribot, ***Quantum mechanics* session**

➢ **Simon Friederich. Introducing the Q-based interpretation of quantum theory**

This contribution determines key features of an interpretation of quantum theory gestured at in recent work by Peter Drummond and Margaret Reid. The core idea of this "Q-based interpretation" is that the Husimi Q-function, a quasi-probability distribution often used in quantum optics, is a proper probability distribution over ontic states. Whereas Drummond and Reid argue that this interpretation avoids various no-go theorems by incorporating retrocausality, I show that it does so by violating an assumption called "lambda-mediation."

The Q-based interpretation has various attractive features: solving the measurement problem, allowing to interpret wave function collapse as Bayesian updating, applying to quantum field theory by construction, and---due to classical-like traits of coherent states---offering a particularly promising approach to the quantum-to-classical transition.

- **Pierre Uzan. Super-Quantum, No-Signaling Correlations Cannot Exist**

The idea that non-local correlations stronger than quantum correlations between two no-signaling systems could 'theoretically' exist is based on an incorrect statistical interpretation of the no-signaling condition. This article shows that any physically realizable no-signaling 'box' involving local incompatible observables indeed requires to be described in a non-commutative, quantum-like language of operators -which leads to the derivation of the Tsirelson bound and then contradicts this idea.

- **Andrea Carosso. The Problem of Quantization**

21 years after Dirac's original formulation, it was realized by Groenewold that the rules of quantization are mathematically inconsistent, a result known as the Groenewold-van Hove theorem. Since then, there have been several attempts by mathematicians to provide a rigorous definition of the quantization map. Some of these attempts take an approach that leads to an intrinsically geometric formulation of quantum theory. Yet there is still today no universally accepted definition of the quantization map. In this talk, I will discuss the history of the problem and comment on its implications in the context of the foundations of quantum theory.

13:00-14:00 — room Curie **lunch**

14:00-16:00 — room Jaurès, **Plenary session**

- **Michel Bitbol. Relational relationism and absolute relationism**

QBism and Relational Quantum Mechanics share a radically anti-realist construal of facts and states. But differences persist despite this family ressemblance, and they can be ascribed to opposite meta-theoretical stances. RQM is still striving towards a "view from nowhere", by absolutizing the interactive relations between physical systems (thus coming close to ontic structural realism). Instead, QBism sticks to a "view from somewhere", by relativizing all its symbols to the interventions and experiences of a pre-theoretical "agent". Here, I'll push this first-person approach of QBism to its ultimate consequences. I'll then show how its meaning can be clarified by phenomenology, a philosophical discipline that purports to base every scientific (or ordinary) discourse on lived experience.

End the conference